The life and labours of John Mercer, F.R.S., F.S.C. etc., the self taught chemical philosopher : including numerous recipes used at the Oakenshaw Calico Print-Works / by Edward A. Parnell.

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JOHN MERCER

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Yours truly

John Mercer

THE LIFE AND LABOURS OF JOHN MERCER, F.R.S., F.C.S.

ETC.

THE SELF-TAUGHT CHEMICAL PHILOSOPHER;

INCLUDING NUMEROUS RECIPES USED AT THE
OAKENSHAW CALICO PRINT-WORKS.

BY

EDWARD A. PARNELL, F.C.S.

AUTHOR OF 'APPLIED CHEMISTRY' ETC.

WITH A PORTRAIT.

LONDON:
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1886.

PREFACE.

OFTENTIMES have the friends and admirers of the remarkable man whose memoir is here presented to the public expressed regret that there has been no adequate published record of his life and work. Nearly twenty years have now elapsed since his death. The principal reason of the delay has been the lamented decease, during this period, of both of his sons; each of whom, first the elder, and after his decease, the younger, having intended to issue a memoir of their father; but both were prevented, by decease in the prime of their lives, from carrying out their intention.

I have prepared this memoir at the request of the surviving daughters of Mr.

Mercer, the Misses Mercer, of Oakenshaw House, Accrington; who kindly placed at my disposal all available documents likely to be serviceable, and furnished me with many interesting details of their father's social life. Mr. Mercer did not keep a regular diary, but he left behind him a large collection of notes, memoranda, and copies of letters; and also a brief account of his youthful days and early labours in calico-printing.

To ensure all possible accuracy in points relating to personal history, the Misses Mercer have kindly revised my memoir with great care. I am also indebted for a similar act of kindness to the Right Hon. Sir Lyon Playfair, who was Mr. Mercer's principal correspondent on chemical subjects.

I have the melancholy gratification of acknowledging my indebtedness, for like assistance, to another intimate and highly esteemed friend of Mr. Mercer, whose decease occurred not long after reading through my manuscript, namely Mr. James Higgin, of

Manchester, the author of the excellent article on calico-printing in the last edition of Ure's 'Dictionary of Arts.'

In attempting to do justice to Mr. Mercer as a man, a technical inventor, and a chemist, it has been necessary to include subjects of very different character; which, although separated to some extent by chapters and an Appendix, may make the present volume appear, to some, a singular admixture of social life (including the religious element), technical recipes, and theoretical chemistry; —three aspects in which we cannot expect any reader to be interested equally. But it will be obvious that neither could be omitted without doing injustice to the subject, and defeating the object in view in the publication of this memoir.

Although great changes have been made in the art of calico-printing since the period of Mr. Mercer's labours, yet it is probable that the calico-printer of to-day will here meet with much interesting information which may be turned to practical advantage.

Numerous recipes for colour preparations in use at the Oakenshaw works at the time of the dissolution of partnership, and which have never before been published, will be found in these pages.

Among the subjects here introduced relating to theoretical chemistry, of course, at the present day, most will be interesting only in their historical aspect. But there will also be found notices of many interesting experiments, not generally known, which even now suggest subjects well deserving of further investigation. Generally speaking, we have retained the nomenclature used by Mr. Mercer and most other chemists of his day.

EDWARD A. PARNELL.

May, 1886.

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THE LIFE AND LABOURS
OF
JOHN MERCER.

CHAPTER I.

HIS YOUTHFUL DAYS.

THE subject of the following memoir was one of those praiseworthy men who, being possessed of remarkable natural abilities, attained a position of distinction among scientific men without the advantages of a scholastic training. His career presents us with a remarkable instance of the success which attends habits of unwearied industry and perseverance, when guided by a sound and an acute judgment, amidst most unfavourable circumstances. He became celebrated chiefly for his

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applications of chemistry to the art of dyeing and calico-printing. That art embraces some of the most ingenious applications of chemical science; not a few of which originated with John Mercer. Amongst his scientific acquaintance, however, he was admired chiefly for the comprehensiveness of his views on all subjects, and for the remarkable acuteness and originality which he displayed in dealing with all questions relating to theoretical chemistry.

John Mercer was born on February 21, 1791, at Dean, in the parish of Great Harwood, a few miles from Blackburn, in Lancashire. His ancestors, who were mostly agriculturists, had resided in that locality for many generations. Their names are to be found in the first page of the register of the parish church of Great Harwood, in the year 1556. Towards the close of last century hand-loom cotton weaving had become the principal industry of that district, the manufacture being carried on in the operatives' cottages and in small factories. At the time of the birth of John Mercer, his father had a small spinning factory by the side of the Dean Brook, the rivulet which now supplies the water reservoir of Harwood and Clayton-le-Moors. A few years later, the changes in his occupation which attended the introduction of machinery and the formation of large cotton-mills induced him to give up the factory and pursue agriculture. For this purpose he acquired the lease of a farm in a pleasant locality in the same parish, and resided in a house, still standing, known as 'The Stoops Farm,' from which, after a few years, he removed to a house in a beautiful situation, near the village of Harwood. His son John always retained an enthusiastic attachment to these (then) picturesque scenes of his childhood; no earthly spot, in his estimation, was more beautiful than Harwood.

But John Mercer's boyhood was not to be passed in tender pastures and beside still waters. In the year 1799, a large district, including Harwood, experienced an entire failure of the corn crops. This was followed by great scarcity of necessary food, and also by an epidemic of a very virulent character. In the year 1800 his father fell a victim to the epidemic (together with other near relatives), leaving his wife and three children with slender means in a season of general distress. One of the children soon died. Shortly afterwards the widowed mother, with her two remaining children, went to reside with her mother, Mrs. Clayton (who was then an aged widow) in the house known as 'Back of Bowley,' in the same parish. On his mother's side, John Mercer had many relatives who were highly esteemed both for ability and piety, particularly among the Wesleyans. John Wesley, when on a preaching tour, had been the guest of his maternal grandparents in the house just named.

The first regular occupation of John Mercer was that of a 'bobbin-winder,' when a boy of about nine years of age; and his next, that of a hand-loom weaver. He was ten years of age before he received his first instruction in reading, writing, and arithmetic. This he obtained from a pattern designer belonging to the Oakenshaw Print Works, with whom he became acquainted, named Blenkinsop, who, recognising his natural abilities, and pleased with his general good conduct, took an interest in him, and kindly offered to give him lessons in the evenings. John at once applied himself to learn to read with the determination and energy which characterised his after life. When an old man, referring to this period, he remarked, 'I remember that wherever I was, my practice was to be running over *ab*, *eb*, *ib*, *ob*, *ub*, &c. &c., and in that way quickly got through the spelling-book and took up arithmetic.' In a short time, Blenkinsop removed to another place, but not before he became justly proud of his pupil, and used to say that he would 'challenge him with any of the scholars of James Fielding'—the village schoolmaster. John, who had by this time reached long division, pursued his studies by himself, and made such progress that he soon acquired a reputation amongst his fellow-villagers as an adept at figures. Some years afterwards, another kind friend, named Lightfoot, to whom we shall subsequently refer, gave him evening instruction in mathematics. The assistance thus rendered by two friends was all that he received in the way of personal tuition; but his fondness for reading, his habits of industry, and his powers of close observation enabled him to go on improving his mind and laying up an amount of information which may well put to shame many a young man who has had great scholastic advantages.

In illustration of his aptitude at figures when quite a lad, the following story is related of him. At the time referred to, Mr. Roger Cunliffe, afterwards the successful banker, of Manchester and London, resided in the neighbourhood. He was fond of mathematics, and frequently brought questions to puzzle a tradesman of Great Harwood, who had a similar taste. One day Mr. Cunliffe entered the tradesman's place of business, and accosted him, 'Well, John, I've got a puzzler for you this time.' John looked at the sum, and saw that he could not grapple with it at once; but observing John Mercer in the street outside, and being aware of his genius, he affected contempt, and replied, 'Oh! don't come to me with such a simple question as that. Why, fetch a boy from the street, he'll work that for you; I'll fetch you one.' So saying, he went out and beckoned to John Mercer, who entered and gave the required answer with ease, to the great surprise of Mr. Cunliffe.

Another subject to which he applied himself when a young man, with great enthusiasm, was music and singing. Failing in all his endeavours to get help from a teacher, he so persevered with very crude materials, as to attain, entirely unaided, a good knowledge of music, and to become a skilful player on various instruments. He soon gave the helping hand to others, and induced several young men to unite to form a choir for the practice of vocal music, and also a band for instrumental.

The following anecdotes of his youthful days are related in illustration of his musical talent. In the time of war, at the early part of the present century, John Mercer, like other young men of physical ability, had to join a militia corps for military exercise and training for active service, if required. This occupation was very uncongenial to John, and so clumsy were his movements that he had to be placed in the 'awkward squad' for extra drilling.

The Major in command, who was an admirer of good music, was particularly fond of a certain air, of which the band did not possess the written music; and only one man in the band could play it. In this difficulty, a man, who was acquainted with John Mercer's musical powers, told the Major that '"Awkward John" will give them all they want.' He was accordingly sent for; the air was played; John first marked the notes on paper with his pen, and afterwards wrote the music in full, supplying suitable 'parts' for all the instruments of the band.

For a time John returned to the ranks; but his inaptitude at drilling, putting the wrong foot forward, carrying his musket on the wrong shoulder, and like irregularities, necessitated his being brought to head-quarters for reproof. John, however, took out his flute, which he managed to carry about with him, and played so effectively that all exclaimed, ‘He ought to go to the band;’ ‘The band is the place for him.’ To the band he was accordingly transferred for the remainder of his period of service.

Although in after years he regretted that he had allowed music to occupy so much of his spare time in his youthful days, yet his musical taste remained the same throughout his life. Though a man of great self-possession, yet he was sometimes entirely overcome by good music and singing. He and his son John were present at the first Handel Festival at the Crystal Palace. During the performance of the Hallelujah Chorus the whole assembly arose and stood. His son, on looking at his father, saw him bathed in tears, unable to rise, and so agitated, at the conclusion, that for some time he was unable to speak. He greatly enjoyed the annual musical festivals at the Crystal Palace, which he attended whenever practicable.

But we must return to the contemplation of John Mercer as a young man working at the looms, and doing his utmost in the evenings to improve both himself and others; and follow him through a few years of chequered life, not without some events of interest in connection with his future course.

On one occasion, in the year 1807, when visiting his mother, who had married a second time, John was so much struck with the beautiful orange colour of the dress of his little step-brother on his mother's knee, that, to use his own words, he 'was all on fire to learn dyeing.' But his difficulty was how to obtain instruction. All his endeavours seemed fruitless. He had no book on the subject, nor could he procure any receipts. There were no dyers in the village where he resided, but there were fancy dyers at Blackburn, about five miles distant.

Undaunted by his obstacles, he resolved on the following expedient. Having learned that the dyers in Blackburn obtained their various materials from a certain druggist in the town, he went to him, and asked to be supplied with materials for dyeing. 'What do you want?' inquired the shopman. 'I can't tell you,' replied John; 'will you tell me the names of all the different materials you sell the dyers here?' 'Oh, I sell them peachwood, Brazil-wood, logwood, quercitron, alum, copperas,' and others, mentioning all their names. John reckoned his money, and found he could manage threepence for each sort; so he asked the shopman to sell him threepennyworth of each kind, and to write on each packet the name of the article. The shopman did so; and John, to use his own words, 'returned home full of dyeing and dyeing materials.' He was fortunate in obtaining the use of a very convenient place for his experiments, where he had all necessary apparatus for small trials. Here he commenced entirely by 'rule of thumb,' but by great industry, perseverance, and close observation he at length acquired a good deal of useful knowledge, and ascertained methods of dyeing in most of the colours then required. He found dyeing with indigo a very difficult problem for some time, but at length was enabled to accomplish that also, by the proper admixture of lime and copperas with the indigo.

Encouraged by the success of his experiments, his next step was to start in business as a dyer in conjunction with a partner who had convenient premises. The principal material operated on was the remnants which were the perquisites of the Great Harwood hand-loom weavers. Of that and other material there was an abundant supply, and the undertaking proved a decided success.

Ere long, however, another change took place. Messrs. Fort, proprietors of the Oakenshaw Print Works, hearing of the success of John Mercer in his dyeing experiments, sent to him an invitation to enter the colour-shop of their factory, but with the proviso that he should be bound as an apprentice for a given period. The opening appeared to be a desirable one, with good opportunity for experiment and prospect of good promotion. With the approval of his mother and the sanction of his partner, John accepted the proposal. He gave up his dyeing business, and in September 1809 became bound as an apprentice at the Oakenshaw Print Works colour-shop.

As all the various materials and mixtures required for the factory were prepared at the colour-shop, John reasonably expected that here he would have every facility for obtaining the best information relating to the art to which he now intended to apply himself. His expectations, however, were not realised. An unforeseen difficulty arose which rendered his position very trying. The old foreman of the colour-shop, instead of giving the young apprentice a helping hand, and treating him with the confidence he deserved, eyed him with great jealousy, and put all possible obstacles in the way of his advancement. He was kept at the most menial and disagreeable operations connected with the colour-shop, which should have been done by the 'unskilled labourer.'

Under such trying circumstances John Mercer spent about ten months, not without making useful observations, and also, by his inventive genius, rendering assistance to the firm, particularly in turning to useful purpose material hitherto rejected as of no value; but his patient endurance and forbearance brought no relaxation of the antipathy of the old foreman.

An opportunity for a change, however, presented itself. The general convulsions on the Continent, at the period at which we are now arrived, were productive of great depression among the Lancashire calico print works, and other industries connected with the cotton manufacture. In the case of the print works, the culmination appears to have been the issue of the obnoxious 'Berlin decree' in the year 1810, which required the burning of printed calicos and other goods of English manufacture then in bond in certain continental States. The effect of this decree was so severely felt at the Oakenshaw Works that the masters determined on making a great reduction in their output, and offered to surrender the indentures of all their apprentices who chose to leave their service. The peculiarly trying position of John Mercer led him to accept the offer; his indenture was cancelled, and for a time he abandoned the calling of a colour-mixer and returned to his original occupation of a hand-loom weaver. Although this employment was not in harmony with Mercer's tastes, yet he applied himself to make improvements in it, and surprised his friends by his ingenious devices for weaving stripes, checks, and designs. His work made with a coloured weft of blue or red was much admired. His leisure hours were chiefly given to music and to the study of mathematics.

It was at this period he received valuable assistance in his mathematical studies from Mr. Lightfoot (to whom reference has already been made), the father of the two well-known calico printers, the late Mr. Thomas Lightfoot and Mr. John Lightfoot, both of Accrington. Mr. Lightfoot was the excise surveyor for many years at the Oakenshaw Print Works, and subsequently at the Broad Oak Print Works, Accrington. His principal duty consisted in ascertaining the quantity of goods turned out at the print works, printed calicos being then subject to an excise duty of threepence per yard. Recognising John Mercer's natural abilities, Mr. Lightfoot took a lively interest in him, which ripened into mutual and abiding friendship. The assistance which he rendered to Mercer, both in tuition and in friendly counsel, was gratefully remembered and acknowledged by Mercer to his last days.

CHAPTER II.

A FRESH START IN LIFE.

After a couple of uneventful years, we are brought to an important period in the life of John Mercer—namely, from his twenty-second to his twenty-fourth year. Like most successful men, he could look back to an epoch in his life when some circumstances occurred which gave him fresh impetus, fixity of principle, and made an impress on his subsequent life and labours. Such was the period at which we are now arrived. Three circumstances happened about the same time to raise him up to a higher sphere, each to exert its own special influence, and all combining to form the man—the man of large mind, vigorous action, and wide sympathy, who was the admiration of all his acquaintance. These were, first, his being led to take decided views on the subject of religion; next, his matrimonial engagement; and the third, his first insight into the science of chemistry.

In the year 1813 he became deeply convinced of the truth of the Christian religion, and of the Divine authority of the Holy Scriptures. In after years, when accustomed to study and speculate deeply about 'things that are seen' with the mind of a true philosopher, he never overlooked the reality and greater importance of 'things which are unseen.' He regarded the latter as the necessary correlative of the former. Concerning material things and the forces which influence them, he heartily assented to the complete couplet—

> All are but parts of one harmonious whole,
> Whose body nature is, and God the soul;

not sympathising with some philosophers who ignore the last four words, as pertaining to a subject with which the student of physical science has no concern. His religion was of an unobtrusive kind, but he was never ashamed of it. Like Faraday, and a host of distinguished philosophers too numerous to mention, he was always ready to give an answer to every man that asked him a reason of the hope that was in him. His faith was of that genuine kind defined by the inspired apostle as the substance (to his affections) of things hoped for, and the evidence (to his understanding) of things unseen; 'head' and 'heart' both fulfilling their proper functions. In manner of public worship he preferred the services of the Wesleyans, whom he joined about this time, and soon became an active and influential member of that body. One of the earliest of his efforts to be useful in advancing the cause of true religion was by opening a Sunday-school at Oakenshaw, the first in that village, which he carried on with the assistance of a few friends from Harwood. At the latter place, about seven years afterwards (1821 or 1822), he erected a building which was for many years used as the Wesleyan chapel. Although a Wesleyan, he was not a Nonconformist in the proper acceptation of that word. He appreciated the services of the Church of England; and, like most Wesleyans of his youthful days, particularly in country parishes, where the church was supplied with a faithful minister, he regarded the chapel services rather as supplementary to those of the church than as substitutive. He recognised the importance of the Established Church as the church of the people, and realising his responsibility as an employer of labour, he was always ready to help and even take a lead in projects for church extension. Illustrations of the practical character of his religion will appear as we proceed.

His matrimonial engagement, formed about this time, was an event on which Mr. Mercer always afterwards looked back with joyful gratitude. The object of his choice, Mary Wolstenholme, was a very superior woman, of high Christian attainments, whose praise was on the lips of all who knew her. Their marriage took place on April 17, 1814. Mrs. Mercer was distinguished by her untiring devotedness to the welfare and comforts of others. To her faithful discharge of conjugal and maternal duties her husband and her children have borne noble testimony. Of the influence on himself of her help, counsel, and sympathy, none but her husband could tell; but he used to say, 'I may thank her, under God, for all I am and all I have.'

In 1813, Mercer resumed operations in dyeing, which he carried on conjointly with weaving. He succeeded in making a profitable application of the imperfectly spent materials of the print works, which he purchased at a low price. With these and other articles he could produce a variety of colours, but as yet he had obtained scarcely any information respecting the chemical nature of the materials with which he operated.

A few days prior to his marriage a little incident occurred, to which Mercer always attached a lively interest, as a new starting-point in his industrial life. Being at Blackburn (where he had gone to procure his marriage licence), his attention was attracted to a second-hand bookstall in the market-place, at which he was led to make several purchases. His selection was much approved of by the old vicar. Among these books was 'The Chemical Pocket-book, or Memoranda Chemica, arranged in a compendium of Chemistry, by James Parkinson, of Hoxton, 1803.' This was his first systematic book on chemistry. He had just before received from Mr. Lightfoot a manuscript copy of 'The Tables of New Nomenclature, proposed by Messrs. De Morveau, Lavoisier, Bertholet, and De Fourcroy, in 1787,' but the tables in this little book were not calculated to be of much service to one with so little previous knowledge of the subject. He used, therefore, to point to Parkinson's 'Chemical Pocket-book' as his first book on chemistry. He studied it with great interest. 'It introduced me,' he has recorded, 'into a new world. I devoured it.' He soon saw the importance of a knowledge of chemistry to the dyer and calico-printer, both to direct him in searching for improvements and to assist him in discovering the causes of unexpected failure; and following up his reading with experiment, after a while he began to make trials with special reference to the improvement of his own art. Ere long his experiments led to successful practical results.

The short account contained in the book just referred to, of sulphide of antimony, led Mercer to procure some of the native sulphide, and experiment upon it with the view of applying the golden sulphide in calico-printing. After many experiments he at length obtained a solution of antimony in sulphide of sodium, suitable for printing on calico, which gave the bright orange sulphide when the cloth was passed through weak sulphuric acid. This, his first invention of importance in calico-printing, was made in 1817. Previous to the introduction of this colour no good orange was known suitable for the calico printer. The best orange was made from a mixture of quercitron yellow and madder red, difficult to adapt to other colours for the production of styles suitable for the demand of that period. Antimony orange supplied the want. It is in itself a fine colour, and is capable of being combined and interspersed with other materials to produce a great variety of styles.

An incident occurred in connection with his discovery of antimony orange which led to an important step in his subsequent course. By the advice of his friend, Mr. Lightfoot, Mercer offered to make known his method of producing the colour to Messrs. Hargreaves, Dugdale, and Co., proprietors of the Broad Oak Print Works, Accrington. He had an interview with Mr. Hargreaves on a Saturday, and arranged to go to their works on the following Monday to give the necessary instructions. On his way thither, on the day appointed, when passing through Oakenshaw, he was met by Mr. John Fort,[1] one of the proprietors of the Oakenshaw Print Works, who, after some conversation, offered him the situation of experimental chemist at their

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[1] The grandfather of Mr. Fort, who now resides at Read Hall.

colour-shop for five years, at a salary, at first, of thirty shillings per week. Mercer at once accepted the offer; but that did not prevent his going to the Broad Oak Works to fulfil his promise to exhibit his process for producing the new colour. Mr. Hargreaves had made up his mind to secure Mercer's services permanently, and manifested great disappointment and displeasure when he was informed of the engagement which Mercer had made that morning with Mr. Fort. Mercer, however, pointed out that Mr. Hargreaves had not given him the smallest intimation that he desired to have him in their employ, and he himself had no expectation of it, seeing that they already had the services of a French chemist, M. Steiner. Mr. Hargreaves acknowledged that Mercer had acted judiciously, and he himself foolishly in not engaging him on the preceding Saturday; and on parting expressed the hope that he would find in Mr. Fort a good master, and that Mr. Fort would find in Mercer a good servant. To this incident in his history Mercer used to refer, as an illustration of the important influence which a very trifling circumstance may exercise on the whole of a man's subsequent life, such as his meeting Mr. Fort while on his way to Broad Oak. The promise was made to Mercer, that if his newly discovered colour became applied successfully at Broad Oak, he should receive a pecuniary compensation. It was used there for some time extensively, with excellent results; but the promise made to Mercer was overlooked; and, though such help would have been very acceptable, Mercer's liberal and friendly disposition prevented him from giving Mr. Hargreaves a reminder of the promise.

The day following the interview just described, in February 1818, Mercer entered the service of Messrs. Fort as experimental chemist at their colour-shop, the place where he had spent some time, eight years previously, under very different circumstances (p. 13). Finding now a good scope for his inventive genius, and for practical application of chemistry, he pursued his experiments with the energy and discretion which together generally lead to success. He first worked with antimony orange, and introduced a variety of ingenious styles in connection with that colouring material. Thus, for example, by exposing cloth printed with antimonial sulphide to weak solution of copper or of lead, he obtained various shades of brown and olive; for a white discharge on the orange, he printed solution of mercuric chloride, which produced chloride of antimony, free sulphur, and mercurous chloride. These various styles were much liked, and a large demand existed for them for some years.

But Mercer did not confine himself to searching for new colours and inventing new styles. Although in many dyeing operations great proficiency had been attained, even from remote ages, yet previous to the time at which we have arrived very little was known of the chemistry of most of the leading processes. He saw that the want of this knowledge was a great disadvantage. Oftentimes loss and trouble occurred which might have been avoided by an acquaintance with the chemical characters of the materials. He knew that serious failures, which often occurred through small causes very difficult to discover without such knowledge, might be traced to their origin, and thereby the recurrence of such accidents be prevented. He therefore zealously availed himself of the best opportunities he possessed of learning the chemical properties of his various materials; and, considering the disadvantages under which he was then placed, his progress was very remarkable.

At this early period, an interesting illustration is presented of his being led to anticipate subsequent conclusions of experimental chemists, in opposition to views then universally accepted. It relates to the constitution of white indigo, which was then regarded as deoxidised indigo; blue indigo being considered the oxide of white indigo. Mercer was led to the conclusion that white indigo is a compound of blue indigo with hydrogen, which was proved to be the case some years afterwards by the analyses of M. Dumas and others.

In Mercer's experiments with combinations of indigo and antimony orange, he observed that when an alkaline sulphide containing *excess of sulphur* is mixed with solution of white indigo, a precipitate of blue indigo is produced; but no such result follows the admixture of the alkaline *monosulphide* with similar solution of white indigo. Hence he concluded that the excess of sulphur combined with the hydrogen of the white indigo to form sulphuretted hydrogen, with production of blue indigo. (See extract from a letter to R. Warington in Appendix II.)

During the next few years Mercer succeeded in introducing several novel styles of calico prints, some of which were so much liked that it is said they produced for a time an excitement in the Manchester market, and the demand was greater than the Oakenshaw Works could supply. But his most interesting discovery about this time was the application of chromate of potash. Some years before this he had procured a small quantity of that article for experiment; but its cost (ten shillings and sixpence per ounce) was then prohibitory to its practical application. In 1823, Mr. Fort brought to Mercer a specimen of French printed calico of madder purple ground with a bright yellow discharge; a novel style which excited much curiosity. Mercer at once suspected the yellow to be chromate of lead, and proved this to be the case by applying chemical tests.[1] As his previous small experiments with a view of obtaining similar work were encouraging, his firm procured from Mr. Andrew Kurtz, the first manufacturer of chromate of potash on the large scale, one hundredweight of impure yellow chromate, the price at that time being eight shillings per pound. It was then only used for preparing bright chrome yellow for carriage and similar decoration. Mercer soon ascertained the right method of applying chromate of lead to calico; first printing the lead material in the form of acetate or nitrate,

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[1] He says, 'I found "sulphuret of lime" changed the yellow to black, and muriate of tin discharged the colour, showing it was not obtained from quercitron bark or Persian berries.'

next transforming this to sulphate by sulphate of soda, and afterwards passing the cloth through the solution of chromate of potash. By the addition of an alkali he obtained the orange subchromate of lead. A fine field was then opened for the interspersion and admixture of these with other colours, which Mercer pursued with vigour and success. He soon brought out styles having designs of chrome yellow or chrome orange on variously coloured grounds; and also, for foreign markets, chrome yellow and orange grounds with designs in various colours. Soon after the purchase of the first hundredweight of the chromate of potash, two men were sent down from London to Oakenshaw, by the manufacturer, to get information respecting this new application. Mr. Fort freely gave them the required information, and they communicated it to other calico-printers, by whom it was readily adopted. From that time the manufacture and applications of chromate of potash developed with great rapidity, and with reasonable reduction in its price.

For a time, Mercer used the chromate of potash only for the production of the chromates of lead, alone or mixed with other colours; but ere long he discovered that the oxidising property of chromic acid (or of a mixture of chromate of potash with sulphuric acid) rendered it capable of another important application, namely, that of a 'discharging material.' As such, it was found to be specially suitable for indigo. The following may be given as illustrations of his earliest productions of works of this kind:

To obtain a white design on a blue ground, cloth dyed with indigo in the usual way was 'padded' in solution of bichromate of potash, dried at ordinary temperature in the shade, and printed with a discharge containing sulphuric and oxalic acids. Free chromic acid was thus produced, which oxidised and bleached the indigo.

To obtain a white design on a green ground, pale indigo-dyed calico was padded with a mixture of bichromate of potash and acetate of alumina, and then printed with a mixture of sulphuric and tartaric acids. The indigo was discharged as well as the aluminous mordant. By next dyeing the cloth in liquor of quercitron bark, the desired result was obtained. Mercer worked with great success on the various applications of the chromate as a discharging material, and introduced a variety of new styles, which for some years met with a large demand. But a detailed account of these would now be uninteresting.

Among the numerous applications of chemistry to calico-printing made about this period, that of manganese bronze, introduced by Mercer in 1823, takes a prominent place. He has left on record that his attention was first directed to this subject some time previously by the dark brown glaze on the coarse earthenware pots made at a pottery in his neighbourhood. He ascertained that this dark colour was obtained by the addition of a mineral known as 'mangs' (manganese) to the materials for the glaze (clay and lead-ore). The question occurred to him—seeing such a colour can be obtained by fire in the dry way—may not something similar be obtained in the wet way? It is very doubtful whether such reasoning would have occurred to him in after years, when he became better acquainted with the chemical properties of the materials used for the glaze; however, he accordingly procured some of the mineral (peroxide of manganese) and set to work to obtain a neutral solution of the sulphate. He first used dilute sulphuric acid mixed with sugar, as the solvent; and, after a short time, found that when cloth, impregnated with that solution, was passed through caustic soda liquor and exposed to the air, it became dark brown, by the formation of a higher oxide of manganese. This soon took an important place as a new colouring material. Mercer afterwards greatly improved his method of obtaining sulphate of manganese by reducing the native peroxide to protoxide previous to mixing it with sulphuric acid. He effected the reduction by heating in iron retorts (such as are used for wood distillation) a mixture of the ground peroxide with small coal. While this calcined oxide was being mixed with dilute sulphuric acid, he added a small quantity of ground peroxide. This served to peroxidise any ferrous sulphate which would otherwise be present; after saturation, chalk was added to precipitate peroxide of iron. He thus obtained a neutral solution free from iron. Another subsequent improvement was the use of a weak solution of bleaching powder to effect the instantaneous peroxidation of the protoxide of manganese precipitated on the cloth; instead of the slower method of exposure to the air.

An important field for experiment was now presented to Mercer in the combination and interspersion of other colours with the new bronze ground. For a white discharge, he used tartaric acid (hanging the cloth for a day or two); also acid protochloride of tin; and by the combination of the latter with various colouring materials he obtained patterns on the bronze ground of red, orange, yellow, blue, green and black. Some of these styles, for a time, met with a large demand.

One, which included chrome-yellow designs on the bronze ground, was much inquired for; also a dark green, obtained by first dyeing the cloth pale blue and afterwards bronze (or the reverse order), which was a special favourite with Quakers. A style containing a 'half discharge' of the manganese bronze, obtained by means of arsenite of soda, was very popular. Mercer made the observation that when a solution of that compound, thickened with gum, is printed on the manganese bronze ground, the colour is reduced to a very uniform 'half shade'; however much of the arsenite is applied there is no complete decolouration, nor are there any irregularities. No other deoxidising agent was discovered by which a similar effect could be obtained.[1] Mercer has remarked, 'By labour and perseverance I was enabled to give a great number of changes and new faces to the bronze style.' By giving it occasionally slight modifications or 'new faces,' this style maintained its popularity for several

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[1] This interesting observation suggests the formation of a definite arseniate of manganic oxide.

years. It has reappeared at various times, with more and more delicate accompaniments, taking a good position about every ten years, the processes practised at the print-works being essentially the same as Mercer's. The bronze style was in large demand three or four years ago.

A discovery which Mercer made in 1823, relating to the use of indigo, deserves notice here. This was the use of metallic tin as a deoxidising agent for the conversion of blue to white indigo. By simply heating indigo in caustic alkaline liquor in contact with metallic tin, he obtained, with great facility, a solution of white indigo which admitted of a variety of useful applications. This solution, simply thickened with gum and mixed with tartaric acid, was printed on the cloth and exposed to the air to become blue by oxidation; or, to obtain a deeper colour, the above solution was neutralised by an acid, the sediment was mixed with protochloride of tin, thickened and printed, and the cloth afterwards passed quickly through alkaline liquor to redissolve the indigo material. The tin solution of indigo was made use of by Mercer in a variety of ways for several years, until it was gradually superseded by improved methods of applying Prussian blue.

The useful application of materials previously wasted, and methods of completely extracting organic colouring matters from their various crude derivatives, received Mercer's attention from his first connection with dyeing and calico-printing. His success in this direction when a young man has already been referred to (page 14). An interesting example of the service he thus rendered his employers is his treatment of cochineal, which he introduced in 1824 or 1825. He ascertained that by the usual mode of extracting the colouring principle of that material, practised until then (that is, simply digesting in hot water), fully one-third of the valuable colouring matter remained in the dregs undissolved, and was therefore wasted. This was a very important matter, considering the high price of cochineal (ten shillings or upwards per pound). Mercer discovered that by the addition of a neutral alkaline oxalate to the water, the whole of the colouring matter can be dissolved without difficulty. In the Appendix (§ III.) will be found a detailed account of the method of making cochineal liquor pursued at Oakenshaw. Although Messrs. Fort communicated this improvement to a few friends in the same business (who afterwards used it regularly), it was not generally known in the trade for many years. About twenty years afterwards, a French chemist came to this country to induce calico-printers to take up his new method of exhausting cochineal. When visiting the Oakenshaw Works, however, he discovered that he had long been forestalled by Mercer. The method of the French chemist was similar in principle, but somewhat more complicated, and not more effective. The same solvent (a solution of a neutral alkaline oxalate) was also used by Mercer for dissolving the colouring matter of lac. He made the observation that its solvent power on that material is 'very remarkable.'

CHAPTER III.

PROGRESS AT THE OAKENSHAW WORKS.

THE important services which Mercer thus rendered his employers received a just recognition in his being admitted into partnership in the year 1825. This connection continued until the retirement from business of the principal partners in the year 1848. By thus securing a continuance of Mercer's services, the firm maintained a high position and became very prosperous; notwithstanding the great impediment which then existed to the development of the art of calico-printing in the odious excise duty of threepence per square yard on all printed calicos.[1]

While thus actively engaged in his technical work, Mercer found time for studying

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[1] The abolition of this duty in the year 1831, and the increased manufacture of cotton cloth about the same time, gave a great impetus to calico-printing in this country.

scientific subjects of a wider range. The mathematical bent of his mind led him to take a deep interest in astronomy; his independence and comprehensiveness of thought sometimes leading him to ingenious speculations and theories. In the year 1835 he wrote, 'My imperfect acquaintance with the astronomical observations of others' (referring especially to French astronomers) 'prevents me from giving them proper attention and following them up. I spend much time on something which I think new, and then all at once some time after I find the idea or theory is not new. Sometimes it is accepted as sound, and sometimes rejected as unsound or doubtful.' Whatever might be the subject under his consideration, he always aimed at reaching abstract principles, and loved to trace the harmony of the various forces of nature.

Of chemical books, after his primer, to which we have already referred, he studied Chaptal's 'Elements of Chemistry,' and Thomson's 'System of Chemical Philosophy.' He was much interested in questions relating to theoretical chemistry; not like many experimenters of that day, who were accustomed to pass on from fact to fact without attempting to deduce general principles; nor was he, on the other hand, one who would accept a theoretical principle as if it were a fact, without considering all the evidences and bearings. His laboratory experiments, whether with a technical object or for scientific research, were usually suggested by some conception or idea in his own mind; and his endeavour was to reduce isolated facts as far as possible to general laws. He had a remarkable comprehensiveness that enabled him to see all sides of a subject, to perceive its bearings, and to trace its results. It was probably this feature that chiefly impressed his chemical friends. A distinguished chemist, writing to him in the year 1846 to ask his opinion respecting a new theory which he was about to publish, said, 'I know of nobody that can see the bearing of an important discovery better than yourself.'

As might be expected from the circumstances in which Mercer was placed, the outcomings of his fruitful mind were more frequently of a technical than of a purely scientific character. Of the latter, interesting examples will appear as we proceed; but as our sketch of his future work must be to a great extent chronological, most of the results of his labours which we have next to notice are of a technical character.

It is probable that half a century ago the position of a chemist at calico-printing works was far more onerous and difficult to fill than it is at present. At that time, his materials were for the most part supplied in a crude state, requiring careful treatment in a great variety of ways, to adapt them for their various uses; whereas now he obtains a large number of colouring materials specially prepared by chemical colour manufacturers, ready for his various requirements, according to simple rules. In the preparation of such materials ('specialties'), the principle, in fact, of subdivision of labour has been largely carried out as a necessity, and the results have proved, in these as in most other instances, highly beneficial to both the consumer and the manufacturer. Fifty years ago, however, the case was different. Much labour was then necessary to ascertain the chemical characters of the various materials, and to deduce therefrom, as far as possible, general principles for guidance in the various operations; and although the practice of the present day differs to a large extent from that of the old printers, yet it may be said that in many respects the present workers reap the fruits of the labours of John Mercer and others of his day.

As soon as he became acquainted with the doctrine of chemical equivalents, he adopted a plan of working in his laboratory and colour-shop which is probably not so fully carried out in the present day as is desirable—namely, that of having the strengths of his various solutions of chemicals adjusted to a simple relation to their chemical equivalents. We refer to the solutions for the colour-shop, and for the general experimental work of the laboratory; not to solutions for volumetric analyses, which are made of special strengths for special objects. For general work, the same volume of his different chemical solutions contained either the equivalent or a simple fraction or multiple of the equivalent. In describing his system in a letter to a friend, he wrote: 'In my branch of business, in adjusting the strength of my liquors, I have always had an eye to the gallon (10 lbs. of water), so as to have in a gallon one equivalent, or "atom" as I call it, or two "atoms" or more, according to the material. For a calico-printer, there are no numbers so convenient as Thomson's (oxygen being 1·0), converted into ounces avoirdupois. By the expression "one atom," I therefore mean the number of ounces on the oxygen scale; and I generally have that quantity in a gallon of liquor.' A gallon of sulphate of copper solution would therefore contain 15½ ounces; that of acetate of lead 23¾ ounces; his nitrate of copper solution was of sp. gr. 12° Twaddell, containing 4 ounces of metallic copper per gallon; his solution of bleaching powder (about sp. gr. 10½° Tw.) contained 4½ ounces of available chlorine per gallon. Those few materials which it was desirable to use in a much stronger form were also adjusted to the gallon: sulphuric acid, for instance, Mercer used for general purposes at 70° Tw., at which strength $\frac{1}{16}$ part of a gallon contains one 'atom,' or 6⅛ ounces of concentrated acid (O.V.). For measuring his liquids for ordinary work, he made use of a peculiar division of the gallon, which he found very convenient, and to which we shall occasionally have to refer. He divided the imperial gallon into 16 parts or 'gills' (not therefore the common gill), and each 'gill' into 16 parts, which he designated 'spoons;' each spoon was further divided into 16 parts.

We may take this opportunity of noticing Mercer's volumetric process for testing bleaching powder and bichromate of potash, which he devised in 1827. At that time the quality of commercial bleaching powder was not only very inferior, as compared with the present manufacture, but subject to considerable variation, to the great inconvenience of the consumer. Its strength, as supplied by the manufacturer, varied from 14 to 25 per cent. of available chlorine; or, as Mercer expressed it, 'from 25 to 45 per cent. of pure dry chloride of lime,' supposed to consist of 1 equivalent of chlorine and 1 equivalent of lime.

The principle of his process consists in ascertaining how much of the bleaching powder or bichromate to be tested is required to convert a given quantity of pure yellow prussiate of potash to red prussiate, indicated by a solution of ferric salt: '53¼ parts of yellow prussiate thus oxidised represent respectively 1 part of oxygen, 4½ parts of chlorine or 8 parts of dry chloride of lime, and 6⅓ parts of bichromate of potash.' It will be obvious that this test may be applied in various ways. Mercer's original measure was a 2½-ounce tube similar to the old alkalimeter, but with four graduated columns for refilling when necessary, each column being marked with the percentage of pure 'chloride of lime.' For testing the various solutions of chloride of lime, or bleaching liquors, used at the works he used a 10-ounce measure having four graduated columns indicating the number of ounces of 'chloride of lime' per gallon, from half an ounce to twenty-four ounces. This process was among the earliest examples of volumetric analysis. Finding it of great utility, Mercer communicated it to those of his friends who might derive advantage from its use, but no account of it was published for several years afterwards. Some particulars of the manner in which this test was subsequently applied at the Oakenshaw Works in testing liquors will be found in the Appendix (§ IV.).

The improvements which the fertile genius of Mercer enabled him to introduce into the Oakenshaw Works during the ten or twelve years following his admission into partnership were of a miscellaneous character, and hardly admit of classification. Some of these proved very remunerative. Among these improvements we may notice the following :

A NEW METHOD OF FIXING PRUSSIAN BLUE.

Having ascertained that the peroxide of iron may be held in solution by means of tartrate of potash, and also sugar, in presence of excess of carbonate of soda, Mercer made use of a mixture of such a solution with yellow prussiate of potash as a means of applying Prussian blue. This was largely used previous to the introduction of 'steam blue.' 'I first added,' he has recorded, 'sugar or tartar to red nitrate of iron, then carbonate of soda until the peroxide of iron was redissolved, and then yellow prussiate of potash. This was printed, and the cloth run through dilute sulphuric acid, when a very bright Prussian blue was fixed on the cloth. I also added to the above mixture alkaline solutions of arsenic and antimony to obtain various shades of green.'

A NEW OXIDISING AGENT FOR CATECHU.

In 1830, or thereabouts, Mercer discovered an excellent method of fixing, by oxidation, the colouring principle of catechu. Though used in the East as a brown dyeing material from time immemorial, catechu was not used in calico-printing until about the year 1829. The basis of the colouring matter is applied in solution to the cloth, and the brown colour is obtained by its oxidation in the fibre. To promote the oxidation, the common practice was either to mix with the catechu liquor some nitrate of copper and sal-ammoniac, which by 'ageing' gave an olive brown; or else to add carbonate of potash, which by steaming gave cinnamon brown. Mercer had noticed the remarkable property possessed by salts of manganese of promoting oxidation of substances under certain circumstances, even when present in very small proportion.[1] On

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[1] Interesting illustrations of this property of salts of manganese will be found in a subsequent notice of Mercer's views on *Catalysis,* in a paper to the British Association in 1842.

trying the effect of these salts on catechu liquor, he found that the oxidation took place with great facility, the manganese salt acting as a bearer of oxygen from the air to the basis of the colouring matter. The salt of manganese preferred by Mercer was the acetate; or, better still, a mixture of acetate of manganese and acetate of lime. After steaming, the catechu was found 'beautifully oxidised, giving a very rich, strong colour,' which was distinguished as 'Russell brown.'[1] For dyeing, Mercer considered this superior to all other methods of oxidising catechu, and used it until the stoppage of the Works at the dissolution of partnership.

APPLICATION OF SULPHOCYANIDE OF POTASSIUM.

The use of sulphocyanide of potassium (or, rather, hydrosulphocyanic acid) as a weak deoxidising agent, capable of discharging certain

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[1] Not a great compliment, it may be thought, to the distinguished statesman, who was then so deservedly popular; but it may be placed in the category of the 'wellington' and the 'brougham.'

colours without affecting others, enabled him to obtain some very peculiar and pleasing styles, not obtainable by other means then known. One of his applications of the sulphocyanide (mixed with a little sulphuric acid) was for discharging manganese bronze without injuring blue, or interfering with subsequent dyeing with madder, logwood, &c. It is not effectual in alkaline liquors. Mercer continued to use this article largely as a deoxidising discharging agent in various ways up to the time of the dissolution. Its utility arises from its being effectual when mixed with weak acids, and from leaving no metallic salt on the cloth.

NEW APPLICATION OF RED PRUSSIATE OF POTASH.

Mercer made the interesting discovery in 1835 that a mixture of red prussiate of potash and caustic potash might be advantageously applied as an oxidising agent. In the presence of certain reducing or deoxidising substances, the caustic potash yields oxygen to these and potassium to the red prussiate; the latter thereby becoming changed to yellow prussiate. To produce the various results required in print-works, it is necessary that the printer should have oxidising agents of different degrees of energy, from atmospheric air to free chlorine. The above mixture was used by Mercer as an oxidising agent of moderate strength with great success in a variety of ways. He found that it oxidises and bleaches indigo, cochineal and safflower, but that it does not affect madder or Persian-berry yellow; it changes Brazilwood and logwood to yellow. An important application of the mixture was for discharging indigo when associated with madder colours, the latter remaining unchanged.

Instead of printing on the dyed cloth a mixture of the red prussiate with the caustic alkali, Mercer sometimes applied them separately. Thus, for example, to obtain a design in red and white on a blue ground, he padded the blue cloth in solution of the red prussiate (which by itself has no action on the indigo), then printed caustic soda for the whites, and aluminate of potash for the reds, thickened with British gum. The cloth was next passed through a solution of sal-ammoniac, and lastly dyed with cochineal. For the latter, various dyeing infusions were sometimes substituted, according to the tints desired. By such modifications, very pleasing effects were obtained. But the improvements introduced some years afterwards in steam colours allowed these styles to be closely imitated with less durable (or, as Mercer termed them, 'false') colours, at a lower cost; for which reason, the application of red prussiate as a discharging material, though very interesting in a scientific aspect, was not long practised extensively. Mercer remarked in 1847, 'that the introduction of such false colours has been a great drawback of late years to the introduction of novelties in durable colours, unless they are cheap or cannot be imitated by steam colours.' In 1847, Mercer contributed a paper on the oxidising power of red prussiate to the Chemical Society, which will be found in the Appendix (§ V.).

PREPARATION OF PROTOSULPHATE OF TIN.

Neutral protosulphate of tin was used by Mercer as an excellent substitute for the protochloride in cases where the use of the chloride was objectionable. No convenient method suitable for the factory was known of preparing this salt in a neutral state without admixture of chloride. Mercer accomplished this by making use of a solution of pure sulphate of copper, which, when treated with metallic tin, gives a precipitate of metallic copper and a solution of protosulphate of tin. This excellent method of preparing the sulphate was devised by Mercer in 1829.

In 1 gallon of warm water he first dissolved 1 lb. of sulphate of copper, added 2 lbs. of finely feathered tin, and stirred until the copper was precipitated; then added 1 lb. more of sulphate of copper, agitating as before, and afterwards another pound of sulphate of copper (making a total of 3 lbs.). This was agitated until the copper was completely precipitated. He thus obtained 'a fine neutral solution' of protosulphate of tin of about 42° Tw., containing about 1½ lbs. of tin to the gallon.'

A more recent receipt directs 4 lbs. of sulphate of copper to 1 gallon of cold water, with excess of feathered tin; which gives liquor of 48° Tw., containing about 2 lbs. of tin to the gallon.

Mercer made the following observations respecting the properties of the solution thus prepared:

1. It (liquor of 42° Tw.) will stand dilution with twelve times its volume of water before a precipitate appears.

2. It will thicken with either gum or starch.

3. Steaming does not cause it to injure the cloth.

4. Tartaric acid added to the sulphate precipitates most of the tin as tartrate. Neutral tartrate of potash, not in excess, precipitates the tin completely, but an excess dissolves the precipitate. When filtered and washed, the precipitate is soluble in a very

small quantity of alkali, either caustic or carbonate.

5. Citrate of potash precipitates citrate of protoxide of tin, soluble in excess.

6. By adding excess of caustic potash or soda to a mixture of protosulphate of tin and sulphate of copper, an alkaline solution of peroxide of tin is produced (a stannate), and a fine black precipitate containing copper.

7. When added to Persian-berry yellow it makes a very fine steam discharge; on buff ground (peroxide of iron) this mixture gives a fine yellow; a part of the protosulphate being oxidised, gives the stannic oxide necessary to form the lemon yellow.

Protosulphate of tin was used at Oakenshaw for making the protonitrate and the protoacetate, by double decomposition with the respective salts of lead; and the prototartrate by precipitation with tartaric acid, and dissolving the washed precipitate in an alkaline tartrate.

Among some pleasing styles which Mercer

introduced at this period may be mentioned the following:

He took pieces of pale blue cloth and run them over three 'ribbon rollers' (a description of which is given in the Appendix, § VI.), the first with water, the second with steam cochineal liquor, the third with steam Persian-berry yellow liquor; the pieces were next steamed and washed, then padded in neutral chromate of potash, and afterwards printed with an acid mixture which discharged all three colours. The result was blue, purple, and green, in shaded stripes, with white running through.

Another, distinguished as the 'Festival style,'[1] was produced thus: The cloth was first printed with a mixture of sulphate of copper and sulphate of lead known as 'yellow paste,' and with sulphate of copper, or 'white paste,' then dyed dark blue; after clearing, the printed parts were white. The cloth was

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[1] So named in commemoration of the first Manchester Musical Festival, in 1827.

'winced' in a mixture of carbonate of potash and carbonate of ammonia, by which the lead sulphate became carbonated; then dyed pale blue; then 'winced' in bichromate solution; and lastly passed through a weak acid liquor (oxalic and sulphuric). The result was a brilliant and fast yellow and a pale blue, on a dark-blue ground.

Another style, which became known as 'Dole yellow,'[1] was obtained by printing on indigo and cochineal colours a paste containing chromate of lead with other materials. By steaming, the indigo or cochineal was discharged and replaced by a fast yellow No preparation or chroming was necessary. This style was produced continuously at Oakenshaw up to the time of the dissolution. The latest receipt for Mercer's 'Dole yellow' will be found in the Appendix (§ VII.).

In 1828 he introduced a good method of producing a light design on a darker ground,

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[1] So named from the circumstance of its introduction affording employment to a large number of the Oakenshaw operatives, who had previously, through slackness of work, been receiving relief, or 'dole,' from the firm.

which was extensively used at the Oakenshaw Works, and probably might be found useful at the present time. He discovered that a mixture of acetate of lead and nitrate of lead in their single equivalent proportions (16½ parts of nitrate and 19 parts of crystallised acetate) dissolves in water to a far larger extent than either of these salts separately, forming a solution which is practically uncrystallisable. According to Mercer, a gallon of water will hold in solution forty-five pounds of the above mixture; whereas, separately, a gallon of water will dissolve scarcely five pounds of nitrate of lead, or scarcely four pounds of the acetate. The first practical application which he made of this discovery was the production of a pattern with sulphate of lead deposited within the fibre of cloth previously coloured, thus producing a lighter shade; the original colour being only weakened, not discharged. The cloth, already dyed or printed with almost any colour, was printed with the following mixture :

Acetate of lead, 6 lbs. 6 oz.; nitrate of lead, 5 lbs. 10 oz.; water to make one gallon, with starch for a thickener: it was then passed through a hot solution of sulphate of soda. White sulphate of lead was thus deposited within the fibre, weakening the colour and giving a very pleasing effect. Neither the acetate nor the nitrate of lead, alone, is sufficiently soluble to allow of being thus applied.

Another of Mercer's styles, for which there was at this period a large demand, was obtained in the following way: The cloth was passed over three 'ribbon rollers,' the first supplying yellow prussiate of potash, the second Brazilwood liquor, and the third Persian-berry liquor, thus covering the whole of the cloth and also overlapping. The cloth was then printed by block with a mixture of protochloride of tin and protosulphate of iron, thickened with starch; the result was blue with the yellow prussiate, yellow with the berry liquor, and red with the Brazilwood liquor; also green, orange, and purple, at the overlappings. The instantaneous appearance of all these colours on applying the block was very striking. The colour of the unmordanted parts was cleared by washing in 'cool bran.' The tin salt prevented the protosulphate of iron from 'sullying' the colours.

'Myrtle green' was a combination of chrome orange and indigo. The cloth was first dyed chrome orange, and afterwards blue. The design was then produced in blue, yellow, or white, by a discharge for either one or both of the colours. Receipts for some of the discharges used at Oakenshaw for this style are given in the Appendix (§ VIII.).

Towards the close of the period comprised in this chapter, Mercer contrived an excellent method of dyeing and printing merino cloth: a black ground, with designs of various colours. If the merino is dyed in the ordinary way with hot liquors, the colouring material becomes too strongly attached to the fibre to admit of being discharged with facility by 'discharge colours;' that is, the mixtures used for discharging the original ground colour, and at the same time imparting another. Mercer conceived the ingenious idea of printing the discharge colours on the black or dark cloth before the colouring matter became properly attached to the fibre. He found that by dyeing the cloth in cold liquors, and carefully avoiding the application of heat until after printing the discharge, he could accomplish the desired effect. For dyeing the merino, he used a cold infusion of gall-nuts with crude acetate of iron and 'wood acid.' After being printed with the various discharges, the cloth was put on the steam roller and steamed for one hour; which not only effected the discharge but completed the attachment of the original ground colour. Mercer had an extensive system of discharge colours for this style, comprising every shade, in all of which the proper discharging agent was oxalic acid and oxalate of ammonia, in conjunction with protochloride of tin. Several selections from his receipts for these will be found in the Appendix (§ IX.). For some years after its introduction this style was in good demand, and proved very remunerative. It excited curious inquiry in the trade; but Mercer, with his usual generosity, did not keep it to himself. He soon communicated it to Messrs. Wilks, Jennings, and Co.

CHAPTER IV.

SOME INVENTIONS OUTSIDE THE FACTORY.

During the period in which Mercer had been making the special improvements in his art, which are described in the preceding chapter, his attention was sometimes given to subjects outside the colour-shop, both theoretical and practical, which we must not overlook. To such subjects as are connected with speculative chemistry we shall again refer. Here we may with propriety notice two inventions of a practical character. In one of these he rendered an important service to the medical practitioner—namely, a ready

PROCESS FOR MAKING ARTIFICIAL MAGNETIC OXIDE OF IRON,

in a light form, adapted for medicinal use. Taken in the precipitated state, washed, *but* *not dried*, this was regarded as a valuable addition to the *Materia medica.* It is said that the use of this oxide by some medical practitioners was so successful that it added largely to their reputation. Probably the circumstance of its being in a solid or precipitated form has hindered it from being used so extensively as it deserves.

In a letter Mercer wrote to Mr. Thomas Starkey Thomson, in 1841, he observes, 'This substance was prepared by me in 1831, and in 1833 applied extensively as a medicine with great success. Mr. Gossage, of the Stoke Prior Alkali Works, who was staying with me at that time for a few days, was so impressed with its value as a medicine, that, upon his return home, he wrote to me for a quantity of it to send to his friend Dr. Jepson, of Leamington, to whom I forwarded a quantity, with the receipt for its preparation, and the dose. This receipt was published by Dr. Jepson and given away among his friends. Dinneford was also employed to make it, and was an agent for the sale of it in Manchester.'

Mercer's mode of preparing this oxide, as communicated by Mr. Thomson to the Chemical Society ('Proceedings of the Society,' vol. i. p. 14), was the following: 'Take a quantity, say one pound, of the common crystallised protosulphate of iron, dissolve it in water, and add nitric acid in sufficient quantity to peroxidise it, and afterwards expel carefully all excess of nitric or nitrous acid by boiling. To this add one pound of protosulphate of iron, with water sufficient for its solution. Pour the mixture into a solution of caustic potash sufficient in quantity and strength to decompose the whole, and then boil. The precipitate thus thrown down consists at first of a mechanical mixture of the protoxide and peroxide of iron; raise the temperature of the mixture to 212° Fahr., and their chemical union is effected. That such is the succession of changes is proved by dipping into the mixture previous to boiling it a piece of clean cotton cloth, which, after exposure to the air for a few minutes and washing in water, exhibits the buff stain peculiar to peroxide of iron precipitated upon cotton fibre. But if this is done after the boiling, a dirty black stain is obtained indicating the formation of the black oxide.' Mr. Thomson adds: 'This fact is further proved by the oxide, after boiling, having a crystalline structure when examined under the microscope, the minute plates having a brown colour and being transparent, although the edges of the crystals are not sufficiently defined to trace the form.'

I have met with various other receipts of Mercer's for the preparation of this oxide, in all of which the precipitation is effected by *carbonate of soda* instead of caustic alkali; or if the latter is used, it is only a small quantity, added to hasten the complete combination of the two oxides towards the end of the operation. Another modification which he latterly adopted, and which he considered improved the oxide as a medicinal agent, consisted in increasing the proportion of ferrous oxide by using three parts of the sulphate in the ferrous state to two parts in the ferric state.

This process presents a few points of interest in a scientific aspect, even at the present day. For instance, it appears that, at a moderate heat, hydrated ferric oxide is capable of decomposing ferrous carbonate with expulsion of carbonic acid. That such is the case may be seen by first adding a hot solution of carbonate of soda in slight excess to the solutions of ferric and ferrous sulphates separately, and then mixing the muddy liquors before the ferrous carbonate has become oxidised by exposure to the air. On applying heat, more carbonic acid gas is disengaged; the two oxides unite to form the black compound, which readily subsides. It may be prepared in this manner entirely free from carbonate.

Another point of interest is the relative proportion of the two oxides. It will be seen that in Mercer's original receipt the proportion is not adapted to produce the common magnetic oxide, $Fe_2O_3 + FeO$, but a compound of one equivalent of ferric oxide with two equivalents of ferrous oxide; and by his improved process a compound of one equivalent of ferric oxide with three equivalents of ferrous oxide. The latter compound shows no indication of the presence of free ferrous oxide. It retains its blackness without alteration after prolonged exposure to the air.[1]

Another interesting feature in the process is that it presents one of the rare cases in which rapid chemical combination takes place between two bodies both being in the solid state. Here is neither fusion nor solution to bring the molecules of the oxides into actual contact. The particles of the oxides, moreover, are

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[1] In some chemical books it is assumed that Mercer's oxide is the ordinary magnetic oxide, and that the deficient oxygen is supplied by the decomposition of water (*Gmelin's Handbook*, vol. v. p. 193). This is not the case. When a caustic alkali is used for the precipitation, no gas is disengaged while the combination takes place, as that assumption would necessitate (*i.e.* hydrogen). It is also stated, in some chemical books, that hydrated ferrous oxide is capable of decomposing water at or under a boiling temperature, with disengagement of hydrogen. This is incorrect.

If the proportion of ferrous oxide is increased to six equivalents to one of ferric oxide, complete combination of the two oxides takes place on boiling the mixture. The compound is magnetic and almost black. On exposure to the air it retains its colour without appreciable change, but it undergoes a very slow partial oxidation.

enveloped in water, which undergoes no chemical change, but acts merely as a mechanical medium. Does not this show that some chemical attractive force extends beyond the molecules? It is probable that when combination between the two oxides has once commenced at one spot, the peculiar magnetic property of the compound would exert some influence in inducing rapid combination throughout the hot mixture.[1]

With reference to the medicinal use of Mercer's oxide, we may observe that it is considered much more efficacious if preserved and used in the moist state than if previously

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[1] I have observed that if a *cold* mixture of the hydrated oxides, precipitated by potash or soda, is added by degrees, with agitation, to a little of the artificial magnetic oxide, also cold, combination gradually takes place; the whole becomes nearly black and magnetic, and the compound retains its dark colour on exposure. Without the admixture of magnetic oxide, the hydrated oxides, at ordinary temperatures, of course remain a mechanical mixture. It is well known that if ammonia is used (instead of potash or soda) as the precipitant for the mixed oxides, combination takes place in the cold with formation of black magnetic oxide; but in such case the ammoniacal salt which is formed acts as a solvent of the ferrous oxide, and thus becomes the medium of communication between the two oxides. No such solvent action occurs with potash or soda.

dried, owing to its assuming a gritty form when dried, even at ordinary temperatures. The magnetic oxide of iron of the British Pharmacopœia (1865) has not the same composition as Mercer's, but that of the native black oxide ($Fe_2O_3 + FeO$); it is ordered to be dried at a temperature not exceeding 140° Fahr.

Another practical application of his chemical knowledge beyond the precincts of his factory was his

METHOD OF BLEACHING PALM OIL.

This is one of the many cases which might be mentioned, which exhibit Mercer's readiness to afford assistance and advice to other manufacturers, without regard to pecuniary compensation. Having been requested by a friend interested in the soap manufacture to devise a process for bleaching palm oil cheaper than that of Watt (by bichromate of potash and hydrochloric acid), he was led to try the oxidising power of the air; and found that thereby, with the assistance of heat, the decolourising of the crude oil could be accomplished to the extent required; that is, to 'a very pale straw tint.' With the united action of steam and air, a few hours suffice for each operation.

Two interesting observations were made by Mercer in relation to this mode of bleaching palm oil. First, that it is not effectual in the presence of an alkaline earth or basic material of any kind. For this reason an iron pan was found unsuitable. A copper vessel was much better, but when the oil acquired a greenish tinge from copper the bleaching became impeded. Borax also hindered the bleaching. These and similar observations led to the conclusion that the colouring matter should be in its natural free acid condition to be easily oxidised by the air.

Also, secondly, that the oxidation is facilitated in an extraordinary way by the addition at first of a very small quantity of oil which has been already bleached. Five or six pounds of the bleached oil suffice for a ton of unbleached. Mercer has left a memorandum to the effect that with such addition the bleaching takes place in one-fourth the time that is necessary without it. This process was first used at a soapery at Enfield, near Accrington, in the year 1839.

CHAPTER V.

A FAMILY BEREAVEMENT.

While thus so actively and successfully occupied, Mr. Mercer's domestic life was for many years, with one exception, one of unbroken happiness. God had blessed his marriage union, and given him three daughters and two sons. As a 'homely man' he loved his home, and his great enjoyment was his domestic circle. But he experienced a bitter affliction (the exception alluded to) in the death, after a short illness, of his eldest daughter, Mary, in July, 1836. So keenly did he feel her removal, that some began to fear whether he would 'ever be himself again.' His intense sorrow, however, was only what might have been expected, when such a loving and intellectual father was called to part with a daughter of extraordinary gifts and winning amiability. The records and reminiscences we have met with relating to her are few, but very interesting. Even in childhood her love of reading and thirst for knowledge of every kind calculated to raise the intellectual and moral faculties were very remarkable, and elicited the general remark, 'How like her father!' We may presume that she did not despise works of amusement, but we are assured that when a child her greater gratification was in reading historical works, both ancient and modern, works on natural history, biography and narratives of travels. Her natural love of poetry led her to delight in reading, when a little girl, the works of Milton, Pollock, Young, &c. When at school she studied with great enthusiasm, and won the admiration of her governess by the proficiency she soon attained in French, music, and other branches of education.

Like her father, she took great pleasure in studying astronomy. To gaze on the starry heavens and make her observations was a great enjoyment. She loved to contemplate 'the glory of God' as declared in the heavens, and 'His handiwork' in 'the firmament;' but she loved still more the study of His 'statutes' which 'rejoice the heart,' and His 'testimony' which 'maketh wise the simple.' She had learned that 'wisdom' which 'is the principal thing,' and had found Him whom to know is 'life eternal.' No wonder that she was the admiration of all who knew her. 'She was the gem,' an old friend of the family once remarked to me, speaking of her; a sentiment which I am sure her surviving sisters gladly echo. No wonder her father so keenly felt her death. Writing to a friend just a month afterwards, he says: 'I feel as if nothing could make up for our loss. She was such a fine girl; of such a sweet temper and disposition. The Lord bless and strengthen us. We have got through to this time with fair health; but in grief I get worse.—J. M.'

At length, however, the thought occurred to him—'Does not my intense sorrow border on want of submission to the dispensation of my best Friend—Him whom I profess to love above all others? He has spared to me my wife and our four children. Am I thankful as I should be for these? Want of submission on my part may bring further trials and more bereavements.' Such thoughts enabled him to look more calmly on the past and more hopefully to the future, and then to resume his ordinary work with his usual energy. To this we now return, trusting that those of our readers who may not care much about Mercer's domestic life will bear with this brief digression.

CHAPTER VI.

FURTHER IMPROVEMENTS IN DYEING AND PRINTING.

We purpose in the present chapter to trace the outcomings of Mercer's inventive genius in some subjects connected with his own art; not, however, in special 'styles,' but in inventions of a more general character and wider application. Among these, the first that presents itself to our notice is the part which he took in introducing the use of

ARSENIATES AND PHOSPHATES AS SUBSTITUTES FOR COW-DUNG,

in what is called the 'dunging' operation; the principal object of which is to remove from the cloth, previous to dyeing, the portion of the mordant which has not become insoluble and firmly attached during the process of ageing. Without this treatment, that portion of the mordant would dissolve in the dyeing bath (before combining with the colouring matter); to the great injury of the whites and the deterioration of the dyeing liquor. For the dunging or clearing to be effective, it is requisite that the superfluous mordant, immediately it is washed out of the cloth, should be precipitated in the bath in an insoluble and harmless condition. We are indebted to an American inventor, J. D. Prince, for the original suggestion to use a soluble phosphate as a substitute for cow-dung. He came to Oakenshaw to confer on the subject with Mercer in 1839. Mercer perceived the importance of the suggestion; but he also saw that, to produce effective work, it is important to mix with the phosphate some mucilaginous or glutinous material. Without such addition, the 'whites' cannot be properly preserved, owing to traces of the dissolved mordant being reprecipitated on the cloth. According to the original process of Prince, the mordanted goods were exposed in a chamber to an atmosphere charged with ammonia and steam, previous to their being passed through the phosphate liquor. But Mercer proved that by the proper admixture of some mucilaginous or glutinous material this inconvenient operation is quite unnecessary. Further, being aware of the correspondence, in many of their chemical properties, between the phosphates and arseniates, he inferred that the latter might also be used as a 'dung-substitute;' which expectation his experiments fully confirmed.

Mercer and Prince therefore acquired conjointly a patent for 'Certain improved processes to be used in the printing, dyeing or colouring of cotton, woollen, silk or other cloths and yarns,' which embraced Mercer's improvements and additions. This was his first patent. The specification will be found in the Appendix (§ XI.), together with some results of his subsequent experience.

The arseniate of soda was found to be even more effective than the phosphate.

Whichever of these was used, great care was taken to ensure neutrality; free acid on the one hand, and also free alkali on the other, being injurious. The phosphate 'substitute' used at Oakenshaw was a partially soluble mixture of phosphate of soda and phosphate of lime; prepared by saturating a phosphoric-acid solution of phosphate of lime with carbonate of soda and evaporating to dryness. The residue, which was known as 'concrete substitute,' gave a muddy liquor when dissolved in water in the proportion of 2 lbs. to 1 gallon, of which 6 gallons were added to 600 gallons of water to make the 'first substitute bath;' after being passed through which, the cloth was passed through another bath considerably weaker. The phosphate of lime in suspension was effective in clearing, as well as the soluble alkaline phosphate. The latter acted also on the attached mordant, converting it, to some extent, to a phosphate.

Mercer attached great importance to the presence of a mucilaginous or glutinous material in the substitute bath. For some months he used for that purpose carrageen moss, which contains a peculiar mucilaginous substance soluble in hot water, which solution, when concentrated, gelatinises on cooling. For this he afterwards substituted linseed meal with good results, also a liquor obtained by the action of caustic alkali on woollen material. This 'woollen liquor' he made by digesting 4 lbs. of old 'steam cloths' (previously well cleaned by boiling water) in 2½ 'gills' of caustic soda liquor of 70° Tw. and water sufficient to make 6 quarts. This was boiled until the wool was dissolved, and then diluted to make 2 gallons of liquor for use, the specific gravity of which was 14° Tw. Mercer made the interesting observation that, in its behaviour with salts of iron, the 'woollen liquor' thus obtained resembles that prepared from cow-dung. When cold, it gives no precipitate with a solution of protosulphate of iron; not even on the addition of more alkali: but if the mixture is heated, a precipitate is produced, either with or without additional alkali. But with solutions of alum and persalts of iron the liquor produces precipitates, whether cold or hot.

A mixture of this 'woollen liquor' with size made from ordinary glue gave excellent results (1 measure of size liquor of 40° Tw.[1] to 6 measures of woollen liquor of 14° Tw.).

With reference to the necessity of attending to the strength of the liquors in the two phosphate cisterns, Mercer made the following memoranda in 1840: 'If the first cistern gets too weak in phosphate, the white begins to show symptoms of purple, and the black is not full enough, although the pale red continues good. Iron is evidently dissolved. On the other hand, too much phosphate is also injurious. . . For some time (July 1840) our strong red has not been turning out well; this I found to be owing to the second cistern having too much phosphate, which combined in too large proportion with the alumina in the strong red, thus hindering it from com-

[1] *Extract from Memoranda.*—'I find that size made of 40° Tw. sp. gr. keeps much longer without becoming putrid than if made of 20° Tw. If it becomes acid, add a little chalk.'

bining readily with the madder. The excess of phosphate also acted injuriously by fastening the starch or flour paste.'

In 1841, and subsequently, the proportions of materials used at Oakenshaw in this operation were the following: For the first cistern, to 600 gallons of water were added 6 gallons of substitute liquor of 10° Tw. (prepared as before described) and 2 gallons of size liquor of 36° Tw., kept at the temperature of 160° Fahr., for pale red and purple; and for every forty or fifty pieces the bath was renewed with 1 gallon of substitute liquor and 1 quart of size liquor. The second cistern, containing 300 gallons, was started with 2 quarts of substitute liquor and 1 pint of size, and renewed with 1 quart of substitute liquor and 1 pint of size for every twenty-eight pieces. The cisterns were started in the morning and run off in the evening, about seven hundred pieces having been passed through. The above proportion of size is more than had previously been used, but 'the working was excellent; the whites were very good; with twice soaping they were good enough without crofting, and the dyeing was effected with one-sixth less madder than was formerly used with dung. The size must be kept up.—J. M.'

A practice which Mercer found to be advantageous, and which he generally adopted, was to add a few ounces of bichromate of potash to the first substitute bath, with the object of producing a partial oxidation of the ferrous salt dissolved out of the cloth, and bringing it into a condition still more readily acted on by the phosphates of soda and lime.

'PREPARING' DELAINES.

In 1839, Messrs. Fort Bros. and Co. enlarged their operations by undertaking the printing of delaines. The inconvenience arising from the unequal absorbing power of the woollen and cotton fibres for certain colours and mordants was a subject to which Mercer at once directed his attention. Some colouring matters are capable of being absorbed by wool without a mordant far more readily than by cotton. But the reverse is the case with nearly all the materials which were in use among printers forty years ago. The difficulty of applying Prussian blue, for example, to the woollen fibre was, at first, a serious impediment to the printing of delaines. To enable the woollen fibre to acquire that and other colours as readily as the cotton fibre does, was the object of Mercer's experiments. He soon came to the conclusion that the difference in the absorbing power arises from the presence of some deoxidising material in the woollen fibre; and discovered that by passing the cloth through a weak solution of free chlorine (bleaching liquor and hydrochloric acid) the woollen fibre is rendered capable of combining with Prussian blue, oxides of tin, and colouring matters, with the same facility as cotton, giving 'full, rich, saturated colours.' The change thus produced in the colour-receptive powers of the wool is very remarkable. The same colouring material which before this treatment of the cloth gives only dull shades, afterwards gives very bright tints, and any required depth of colour can be obtained. Chromic acid—that is, a mixture of bichromate of potash and sulphuric acid—was found to produce the same effect on the woollen fibre as chlorine; but it left a slight stain which, in the case of printed delaines, was generally objectionable. Chlorine, therefore, was adopted as the oxidising agent for general use.

By means of this process the firm was enabled to introduce a pleasing new style distinguished as 'Royal blue,' in which for some time they had a good monopoly. Mercer communicated the process, however, to a few friends in the trade, and before long it became generally known and practised by calico-printers throughout England, Scotland, and France. Had he patented this invention, there is no doubt he might have realised a large sum for granting licences; but he gave it to the trade with no reservation whatever. The woollen dyers of Leeds adopted the chromic-acid method, as the tinge derived from the chromate was generally of no inconvenience to them. In a communication made in the year 1848, this discovery of Mercer's is described as 'the most important hitherto made in dyeing and printing woollen goods.'

In the Appendix (§ XII.) will be found some of his observations on this subject, relating more especially to the use of solutions of tin in conjunction with chlorine.

ALUMINOUS COLOUR PRECIPITATES.

The next important improvement in calico-printing introduced by Mercer was the employment of lakes, or compounds of various colouring matters with alumina, for steam-colour work. He was led to this by observing the extraordinary facility with which those compounds may be dissolved in a solution of neutral oxalate of ammonia. He found that strong solutions of the colouring matters may thus be prepared, differing somewhat in properties from the solutions of similar compounds in acids; and further, that when cloth printed with such solutions is steamed, the colours become firmly attached. A new method of printing was here presented, which in many cases proved highly beneficial; especially with logwood, Persian berries, peachwood, cochineal, Brazilwood and barwood. Mercer soon communicated his discovery to his friends at the Sabden Works, and subsequently to Messrs. Hargreaves, of the Broad Oak Works. Wherever the process became known it was appreciated and adopted. The following are examples of the method of making the precipitates:

'Peachwood precipitate' was prepared by boiling 100 lbs. of properly aged ground peachwood in three successive portions of water to make 140 gallons of liquor; a solution of 10 ounces of bichromate in two quarts of water was added to the clear liquor; an hour afterwards 12 lbs. of alum, and when that was dissolved, 2 quarts of caustic soda of 70° Tw. The mud was collected by filtration to a bulk of from 10 to 12 gallons.

'Logwood precipitate' was prepared by passing boiling water through 120 lbs. of logwood to make 140 gallons, and adding successively 8 ounces of sal-ammoniac, 1 gallon of chloride of lime liquor of 10° Tw., 12 quarts of red liquor, and 7 gills of caustic soda. The precipitate was filtered to about 18 gallons.

'Barwood precipitate' was prepared by boiling 50 lbs. of barwood in three successive portions of water, 50 gallons each time; adding at the first boiling 3 lbs. of borax, at the second boiling 2 lbs. of borax, and at the third boiling 1 lb. of borax; 6 lbs. of alum were added to the mixed liquors, and the precipitate was filtered to 5 gallons.

Similar precipitates, containing protoxide or peroxide of tin, or peroxide of iron (instead of alumina), were prepared for use in the same manner. For example:

'Barwood tin precipitate' was made by adding to such a decoction as the preceding, with borax, 6 lbs. of tin crystals, and filtering to 6 gallons.

'Quercitron bark tin precipitate' was prepared by boiling 25 lbs. of the bark in 50 gallons of water, in two equal portions; adding to the clear decoction 2 lbs. of tin crystals, boiling for ten minutes, and then adding 18 ounces of carbonate of soda, or enough for complete precipitation. The precipitate after filtration measured 3 gallons.

'Logwood iron precipitate' was prepared by passing boiling water through 120 lbs. of ground aged logwood, to make 140 gallons; adding 6 quarts of chloride of lime liquor of 10° Tw. (or as much as is necessary for oxidation), then 4 quarts of 'red nitrate of iron liquor' of 60° Tw., and lastly, 1 quart of caustic soda of 70° Tw. The precipitate, after filtration, measured 10 gallons.

For application to the cloth, these various precipitates were mixed with oxalate of ammonia (or first with oxalic acid and afterwards ammonia to saturation). By gently heating the muddy mixture, a complete solution was effected, fit for thickening and printing. Examples of mixtures of such solutions for printing cottons and delaines will be found in the Appendix.

For a resist for such colours, acetate of lime, alone or mixed with chalk, was found to be quite effectual; by decomposing the oxalate of ammonia, and thus rendering the colour compound insoluble.

'ASSISTANT MORDANT LIQUOR,' AND 'FARINA PREPARATION.'

The useful material known as 'assistant mordant liquor' was introduced by Mercer in 1842. It consists of a mixture of pyroligneous acid with the acid liquor obtained by the partial oxidation of saccharine and amylaceous materials by nitric acid. Many years previously he had experimented on the partial oxidation of sugar by nitric acid, taking care to use too small a proportion of the latter to allow of the production of oxalic acid, in the expectation of obtaining thereby a material which might be useful as an adjunct to mordants.[1] He found that the

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[1] 'November 18, 1828. I have for a few days past been engaged in experimenting on the action of sugar on metallic oxides, and its power of rendering alumina and metallic oxides soluble in carbonate of potash. I find that this property of sugar is much more powerful if the sugar has been previously

product (which probably consisted for the most part of saccharic acid), when mixed with excess of alkaline carbonates, possesses a high solvent power for alumina, oxides of iron, peroxide of tin, and other metallic oxides. This property at once suggested useful applications. Another property possessed by this material, which Mercer regarded as of great practical importance, is that of retarding the oxidation of substances with which it is mixed. It was with that object that he mixed it with mordants containing protoxide of iron, so that the partial oxidation of the protoxide should not take place before the solution had become thoroughly imbibed by the fibre of the cloth. Finding that this 'farina' or 'sugar preparation,' as he designated it, was improved by the addition of pyroligneous acid, the preparation and use of that mixture was made the subject of a patent by Mercer in 1842, the leading points

acted on by nitric acid' (*Extract from his Note-book*). He then describes some excellent results obtained by printing cotton with such an alkaline solution of iron (made with 'nitrate of iron'), and dyeing with a mixture of peachwood and sumac.

of the specification of which will be found in the Appendix (§ XIV.). Potato starch was the material at first employed for preparing the 'assistant mordant liquor,' as the patented mixture was termed; but subsequently, when sugar became much reduced in price, preference was given to the latter.

A point of interest in a chemical aspect, in the patented process, is the addition of a trace of oxide of manganese, or a salt of manganese. According to Mercer, this addition prevents or impedes the formation of oxalic acid. For this purpose, one part of oxide of manganese suffices for five thousand parts of starch. At the end of the reaction, the salt of manganese is found unchanged, therefore this appears to be another of those influences we commonly call catalytic.

The 'sugar preparation' used at the Oakenshaw Works at the time of their being discontinued was made by mixing one quart of nitric acid of 60° Tw. with a solution of four pounds of sugar in one quart of water; and 'when the liquor became brown' it was diluted to make one gallon. This was mixed with more or less alkaline carbonate, according to special requirement.

STANNATE OF SODA.

Mercer's process for making stannate of soda in the dry way was an important invention patented in the year 1845. Previous to its introduction the stannate was made at all works in the liquid way, by adding excess of soda liquor to perchloride of tin. A chemical manufacturing firm in the neighbourhood, having experienced some difficulty in the ordinary process, applied for assistance to Mercer. He afforded them the required help, and also told them that he had already been experimenting on a new method of making the stannate—namely, by heating a mixture of nitrate of soda, alkali, and metallic tin. The stannate which he thus obtained, when digested in water, gave a solution of tin very suitable for 'preparing,' but a good deal of oxide of tin remained undissolved. Further experiments were carried out conjointly by Mercer and the manufacturing firm above referred to, which soon resulted in the excellent process described in the patent specification (see Appendix, § XV.). Briefly, the process consists in adding metallic tin and nitrate of soda to a fused mixture of hydrate of soda and chloride of sodium. Ammonia is disengaged in large quantity (from the nitrogen of a portion of the nitrate and the hydrogen of the hydrate of soda); the tin passes first into the state of black protoxide, which is presently further oxidised by another portion of the nitrate, the whole mass becoming thereby intensely hot. The mass is removed from the pot in a pasty state, and when cold is ready for dissolving in water. The solution is fit for use. Mercer has remarked that the addition of chloride of sodium completely prevents the material from acting on the iron pot; without such addition the pot would be acted on rapidly, and the stannate be contaminated with oxide of iron.

The stannate thus prepared was found to be admirably adapted for 'preparing' and various other applications; and being much cheaper than the stannate made by the old liquid process, it soon became adopted in most of the print-works throughout England and Scotland. In France, where Mercer had also obtained a patent, the manufacture of the stannate was likewise carried out extensively, under licences. Modifications of this process have been since introduced by others, but to Mercer belongs the credit of having originated the manufacture of the solid stannate, which has proved a great boon to the calico-printer; and his original process still maintains a good position.

MERCER'S 'SCOURING SALTS,'

for 'scouring and clearing wool and woollen fabrics,' was another of his improvements connected with his own art (introduced about the same time as the stannate), with a reference to which we shall conclude the present series. The materials thus designated were sub-phosphate of soda, or 'P scouring salt,' and sub-arseniate of soda, or 'A scouring salt.'

These were found to be of great utility when added to the materials commonly employed for the above purpose; as soap, soda-ash, pearlash, stale urine, &c. He patented this application of the various alkaline phosphates and arseniates in 1846.

CHAPTER VII.

HIS VIEWS AND RESEARCHES ON SOME SUBJECTS CONNECTED WITH THEORETICAL CHEMISTRY.

THE introduction and development of the various inventions and improvements which we have described, together with the constant close attention necessary for the successful superintendence of the operations of a large establishment, subject in their details to variations necessary to meet the changes of popular demand and fashion, could only have been attained by an unusual combination of unwearied diligence, sound judgment, and great energy. But, as we have before stated, Mercer, while thus assiduously and successfully engaged in his technical work, took a lively interest in subjects connected with speculative and theoretical chemistry. He seldom, however, appeared before the chemical world as an original worker in that field. It was rather in his personal intercourse with his chemical friends, and in his correspondence, that he manifested his great interest in such subjects, and his keen appreciation of the labours of others who devoted themselves to researches in theoretical chemistry.

Particularly impressive was the readiness with which he recognised the bearings, the consequences, and applications, of such researches. We find an early illustration of this in a memorandum which he made after reading Graham's early researches on the diffusion of gases. A few chemists still adhered to the old view of Berthollet that the atmosphere is a chemical compound of oxygen and nitrogen. 'Here we have,' he observed, 'the means of giving a final answer to those who hold the view of Berthollet. If air is a mixture, seeing there is a little difference between the specific gravity of oxygen gas and nitrogen gas, the air left after long diffusion should have a little larger proportion of oxygen than before ; if it is a chemical compound there will be no change.' He was then unable to make the experiment, and, so far as his special object was concerned, it soon became superfluous; but it is interesting to know that, many years afterwards, the experiment was made, and Mercer's anticipation was realised. It may be said that his faculty of making clear, broad, inferential deductions from observed facts greatly contributed to his success in technical work.

For many years Mercer had very little intercourse with scientific chemists. He had been making his own observations and forming his own conclusions without assistance from scientific friends, and without the stimulus derived from intercourse with kindred spirits. Publicity and distinction, moreover, were not the objects which he sought to attain. In 1841 he became acquainted with Dr. Playfair (the Right Hon. Sir Lyon Playfair), who for a short time held the post of chemist at the Primrose Print Works, near Clitheroe, Lancashire, belonging to Messrs.

Thompson and Co. Dr. Playfair was much impressed with the genius and worth of his new acquaintance. A permanent friendship, marked by mutual confidence, sprung up, which led to long and interesting correspondence. Two years later, it was my privilege to make his personal acquaintance, and to partake of the kind sympathy which he always showed to young men entering on their callings in life. At that time, I was endeavouring to obtain practical information on the processes of print-works; and I have a grateful recollection of the assistance and hospitality he kindly rendered to me. An abiding friendship, which I greatly valued, was the result.

A biographical sketch of Mercer would be incomplete without reference to the periodical meetings of a few scientific friends (ten at first), in which he took a lively interest, known as ‘the Whalley meetings,’ so named from the place of meeting. They were started at the suggestion of Dr. Playfair, and were held monthly; each of the members was expected to contribute an essay in rotation, one for each meeting; a reserve subject for discussion being always fixed upon in case of the non-attendance of the essayist. The subject was generally chemical, but not exclusively. Occasionally, an evening was devoted to the discussion of chemical subjects of recent discovery. We can well imagine that Mercer's originality of thought contributed in no small degree to the interest which the various members took in these meetings; and sometimes, in the discussions, embryonic facts were made known, and germinant ideas elicited, which afterwards ripened to important and interesting results.

At these 'Whalley meetings' Mercer communicated to his friends those interesting cases of so-called 'catalytic action' with which he illustrated

HIS VIEWS ON 'CATALYSIS,'

in a paper read before the British Association at their meeting in Manchester in 1842. Considerable interest had been excited amongst chemists respecting the numerous instances of chemical decomposition and combination which are produced by the presence of a third body, which itself, apparently, undergoes no change whatever. Berzelius had referred them to a peculiar electro-chemical agency, distinct from other recognised powers, which he designated 'catalytic force.' Liebig had advanced the view that such decompositions resulted from a dynamical action communicated by a body in a state of motion to the atoms of a complex molecule previously in a state of rest. But neither of these suggestions could be regarded as a satisfactory explanation. The question still presented itself—may not these cases be referable to chemical affinity, such as we are familiar with, but modified by special circumstances?

'The beautiful example,' observed Mercer in his paper above referred to, 'of chemical affinity exhibited in the action which oxalic acid exerts upon oxamide was at first hailed by the advocates of a catalytic force as an evidence of the certain existence of their hypothetical power. It is well known that the most minute portion of oxalic acid is capable of converting an indefinite quantity of oxamide into oxalate of ammonia. But this has since been shown to be a true case of chemical decomposition; for oxalic acid extracts ammonia from oxamide, whilst the remainder of the elements of oxamide assume the form of oxalic acid, which again acts on a fresh portion of oxamide. In this case, a minute portion of a substance effects the decomposition of an unlimited quantity of another compound; and here it is proved that it does so by the usual laws of chemical affinity.

'This led me to consider that other cases of catalytic action might also be referred, in a somewhat similar manner, to true chemical affinity, although the indications of that affinity might not be so apparent as they usually are.

'All the phenomena of combination and decomposition prove that elements never have their inherent affinities so completely satisfied by combination with each other as to become inert, and incapable of further change, by external agencies. On the contrary, we know that all matter is capable of undergoing change and receiving new forms and conditions. Suppose, for example, that the union of one equivalent of iron with one equivalent of oxygen completely gratified the affinity of iron for oxygen, and that the affinities possessed by that metal were entirely exhausted by the union which it had formed with one equivalent of oxygen ; in such a case the iron would not be susceptible of a higher degree of oxidation. But as it can unite with more oxygen, we must suppose that its inherent affinities still exist. A compound molecule can merely be an aggregation of certain simple atoms in a definite form ; it cannot, strictly speaking, be an incorporation of the atoms one with the other, for an ultimate atom must be impenetrable.

'The intensity of affinity by which elementary atoms are joined in the complex molecule must be the measure of the stability of the compound. If we have a body the atoms of which are held in mere static equilibrium by virtue of a feeble attraction, and act upon this by a compound molecule not completely charged with one of its constituents, and which possesses merely a feeble affinity for this constituent, which constituent on the other hand can enter into the composition of the body acted upon, it is probable that, in such a case, what is called Catalysis would ensue.

'If we dissolve 1 oz. of oxalic acid in half a pint of water at a temperature of 180° Fahr., and to this add 1 oz. of nitric acid of 1·300 sp. gr., taking care that it is free from nitrous acid, no action ensues. In this mixture, the oxalic acid has a disposition to unite with more oxygen, and endeavours to withdraw that element from the nitric acid;

and we may also imagine that the atoms of the complex molecule nitric acid are in their highest degree of tension, as if ready for disruption. But the affinity existing between the oxalic acid and the oxygen is not quite sufficient to decompose the nitric acid. According to the view of catalysis I have suggested, if another affinity is brought into play, similar to, but smaller, than that exerted by the oxalic acid, the decomposition of the nitric acid and oxidation of the oxalic acid may be effected. Protoxide of manganese is an oxide susceptible of a higher state of oxidation, and the compounds of the higher oxides with acids (manganic salts) are very unstable. Hence it is well suited for our purpose. If to the above mixture of nitric and oxalic acids, which, as I have already mentioned, is perfectly quiescent, we add a small quantity of any proto-salt of manganese, say 30 grains of oxalate, a brisk action immediately commences; all the oxalic acid is converted into carbonic acid, and all the nitric acid into nitrous acid. If the proportions are well adapted, nothing remains after the action except the original salt of manganese. A fresh mixture of nitric and oxalic acids may now be added to this salt, when the same action ensues, and will proceed with fresh additions *ad infinitum.*[1]

'The explanation I would offer of this action of the proto-salt of manganese is this. The atoms of nitric acid being already in a state of tension by the attraction of the oxalic acid for its oxygen, a very feeble additional force suffices to complete the decomposition of the nitric acid. This is supplied by the salt of protoxide of manganese, which has a slight tendency to unite with oxygen; but at the instant of its liberation, the oxygen is called upon to select with which of the bodies it will unite, as both exercise a certain amount of affinity for it. The affinity of oxalic acid for oxygen being

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[1] The experiment may be modified by heating a mixture of oxalic acid and nitric acid until oxidation of the oxalic acid commences, and then diluting it until the action ceases. It immediately recommences on the addition of a small quantity of proto-salt of manganese.

far greater, under the existing circumstances, it therefore becomes oxidised with production of carbonic acid, while the protoxide of manganese is free to exert a similar influence on other molecules of oxalic and nitric acids.

'Mixtures of nitric acid with tartaric and other vegetable acids, the nitric acid being too weak for direct oxidation, undergo a similar change by the addition of a small quantity of a proto-salt of manganese.'

The influence by which such decompositions are effected Mercer proposed to designate, until a better name should be suggested, 'assistant affinity.' In the same communication to the British Association he also described other interesting illustrations of his views on this subject. He pointed out the striking decomposition which solutions of the hypochlorites undergo by the addition of a small quantity of various metallic oxides.

If a minute quantity of hydrated peroxide of manganese is added to a solution of hypochlorite of lime, decomposition immediately takes place with disengagement of oxygen gas and production of chloride of calcium, and continues until the whole of the hypochlorite is decomposed. The peroxide of manganese remains apparently unchanged.

Peroxide of lead and hydrated peroxide of iron produce a similar decomposition of the hypochlorite, but much slower.

Oxygen is

With oxides of copper, the decomposition of hypochlorite of lime is rapid and complete. A few grains of black oxide of copper, or a few drops of solution of nitrate of copper, will suffice to effect the decomposition of an ounce of bleaching powder, which should be well mixed with about half a pint of water. Copper filings, which soon become oxidised, produce the same effect. The hypochlorite should contain excess of lime, to prevent the copper from being dissolved. In all these cases peroxide of copper is formed, which appears to be the active agent in effecting the decomposition. If hypochlorite of soda, to which a little caustic soda has been added, is substituted for the lime compound, corresponding results are produced.

Such decompositions of hypochlorites were considered by Mercer to be effected by the feeble affinity which the various metallic oxides possess for additional oxygen. Under its influence the molecule of the hypochlorite, which under all circumstances is very unstable, splits up into chloride of calcium (or other chloride) and free oxygen. The inherent elastic force of the latter then comes into play, and proves, under existing circumstances of temperature and pressure, stronger than the affinity of the metallic oxide. Oxygen gas is therefore disengaged, and the metallic oxide left to exert its influence on other molecules of the hypochlorite.

In further illustration of his views, Mercer referred to a circumstance well known to makers of 'oxymuriate of tin.' Nitric acid, of moderate strength, may be mixed with protochloride of tin without immediate oxidation; if a fragment of metallic tin is added, its 'assistant affinity' causes immediate action. The same effect is produced by passing a few bubbles of nitric oxide gas through a similar mixture. Neither nitric oxide nor the protochloride effects the decomposition of the nitric acid separately, but by their conjoined action decomposition takes place, and proceeds with continuous production of more nitric oxide.

Again, if to a solution of chlorate of potash in hydrochloric acid, just sufficiently dilute to have no bleaching power on indigo-dyed cloth, we add a little chloride of manganese, the mixture acquires bleaching power from the production of free chlorine.

From these and other similar experiments Mercer was led to the general conclusion that most of the cases then known of catalysis are referable to the feeble 'assistant affinity' of the catalytic agent, but under circumstances which prevent that affinity from being gratified by combination. Mercer's theory was afterwards amply enunciated and illustrated by Dr. Playfair, in a paper to the Chemical Society ('Memoirs,' vol. iii. 348). It is the only satisfactory explanation yet given of catalysis.

ON THE CHEMICAL CONSTITUTION OF BLEACHING POWDER.

The chemical constitution of bleaching powder was made a subject of investigation by Mercer before it had received much attention from scientific chemists. He did not publish his views on the subject; but it appears from various memoranda and letters that, before he became acquainted with the researches of others, he adopted the same views which are now generally held, after a great deal of investigation and discussion by various chemists, reaching to within the last few years. The important question was this—whether bleaching powder is a compound of lime and chlorine, corresponding to a peroxide, in which chlorine takes the place of extra oxygen in the peroxide, according to Millon; or whether it is a mixture of chloride of calcium and hypochlorite of lime, according to Balard. The conclusion at which Mercer arrived was that fresh, dry, well-made bleaching powder is to be regarded as a simple combination of lime and chlorine; but *when mixed with water*, it becomes changed to a mixture of chloride of calcium and hypochlorite of lime.

The fact that dry, recently made bleaching powder can be completely decomposed by exposure to carbonic acid gas, with disengagement not of hypochlorous acid but of free chlorine, is a strong evidence in favour of Millon's view. But a change appears to take place when it is dissolved in water. Mercer was led to adopt Balard's view as to the constitution of 'bleaching liquor,' chiefly from its behaviour with solutions of salts of copper and with indigo. He reasoned that, if Millon's theory is correct, a quantity of bleaching liquor containing one equivalent of chlorine united with one equivalent of lime (in addition to a little free lime always present) should precipitate the whole of the copper from one equivalent of the nitrate; and that, if the copper solution is gradually added to the bleaching liquor, the precipitate (after the saturation of the free lime) should be of the same character throughout, until the full equivalent has been added; but this would not be the case if Balard's theory is correct.

To a quantity of normal bleaching liquor containing, say, one equivalent of available chlorine (or the corresponding quantity of hypochlorous acid), he added first a little solution of nitrate of copper to saturate the free lime always present, and immediately afterwards (before the catalytic decomposition just described had commenced) an additional quantity of known strength. Copper was precipitated, at first of a dark colour (a mixture of protoxide and peroxide), afterwards as a green precipitate, until half an equivalent was added; all the copper afterwards remained in solution. The liquid did not smell of free chlorine, but evidently contained free hypochlorous acid. It soon underwent decomposition ('through the catalytic influence of the precipitated oxide of copper'), but, when tested promptly, was found to have at least four-fifths of the oxidising power of the original bleaching liquor. This result was evidently in favour of Balard's view, according to which one-half of the lime exists as hypochlorite and the other half as chloride of calcium. The former only can precipitate copper from the nitrate; the hypochlorite of lime is decomposed by the nitrate of copper with formation of nitrate of lime, and as hypochlorous acid is incapable of maintaining oxide of copper in solution, the latter is precipitated and the liquor contains free hypochlorous acid. Thus one equivalent of available chlorine in bleaching liquor precipitates only half an equivalent of copper from the nitrate.[1] Mercer's experiments with sulphate of copper and bleaching liquor gave results corresponding to those with the nitrate. Every manipulator with bleaching powder is aware that on mixing good powder in a mortar with water, the mixture, at first thin, in a few minutes becomes thick and stiff, suggesting a chemical combination with water, or some change in chemical constitu-

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[1] In the Appendix (§ XVI.) will be found a letter from Mercer to Dr. Playfair, written some years afterwards (1841), containing an account of his repetition of the nitrate of copper experiment, with like results.

tion. Mercer regarded this as the change from Millon's dry chloride to Balard's mixed hypochlorite and chloride.

Experiments on the action of bleaching liquor on indigo, made about the same time, gave him results in accordance with the above conclusion. In a memorandum on this subject he has observed that when cotton[1] cloth dyed with indigo is exposed to true oxidising agents, free from chlorine, such as permanganate of potash and sulphuric acid, bichromate and sulphuric acid, peroxide of manganese and an acid, peroxide of lead and an acid, and red prussiate of potash and caustic alkali, the blue becomes weaker and is presently discharged, leaving the cloth white. But with free chlorine and free hypochlorous acid different effects are produced; as appears from the following observations on the action, on indigo cloth, of bleaching liquor (of $1\frac{1}{4}$ pound to the gallon) after the addition of

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[1] The above statement does not apply to silk and wool, dyed with indigo in the same manner as cotton. On these the action of the above agents is somewhat different. (Mercer.)

successive portions of hydrochloric acid. Assuming the lime in the liquor to be one equivalent, the addition of acid up to one-fourth of an equivalent gives a mixture which immediately diminishes the colour of indigo cotton cloth, through fine pale blue to white. Above one-fourth of an equivalent of acid, a buff or orange colour appears, at first mixed with blue; at half an equivalent of acid the buff colour is immediately produced 'clean and perfect;' above half an equivalent of acid the mixture gradually loses its property of producing the buff colour, and its decolourising power also diminishes so that the blue is not at once discharged; it acquires, however, a greyish tint. When a full equivalent of acid is added, the blue is scarcely affected at first; 'instead of being discharged in a second or two, the colour is strong, after the lapse of a quarter or even half an hour.' There appear, therefore, to be three stages: in the first, the blue is diminished and presently disappears; in the second, it is changed to buff; and in the third, there is comparatively little immediate action. It will be obvious that these results favour the views of Balard rather than those of Millon. Hypochlorite of lime, with only a little free hypochlorous acid, appears to act similar to the above oxidising agents; free hypochlorous acid produces the buff compound of indigo with chlorine; but free chlorine, produced on the addition of the second half equivalent of hydrochloric acid, does not, under the above circumstances, form that compound.

With reference to the best proportion of acid and bleaching liquor to produce a buff, Mercer has observed: 'I have found, by careful trials with the strengths properly ascertained, the pure buff is obtained when the acid is just enough to unite with the whole of the free lime and half of the combined lime (that is, lime combined with chlorine).' The buff compound may also be produced on blue cotton by the mixture of nitrate of copper with bleaching liquor.

In connection with this subject Mercer made a few other interesting observations.

When the buff cloth, prepared as above, with the half equivalent of acid is put into caustic alkali which has previously been boiled with sugar, the blue colour reappears of about one-half the original depth ; but when similar cloth is put into alkali without sugar, 'it acquires a very pale shade not nearly so deep. The alkali, by combining with chlorine, parts with oxygen, which acts in one case on the sugar, in the other on the indigo.' After keeping for some time, either with or without exposure to light, the buff colour gradually disappears, and is replaced by blue to a depth of about one-third of the original colour.

Iodine water produced little or no effect on indigo-dyed cotton, but on the addition of a little lime, chalk, or sesquicarbonate of ammonia, the colour was discharged. In bromine water the colour disappeared.

From all his experiments on this subject, Mercer concluded that the proper bleaching agent for indigo is oxygen rather than chlorine ; in which respect it differs from madder and most other organic colouring matters. In accordance with this view is his application of a mixture of red prussiate of potash and alkali before referred to.

In his experiments with nitrate of copper and solution of bleaching powder, Mercer observed the formation, under some circumstances, of a higher oxide of copper than the protoxide, to which he refers in the above-mentioned letter to Dr. Playfair, to be found in the Appendix. He did not, however, at that time pursue his experiments on that subject, as he soon learned that Thénard had already discovered the existence of a peroxide of copper, which he prepared by means of peroxide of hydrogen; and that Winkieblech had made peroxides by a method similar to his own, namely, by mixing solutions of metallic salts with solution of hypochlorite of soda. Mr. Walter Crum, of Glasgow, in a paper on this subject to the Chemical Society in 1845, refers to Mercer's having observed the formation of a peroxide of copper 'many years' previously. The same experiments with bleaching powder and nitrate of copper led him to make the interesting observations, to which we have already referred, on the catalytic decomposition of the hypochlorites by contact with a small quantity of certain metallic oxides.

ON SOLUTIONS OF METALLIC OXIDES IN LIQUIDS CONTAINING ORGANIC MATTERS.

At a very early period in the course of his experimental investigations, Mercer had noticed the property possessed by albuminous and gelatinous liquors of dissolving certain metallic oxides, thus forming solutions from which the oxide is not precipitated on the addition of an alkali. He had also observed that when a piece of cotton cloth impregnated with peroxide of iron is soaked in an infusion of cochineal in distilled water, the oxide of iron is entirely dissolved. In 1842 he examined this subject more minutely, and communicated some of his results to the British Association at their Manchester meeting, not as a separate paper, but in connection with remarks which had been made by Dr. Playfair. He then gave the following account of experiments with infusion of cochineal, made by pouring a gallon of boiling distilled water on eight ounces of powdered cochineal.

To half a pint of that infusion he added his black or artificial magnetic oxide of iron ($Fe_2O_3 + 2FeO$, see p. 67), which had not been dried, equivalent to $\frac{1}{16}$ of an ounce of crystallised protosulphate, together with $\frac{1}{16}$ of an ounce of soda crystals; on heating the liquor to near the boiling-point, the whole of the oxide dissolved, 'forming a beautiful solution much resembling orchil liquor.' The residue obtained on evaporating this liquor to dryness was completely soluble in distilled water, the solution having the same colour as before evaporation.

To another similar portion he added solution of protochloride of iron equivalent to $\frac{1}{16}$ of an ounce of crystallised protosulphate, and $\frac{3}{16}$ of an ounce of soda crystals; on heating, the whole of the protoxide of iron was dissolved, forming a liquor of 'a deep slate colour or bluish black.'

To another portion of the cochineal infusion he added, in similar proportions, pernitrate of iron and carbonate of soda. The peroxide of iron was completely dissolved, 'the red colour of the liquor remaining almost unchanged by the iron.'

In these various solutions the oxides of iron form peculiar combinations with the colouring matter, which are not decomposable by an alkali; neither is any precipitate produced when the alkali present is neutralised by the addition of an acid. These compounds, therefore, are not to be regarded as ordinary salts. consisting of the oxide with an excess of the acid colouring matter (or, as it is now termed, carminic acid). Mercer remarked that the only way by which he had been able to produce a precipitate of oxide and colouring matter (or a lake) from such liquors, was by adding more of the oxide; the whole of the colouring matter was then precipitated.

From these experiments, and others performed in a similar manner with oxides of tin, Mercer concluded that the colouring matter of cochineal is capable of uniting with such oxides in at least two proportions; that, in the first place, it forms compounds which may be regarded as acids capable of uniting with bases, forming soluble compounds with alkalies, and insoluble compounds (lakes) with metallic oxides. In the case of protoxide of iron, for example, the colouring matter forms, with the first portion of oxide, a soluble combination which may be compared to a ferrocyanide (or hydroferrocyanic acid); which, by the addition of more oxide of iron, affords the insoluble lake, corresponding to Prussian blue. That this view is correct is highly probable from the fact observed by Mercer, that the insoluble compounds with full proportion of the oxides are capable of decomposition by an alkali in the same manner as Prussian blue; the results being a part of the oxide in an insoluble state, and a solution of the alkaline salt containing the other portion of the oxide (or metal) in combination with the colouring matter.

Some experiments which he afterwards made with other liquors gave corresponding results. On adding to a gallon of Persian-berry liquor four ounces of tin crystals and four and a half ounces of soda crystals, the protoxide of tin was completely dissolved. No deposit was formed on boiling. On the addition of four ounces more of tin crystals, the boiling being continued, nearly all the colouring matter was separated from the liquor in combination with protoxide of tin as 'a very fine orange precipitate.' On substituting perchloride of tin for the second portion of tin salt, the precipitation was so complete that the supernatant liquor was colourless. To obtain the soluble compound of the oxide and colouring matter, it was found necessary to use the oxide (or carbonate) instead of the chloride; with tin salt (in the same proportion) without soda, a dense orange precipitate was formed on boiling.

Infusion of madder was also found to possess the property of dissolving oxides in small quantity. One pint of an infusion made with eight ounces of Turkey madder and one gallon of boiling water (filtered and then allowed to stand for a few days to become perfectly clear), when mixed with $\frac{1}{32}$ of an ounce of alum and $\frac{1}{32}$ of an ounce of soda crystals, formed a perfect solution. The same was the case with $\frac{1}{32}$ of an ounce of tin crystals and $\frac{1}{32}$ of an ounce of soda crystals. With twice these proportions, the precipitate which appeared was only a trace. Boiling the liquor caused no precipitation.

The difference in the colours of the cochineal compounds with protoxide and peroxide of iron, the former being deep slate colour and the latter red, was a subject of peculiar interest at the time when Mercer made it known, from the support which it gave to Liebig's views concerning the difference between arterial and venous blood. That philosopher had not long before published his opinion that, in the change from one kind of blood to the other, oxide of iron plays an active part; and that it exists in the state of peroxide in arterial, and as protoxide in venous blood. So far as regards the difference in colour, this view derived considerable support from the above observations on the cochineal compounds. Mercer used to speak to his medical friends about the desirability of having a compound of hæmatosyn (prepared from the blood of cattle) and oxide of iron for medicinal use, but I am not aware that the suggestion was ever carried out.

ON FERROCYANIDES AND NITROPRUSSIDES.

Another chemical subject, extending beyond the bounds of strictly technical work, to which Mercer bestowed some attention in spare hours, was the chemical constitution of the ferrocyanides.

He entirely concurred with the view propounded by Liebig concerning the existence of the salt-radical ferrocyanogen; but numerous experimental observations led him to the conclusion that the equivalent weight of ferrocyanide of potassium is double that which was then generally received; as its molecule contains four equivalents of potassium instead of two, as was then believed. Many years subsequently, theoretical considerations in connection with atomic volumes led chemists to the same conclusion. The doubling of the equivalent of iron necessitated that of the ferrocyanides.[1]

The experiments referred to convinced Mercer that one-fourth of the base in ferrocyanide of potassium exists in a different state of combination with ferrocyanogen from the remaining three-fourths. He observed that on adding diluted sulphuric acid to solution of the ferrocyanide, when the proportion of sulphuric acid exceeded the equivalent of three-fourths of the potash, the mixture gave indications of the presence of free sulphuric acid. This was proved by its action on cotton cloth. If such a mixture, previous to the formation of a precipitate, is spotted on a piece of calico, dried without allowing time for

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[1] The new formula for yellow prussiate of potash, $K_4 + FeCy_6$, having been substituted for the old formula, $K_2 + FeCy_3$.

oxidation, and then heated in an oil bath, the cloth is uninjured if the acid does not exceed three-fourths of the potash, but it becomes 'tendered' if the acid exceeds that proportion. If, however, oxidation is allowed to take place on the cloth previous to the heating, Prussian blue is formed together with red prussiate, and the free sulphuric acid becomes neutralised.

Again, according to Mercer, the ferrocyanides precipitated on the addition of solution of yellow prussiate of potash to various metallic solutions—namely, those of iron (in the ferrous state), copper, manganese, and zinc—contain three equivalents of the metal with one equivalent of potassium; notwithstanding the metallic salt may be present in large excess. Solutions of tin and lead, on the contrary, afford precipitates containing four equivalents of the metal, free from potassium.[1] He also advocated doubling the equivalent of

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[1] Referring to these exceptions, Mercer said: 'I suspect one equivalent of lead or tin is in quite a different state from the other three equivalents.'

ferrocyanogen from the fact that the ferrocyanides of barium and calcium retain, when dried at a strong heat, approaching that of complete decomposition, half an equivalent of water, calculated on the old equivalent.

In a letter written in 1846 to Dr. Playfair, who was then making some researches on the prussiates, he wrote: 'You may remember how many things I mentioned at the Whalley meetings in proof that one equivalent of potassium is held more powerfully than the other three. . . . In the production of steam Prussian blue by means of a mixture of yellow prussiate of potash with an acid (usually tartaric), the depth of the colour is in proportion to the quantity of acid employed up to three equivalents to four of potash. Increase of acid beyond that proportion gives no increase of colour.' Such was the conclusion derived from practical observations; but it is not to be inferred therefrom that an excess of tartaric acid cannot under certain circumstances unite with all the potash. This has been proved to be the case. He also remarked that to produce their best blues they always introduced an ammoniacal salt and a tin material; the improvement caused by that addition is very considerable. 'I do not think you can find,' he wrote to the same correspondent, 'any parallel between the phosphates and ferrocyanides. There is more analogy between the latter and the tartrates. In the ferrocyanides, we have not only binary but tertiary and quadruple combinations; compounds of the proto-type and compounds of the sesqui-type, easily convertible into each other, and capable of combining with each other; slight circumstantial changes affecting the result. This subject is therefore one not only of complexity but of perplexity.'

In his memoranda he has frequently noticed the fact since pointed out by Dr. Williamson,[1] that yellow prussiate of potash, in contact with Prussian blue, becomes changed to red prussiate; and concluded, from the diminution in the specific gravity of the liquor, that the change consists not in the transfer of cyanogen

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[1] *Mem. Chem. Soc.* vol. iii. p. 125.

from the insoluble blue to the yellow prussiate, but from the transfer of potassium from the soluble to the insoluble prussiate.

In his experiments with the prussiates, Mercer did not overlook the peculiar action of nitric acid on ferrocyanide of potassium. This was a subject of discussion at the Whalley meetings in 1842; and observations then made induced Dr. Playfair to investigate the subject thoroughly. The results of his researches were communicated to the Royal Society, and published in the Philosophical Transactions in 1849. In Mercer's correspondence with Dr. Playfair in 1847, he gave some account of his old experiments in 1843, and also of more recent experiments. He stated that 'the red modification of ferricyanic acid' (the acid of the class of salts since called 'nitroprussides,' the composition of which was then unknown) 'cannot be obtained without nitric acid. It may be produced by the action of nitric acid not only on ferrocyanide of potassium, but on the ferrocyanides of lead and tin, and the white ferrocyanide of iron.' The most characteristic property of nitroprussic acid and its soluble salts is that of forming a deep-coloured liquid by admixture with a soluble sulphide. 'The most striking colours I ever saw,' wrote Mercer, 'are produced by adding a drop or two of this modification of ferricyanic acid to a solution of any hydrosulphuret, such as the colourless liquor made with gas-lime (of 3° Tw. or more). I think the red hydrosulphuret, containing free sulphur, does not act so well as when there is no excess of sulphur. A little red arsenic dissolved in caustic alkali does very well. The colours may be modified by the addition of caustic alkali or ammonia. A little of the red modification gives a rich pink; by gradually increasing the quantity the colour passes through the richest orchil purples to a fine ultramarine blue, and also green. The colours are well exhibited by dropping the liquid on bleached calico; but, unfortunately, they soon fade, even before the cloth is dry.' In another letter he writes: 'Although the colour is so unstable, yet we should not give up the hope of getting it in a permanent form. We have seen it only in a fleeting condition; but many compounds which have only a temporary existence under peculiar circumstances, are permanent under other circumstances.'

The proportions of materials which Mercer considered the best for making the nitroprussiate are 3½ ounces of ferrocyanide of potassium mixed first with 2 ounces of water, and 5¼ ounces of nitric acid of 58° Tw.; the latter should be added gradually, to avoid too energetic action. From subsequent experiments, in which the materials were allowed to act slowly, at ordinary temperature, for a considerable time, until quite free from ferrocyanide and ferricyanide, Mercer concluded that the resulting nitroprusside is mixed with a peculiar soluble compound containing iron and cyanogen (comprising ⅙ of the iron present in the original ferrocyanide); in which the iron is in an anomalous state, not detectable by the ordinary tests. This peculiar compound is slowly decomposed by heat. It is also decomposed by alkalies; slowly in the cold, but quickly when heat is applied, giving a precipitate which contains peroxide of iron.[1]

ON SOME PROPERTIES OF ALUMINA AND METALLIC PEROXIDES.

As every particular respecting the properties of alumina is of special interest to the scientific calico-printer, Mercer made numerous experiments on that subject, and brought to light some points of interest which had not been previously noticed in chemical treatises. In a letter to Dr. Playfair, dated February 1842, he remarks: 'I have a few facts relating to the politics of alumina which I have not seen in books, and have noticed some peculiar properties of alumina in the moist precipitated state which are not well understood. Alumina has a great tendency to

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[1] In his correspondence on the nitroprussides, he incidentally makes the following observation: 'A solution containing red prussiate of potash, sulphocyanide of potassium and caustic alkali may be boiled without oxidation of the sulphocyanide taking place; yet sulphocyanide, mixed with a little free acid, is one of our best deoxidisers. It is largely used by us for that purpose.'

assume a form which is scarcely acted on by either acids or alkalies. Does not this show that there is some union or new arrangement of the aluminous particles among themselves (as of an acid with a base)? This may be the reason of the difficulty of reducing alumina to a lower oxide and to aluminum when heated with carbon.'

He observed that there are two ways whereby precipitated alumina may be made to assume this form of difficult solubility:

1. By prolonged boiling of the precipitate formed in a dilute solution of alum by a very slight excess of carbonate of soda; and

2. By digesting moist precipitated alumina in a small quantity of soda solution; when it combines with a little soda, forming a compound which, according to Mercer, is scarcely at all soluble in acids or alkalies.

To obtain this peculiar form of alumina he recommended the following process: 'To a solution of 5 ounces of alum in a pint of water add a solution of $4\frac{1}{2}$ ounces of soda crystals in a pint of water (both cold), and wash the precipitate on a filter with cold water. To remove all sulphate, dissolve the precipitate in nitric acid ($\frac{3}{16}$ of a gill, 58° Tw. will suffice, which corresponds to half the sulphuric acid originally combined with alumina in the alum) and reprecipitate the alumina by a slight excess of carbonate of soda. Then boil the mixture, filter, and wash. While moist, remove the alumina from the filter and mix it with a little weak caustic soda. I use one-eighth of the soda which would have been necessary to neutralise the sulphuric acid originally present in combination with alumina. Boil for a short time, and then filter. About half of the soda becomes attached to the alumina; the other half is removed by washing.' Such a proportion would suggest for the composition of this aluminous compound five equivalents of alumina and one equivalent of soda. If mixed with excess of nitric acid, it gradually becomes gelatinous, but is still insoluble in acids.

This insoluble alumina of Mercer appears to be the 'pectous' form of *metalumina*, obtained several years afterwards by Mr. Walter Crum by prolonged heating of a solution of acetate of alumina in a close vessel.

A subject among 'the politics of alumina,' on which Mercer made numerous experiments at an early period in his course, was the question—to what extent can alumina be dissolved by the three mineral acids, sulphuric, hydrochloric, and nitric?

His results, which were generally uniform, led him to the conclusion that one equivalent of sulphuric acid can dissolve one equivalent of alumina; that is to say, three times the proportion existing in common alum, disregarding the sulphate of potash. He found that hydrochloric acid is capable of dissolving more than that proportion, and that nitric acid does not dissolve alumina so readily as either sulphuric or hydrochloric acid. He recommended the following method of obtaining a strong solution of the basic sulphate: Dissolve 487 grains of ground potash alum in

'2 spoons' ($\frac{1}{16}$ of a pint) of boiling water; also 288 grains of soda crystals in a similar quantity of water; add two-thirds of the alum solution to the soda solution; mix well to ensure complete precipitation; and then add the remainder of the alum solution. 'The precipitated alumina is all redissolved.' When a little of this solution is dropped into water, alumina is immediately precipitated. No precipitate is produced when it is added to a saturated solution of chloride of sodium. When added to strong solutions of sulphate of zinc, sulphate of manganese, and protosulphate of iron, no immediate precipitation takes place The strong solution of subsulphate of alumina and also the mixture with chloride of sodium soon become gelatinous on standing. By evaporation at ordinary temperatures it acquires a gummy consistence.

In hydrochloric acid, Mercer found that alumina may, under certain circumstances, be dissolved to a larger extent than in sulphuric acid. He first observed that alumina precipitated from cold solutions of alum and carbonate of soda, washed with cold water, may be dissolved in a quantity of cold hydrochloric acid corresponding to one-fourth of the sulphuric acid in the tersulphate; but, on taking precautions to avoid the presence of a trace of sulphate, he obtained a solution containing a much larger proportion of alumina. He operated on chloride of aluminium prepared by double decomposition of the sulphate with chloride of barium; and found that alumina precipitated from the chloride by carbonate of ammonia could be dissolved in the chloride to an extent corresponding to nine times the proportion of base in normal aluminous salts. For a further account of his experiments on this subject, with special reference to the application of the basic chloride of aluminium to calico-printing, the reader is referred to the Appendix (§ XVII.).

From similar basic solutions of chloride of aluminium Graham was enabled, many years after Mercer's experiments, to obtain, by means of his dialyser, soluble alumina almost free from chloride of aluminium.

Mercer's letters and memoranda contain interesting observations on some compounds of alumina with metallic oxides, and other analogous compounds.

On adding a solution of sulphate of manganese or chloride of manganese to the solution of alumina obtained by the partial decomposition of alum by carbonate of soda, *both being dilute*, a white precipitate falls, consisting of alumina and protoxide of manganese. If any carbonate is present, the precipitate, by being heated in the liquid, disengages carbonic acid, and is then free from carbonate. This precipitate retains its whiteness on exposure to the air; which shows it to be a true chemical combination of alumina with protoxide of manganese. It is only partially soluble in strong acetic acid; both the undissolved portion and the solution contain both alumina and protoxide of manganese. It is darkened by solution of chloride of lime, also by exposure to air after treatment with a caustic alkali. By being heated in the air to dull redness, it becomes dark brown. The solution of alumina which Mercer used for preparing this compound was made by adding to a solution of alum, carbonate of soda corresponding to one-half the sulphuric acid in combination with alumina. The mixture was boiled after the addition of the salt of manganese. He also obtained it by adding caustic potash to the mixture of the two sulphates, avoiding excess of the precipitant.

Mercer likewise ascertained that alumina forms a chemical combination with protoxide of lead. His experiment to illustrate this consists in spotting a piece of cotton cloth with acetate of alumina, and after 'ageing' and washing in hot water (whereby alumina is left deposited on the cloth), steeping for some time in weak solution of acetate of lead (half an ounce to a pint of distilled water). The cloth is next dipped in water acidified with acetic acid to dissolve any lead which may have been deposited on the part not spotted; and lastly, winced in a solution of bichromate of potash. The production of chrome yellow on the spot of alumina shows that a large quantity of oxide of lead has been absorbed by the alumina; the unspotted portion contains none.

He concluded that all oxides above the prototype have more or less tendency to combine with strong bases. A compound of that class may be obtained with peroxide of iron and lime. He found that on adding a slight excess of caustic soda to a mixture of two equivalents of perchloride of iron with three equivalents of chloride of calcium, not very dilute, the brown precipitate, on standing for some hours with occasional agitation, 'becomes as white as milk.' A combination takes place corresponding to the compound of the two oxides of iron (p. 67). Again, if a piece of cloth spotted with pure peroxide of iron is soaked in solution of acetate of lead, in the manner just described for alumina, the peroxide of iron combines with oxide of lead; as is manifest by the action of the bichromate.

When cloth spotted with peroxide of manganese is treated in like manner with acetate of lead, and subsequently with bichromate, the result shows that a combination had also taken place between the peroxide of manganese and the protoxide of lead. By further treatment with a reducing agent the brown manganese may be separated, and the chromate of lead appears of a bright yellow. A similar experiment with peroxide of tin gives a corresponding result.

Mercer also showed the existence of a compound of sesquioxide (or peroxide) of lead with lime by the following experiment: First, prepare hydrated protoxide of lead from a solution of 5¼ ounces of nitrate of lead by adding the equivalent of fine hydrate of lime; and, after washing, mix the oxide in a pulpy state (about half a pint), first with 6 ounces of bleaching powder, and afterwards with 3 ounces of fine hydrate of lime. Stir occasionally for a few days. The mixture gradually loses its colour and becomes perfectly white. This compound is decomposed by acetic acid, with separation of peroxide of lead.

Such are the illustrations which Mercer gave of the disposition of the higher or sesquioxides to unite with bases. He also noted the following characteristics of such oxides, as distinguishing them from protoxides; namely,—their capability of forming soluble compounds with much less acid than corresponds to the proportion of oxygen in the base;—also their disposition to assume a 'meta' state, not only when solid, but also in solution (two solutions of the same oxide exhibiting a difference in properties although their percentage composition may be identical);—and the disposition of the sesqui and higher oxides, generally, to assume a more gelatinous state, when precipitated, than protoxides.

CHAPTER VIII.

ON TURKEY RED, MADDER, AND GARANCIN.

Like many other calico-printers who were desirous of applying their chemical knowledge to the improvement of their operations, Mercer paid considerable attention to the Turkey-red process, with the view of simplifying and shortening it. His attention was directed chiefly to the preparatory oiling process, essential in Turkey-red dyeing, whereby the cloth becomes impregnated with an oily material, which fulfils, to some extent, the purpose of a mordant. In the old oiling process universally practised up to the time of Mercer's experiments, the cloth was impregnated with oil, in the state of an alkaline emulsion, from five to eight times, with long exposure to the air between each application of oil. This process, therefore, occupied considerable time. Assuming that the oil, or one of its constituents, undergoes oxidation during this long exposure to the air, he endeavoured to effect such a change more rapidly by treating it with oxidising agents; and succeeded in devising practical methods for carrying this out on the large scale, by means of hypochlorite of lime, bichromate of potash, chlorate of potash, and nitrate of potash, in conjunction with sulphuric acid; also by means of hot air and steam. By the use of the oil thus prepared, the long exposure of the oiled cloth, by the old method, was no longer necessary. Details of the methods which he prescribed for preparing the oil will be found in the Appendix (§ XVIII.), in the specification of his patent 'for certain improvements in dyeing and printing Turkey red and other colours.' This specification also contains an account of an oily mixture (oxidised) suitable for printing on cloth, and a method of oxidising oil already applied to cloth in the ordinary state, by exposing the cloth in a chamber to air mixed with gases disengaged from a mixture of hypochlorite of lime and sal-ammoniac.

As the result of a long series of experiments on this subject, Mercer arrived at and recorded the following conclusions:

'1. The oil must either be oxidised or chlorinated.

'2. Good padding afterwards in solution of pearlash or soda ash is absolutely necessary to obtain the best colours.

'3. With chlorinated oil, and padding in pearlash liquor, the cloth requires no ageing in the hanging-room.

'4. Acid oils do not fix well unless they are strongly heated, and even then the colour is not the best.

'5. Neutral oils do not require much heat; in fact they are injured thereby.

'6. It is very important to cleanse the cloth from the loose oily material before mordanting; if not so cleansed, this comes off on clearing after dyeing, and carries with it both mordant and colouring matter.

'7. The oil may be applied to the cloth by the pin roller, or by two pin rollers and the printing-machine.'

Although madder, since the introduction of artificial alizarin, has ceased to hold the important position it formerly held among tinctorial matters, yet it will continue to be a subject of great interest, and the various researches which have been made on its colouring principles by several chemists will probably be helpful to future investigators on collateral subjects. Mercer has left some remarks on madder, garancin, and madder-dyeing which are of interest as the result of his own experience. These observations were made between 1846 and 1849; previous, therefore, to the publication of Dr. Schunk's interesting researches on madder.

Of the three principal colouring matters contained in madder, then known by the names of xanthin, rubiacin, and alizarin, Mercer considered the two latter to be derivates of the first, whether produced in the living root during the process of maturation, or subsequently in the dried root and in aqueous infusion by the action of a nitrogenous ferment.[1] Alizarin is the only colouring principle contained in madder which gives a good fast colour, and is therefore the only one of practical importance. Xanthin,[2] the base from which the others are derived, is yellow, and does not combine with mordants. Mercer observed that, 'although alizarin is scarcely soluble in cold water, and not much more so in hot water, it is much more soluble when mixed with xanthin and rubiacin. The three together dissolve freely in hot or cold water. In this property it resembles several other vegetable colouring matters, which, though scarcely soluble in water in their fully developed (or oxidised) state, dissolve freely in the solutions of the bases from which they are derived. For example, the colouring

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[1] He noted that the influence of a ferment in producing the development of alizarin had been pointed out by Mr. James Higgin.

[2] Or, as it is now termed, 'rubian;' a glucoside, which + H_2O, yields alizarin + glucose.

matters of logwood, peachwood, Brazilwood and sapanwood, when properly developed or oxidised, are scarcely at all soluble in water, but the (unoxidised) principles from which these are derived are freely soluble. By pouring hot water on these fresh woods, newly rasped, strong infusions, almost colourless, may be obtained, which readily dissolve the colouring matters in their fully developed or oxidised state. A similar property is exhibited by catechu, galls, quercitron bark, &c. The colouring principles of catechu (oxidised and unoxidised) dissolve easily together in hot water; but if ground catechu is digested first in cold water, one portion entirely dissolves; if the undissolved portion is well washed in cold and afterwards digested in boiling water, the colouring principle which remains dissolves very imperfectly, and the small quantity which does dissolve is deposited as the liquid cools. Closely connected with this is the property which some colouring matters possess of dissolving others which are barely soluble by themselves. For example, by boiling common barwood in water, it is scarcely possible to obtain a liquor stronger than ½° Tw., but a strong decoction of barwood may be obtained by the addition of some Persian-berry liquor.'[1]

'The chief cause,' Mercer also remarked, 'of difficulty in working with madder arises not so much from peculiarities in the colouring matters themselves as from the influence exerted on them by other matters contained in the madder; especially earthy substances (lime, magnesia, &c.), and pectose or other similar substance from which gelatinous pectic acid is derived.

'If a pound of madder is mixed with a quart of water at about 100° Fahr., in a few hours the mass becomes quite gelatinous from the presence of pectic acid; some of the colouring matter is at first dissolved, but this becomes absorbed by the pectic acid forming a compound which is insoluble in water. If the mass is pressed and washed several times, to afford, say, a gallon of liquor, half of the

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[1] From a letter to Dr. Playfair.

weight of the madder is dissolved: the liquor has the properties of a solution of dextrin; it deoxidises indigo in the presence of alkalies, and it dissolves alumina and oxides of iron, copper, tin, &c., but this liquor contains no colouring matter. The washed gelatinous madder, mixed with pure water, has scarcely any dyeing property, the colouring matter being held in an insoluble form by pectic acid, but its dyeing power may be much increased by the addition of sumac (or other astringent vegetable), which combines with the pectic acid and liberates, to some extent, the colouring matter. The addition of chalk produces a similar effect. In the dyeing process, at a moderate heat, the xanthin is changed to alizarin under the influence of the nitrogenous ferment;[1] but there is also developed pectic acid, which absorbs a large portion of the alizarin; the earthy constituents of the madder exercise the same injurious influence, hence it happens that what is called "spent madder" retains from thirty to forty per cent. of the

[1] Now known as erythrozym.

original colouring matter of the root in a state insoluble in water.

'By soaking spent madder in cold dilute sulphuric or hydrochloric acid the earthy compounds are decomposed, and the earths may be removed by washing. The material thus obtained yields a little colour to mordanted cloth, but the colour is neither good nor fast. Pectic acid, which is insoluble in the *cold* acid, still remains to exert its injurious influence. If, however, the mixture of spent madder and dilute acid be heated for a little while to about 212° Fahr., the pectic acid is also removed, being first converted, under the influence of the acid, into a more soluble modification. The material thus obtained, that is, garancin, now dyes very well.'

His observations on the difference between the action of hot acid and that of cold acid in the preparation of garancin from spent madder had a special connection with an important legal case tried in 1849—namely, that of Steiner *v.* Wilson. Mr. Steiner had patented a method of making a variety of garancin by the action of acids on spent madder, without specifying the application of heat; and had also obtained a patent for an improvement on this, in which the use of hot acid was the essential feature. The maintenance of the validity of the second patent was the object of the legal proceedings referred to. Mercer gave evidence, on Mr. Steiner's behalf, to the effect that the first patent, for the reasons above mentioned, was a complete failure; the 'chemical madder' (as it was termed) made thereby having scarcely any value as a dye-stuff; but that the essential improvement claimed in the second patent—that is, the application of heat—rendered that eminently successful. Mercer's view was that at a boiling heat the acid (which may be either dilute hydrochloric or sulphuric) decomposes the insoluble compounds of colouring matters and pectic acid contained in the spent madder, and converts the pectic acid into a more soluble modification, easily washed away by cold water; while the colouring matter, being insoluble in hot acid and in cold water, is retained in the grains, mechanically mixed with the woody fibre.

Mercer also made the observation that the hot acid exerts a beneficial influence on the colouring matters, either by developing more alizarin, or in some other way giving a permanent brightness which is not injured by soaping or weak alkaline liquors. Cloth dyed pink with garancin made with hot acid is not rendered so blue by ammonia as cloth of the same colour dyed with common madder.

We may appropriately conclude this chapter with a few observations made by Mercer on the two mordants used in madder dyeing and printing—namely, red liquor and iron liquor. He observed that, to obtain good colours, it is essential that the mordants are applied in such a state of solution as to penetrate easily to the interior of the cotton fibre, instead of being deposited in an insoluble form on the exterior. Further, the solution should be of a character to deposit the mordant in a highly attenuated form, rather than granular or aggregated. Solutions of alumina, peroxide of iron and peroxide of tin, in what is called the 'meta' state, give more granular or aggregated precipitates than ordinary solutions. For these reasons, in making red liquor for madder work with alum and acetate of lead, it is better not to precipitate more than two of the three equivalents of sulphuric acid combined with alumina. For pale reds, it is desirable to precipitate only one-half of the sulphuric acid ($1\frac{1}{2}$ equivalent).

On the subject of *iron mordant* he made the following observations: Crude acetic acid (pyroligneous acid) is of great value to the calico-printer as a solvent for iron. The iron must be applied to the cloth in the state of protoxide, and its partial oxidation within the fibre must proceed gradually. It is well known that pure acetic acid cannot be employed for this purpose; pure protoacetate of iron oxidises too rapidly; and, moreover, it deposits the oxide of iron in a form too aggregated to absorb the colouring matter efficiently. By saturation with metallic iron pyroligneous acid yields a solution of protoacetate of iron, which, after separation of the principal tarry matters, contains several other impurities possessing a deoxidising power. These comprise a dark brown colouring matter, a substance similar to pyrogallic acid, wood-spirit, and kreasote (carbolic acid). The strong deoxidising power of pyroligneous acid (after separation of the tar) may be seen by heating it with indigo and excess of lime or an alkali. These impurities act beneficially in two ways—first, by retarding the oxidation of the iron until it has had time to diffuse throughout the interior of the fibre; and secondly, by determining the formation of the deposit of oxide of iron in a highly attenuated form instead of the granular deposit which the pure acetate yields. In the production of pale lilacs the latter point is of so much importance that it is beneficial to use a large excess of pyroligneous acid; also to add arsenite of soda to the iron liquor (with acid in sufficient quantity to maintain the solution); this prevents the formation of the meta or aggregated form of the oxide; the arsenite of iron, which is formed on the cloth after printing and ageing, is in a highly disseminated state. Some of the best printers pad their cloth intended for fine lilac with dilute solution of arsenite of soda; particularly if the subsequent clearing off is to be done with cow-dung: but such padding is unnecessary if arsenite of soda is added to the iron liquor, with plenty of pyroligneous acid, and the subsequent clearing done with substitute, for which either arseniate or phosphate of soda will answer.

The following is a receipt of Mercer's for the preparation of iron liquor for such purposes:—To two pints of ordinary iron liquor of 24° Tw. add two pints of pyroligneous acid; and afterwards a solution of arsenite of soda made by boiling in one pint of water two ounces of arsenious acid and two and a quarter ounces of soda crystals. Add water sufficient to make the whole to one gallon.

CHAPTER IX.

EVENTS IN HIS PERSONAL HISTORY.

A FEW interesting events in Mercer's personal history now draw us away, for a little while, from the factory and laboratory, to the social and outer circle. We have already noticed his attachment in early life to the Wesleyans, and some of his efforts of useful religious instrumentality in connection with that body. Much might be added to the same effect. On coming to reside at Oakenshaw he and his wife became the principal helpers of 'the society' in that place. To contribute to the necessities of the members, who were generally poor, was the greatest happiness of John Mercer and his wife. Through his exertions a Wesleyan chapel was built at Oakenshaw in the year 1829, which was the only Protestant place of worship in that neighbourhood for several years. In 1837 Messrs. Fort expressed to Mercer their high appreciation of his efforts in providing Christian instruction for the district; they presented him with means for discharging all the remaining debt on the chapel, and made a free grant of the ground on which the chapel was built, together with a surrounding burial-ground. They also rendered him assistance in forming a lending library; and a few years afterwards built a house for a public reading-room, in which Mercer used occasionally to deliver lectures in the winter evenings.

With the increase of population, a large proportion of whom were employed at the Oakenshaw Print Works, Mercer deeply felt the responsibility of himself and partners for the provision of further facilities for public worship. With a catholic spirit, he earnestly pressed on his partners the desirability of building a church at Clayton-le-Moors in connection with the Established Church of England. Having written on the subject to the senior partner, who was then engaged in his parliamentary duties, he had the gratification of receiving a hearty assent to his proposal, with the request that he would at once select a proper site on the Oakenshaw estate for the erection of a church. This was accordingly done, and the present church of All Saints, Clayton-le-Moors, was consecrated in 1840, Messrs. Fort and Miss Fort having together contributed the land, 2,500*l.* towards the erection (about three-fourths of the entire amount), and also a permanent endowment.

After his long and devoted attachment to the Wesleyans, it may well be imagined that it was not without great sorrow, and a high sense of duty, that he withdrew from that body, as a member, in 1849, when a large secession took place on the ground of disapproval of some points of church government adopted by the Conference. He continued, however, to attend the services of the Wesleyans as well as those of the Established Church, and was always ready to give the former a helping hand in their time of need.

Between him and the members in that locality there was, therefore, no estrangement. In 1853 Mrs. Mercer laid the foundation-stone of a new Wesleyan school at Clayton-le-Moors, on which occasion she was presented with a silver trowel; and in 1861, when a much larger chapel had to be erected there, Mr. Mercer became the principal contributor to the building fund; he laid the foundation-stone, and received the usual token of esteem, the silver trowel.

As the result of Mercer's ingenious devices and applications, the Oakenshaw Print Works had a long season of commercial prosperity. His aim had always been the production of first-class goods; and the reputation which the firm acquired for goods of that class was well deserved. But the active competition which sprang up in this, as in other industries, gradually led to the large production of inferior goods at a cheaper rate—a kind of work which was not altogether in harmony with Mercer's tastes. And as the principal partners of the Oakenshaw firm were indisposed to incur the risks which, in large transactions, generally accompany close competition, the question was raised of retirement and dissolution of partnership. This course was mutually agreed upon, and the dissolution took place in 1848. Fears were at first entertained by the proprietors that the balancing of the books would show an unfavourable result. When, however, the full value of the stock came to be realised, all such fears were found to have been groundless: the profits of the previous year's working had been very good.

Mercer was enabled to acquire a competence; but to amass wealth was not his object. We have heard the remark made that, if he had chosen to apply his inventive genius to the making of money, he might have become a wealthy man. But he had no sympathy with those who made money their idol, nor with those who were 'making haste to be rich' by uncalled-for speculation. We find an expression of his thoughts on these matters in a letter written in 1837 to a young friend, who appears to have entertained expectations of great commercial success, but of a very speculative character. He remarked:

'When I read your letter, I wondered how light and "bouncy" your mind was, amidst such uncertainty in matters of so much importance. Mine would be like lead or clay, and when down might be too apt to remain there. But yours is like something with great elasticity; no sooner down than up again, as if it contained a large proportion of the imponderable element, call it what you like. But I find something in your letter of real weight; that is, the prospect of your ultimate success. . . . Now let me advise you, when you get your money into your pocket, be careful of it. Use it prudently. I fear you don't follow as closely as desirable the example of the careful industrious farmer, who takes a long time in unbuttoning his purse and taking out his coin, and is as careful in tying up his purse again and replacing it safely in his pocket.

. . . You ask me the question, whether I am happier now[1] than I was formerly? I answer unhesitatingly—No. Further, had I the ambition which you say you have, I should be truly miserable. The slow but steady improvement in our temporal affairs, as the result of our labour and the proper discharge of duty, is the state to be desired. How different from that of the avaricious, money-seeking soul, unsatisfied even if he attain the object of his first desires; and if he fail—how wretched, with his disappointed expectations. . . . "Love of gain usurps his breast and harasses his brain."

'Yours truly,
'JOHN MERCER.'

The opportunity for relaxation did not come before it was needed. Scarcely was Mercer relieved from the cares and anxieties of the management of print works, before he was attacked by a severe illness, of neuralgic character, induced, it was believed, by his

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[1] In his present improved pecuniary circumstances.

close mental application; so serious, at one time, that it was considered likely to prove fatal.

For many years previously he had been subject to periodical attacks, three or four times monthly, in the morning, of a somewhat similar nature, producing severe headache with nausea. These attacks were caused by a straining of his mental organs, with too little rest. Perfect quietude until the evening, and frequent draughts of warm water, were his means of obtaining relief. In the evening he was able to resume his work, and the day following he designated his 'best day in the week for work.' These attacks were an inducement to Mercer to examine carefully the claims of homœopathy, on which subject his conclusions and anticipations, considering that they were written thirty-five years ago, may be regarded by medical men of the present day as specimens of his good judgment and correct reasoning. While regarding as ridiculous the first principles of homœopathy as enunciated by its founder (that is, of 'like curing like,' and the efficacy of infinitesimal doses), he admitted much of the success claimed by the advocates of the system; and therein recognised—first, the importance of good nursing and a good dietary; and secondly, the importance, in many diseases, of 'faith in the remedy' as one of the ingredients; just as a cheerful state of mind exerts an influence in assisting digestion of food. Referring to an English advocate of homœopathy, he says: 'Dr. Sharp has purged the system from most of the reveries of Hahnemann, but he still retains too much of the infinitesimal doses; if other able men were to remove remaining absurdities, they might leave a practice of medicine which would quietly and silently exert wholesome influence on the general practice. . . . After much careful reading and thinking on this subject I must come to the conclusion that, generally speaking, more careful nursing and dietary, and less physic, would improve the practice of the allopathist.' In the severe illness which he experienced in 1849 he had recourse to the best medical advice procurable, including that of Dr. Charles Bell (nephew to Sir Charles Bell), who spent several nights in his house, and through whose judicious treatment, under the Divine blessing, Mercer was soon restored to a state of health better than he had for a long while previously experienced. It may here be observed that he highly valued the professional advice and also the personal friendship of Dr. Joseph Jordan, the distinguished surgeon, of Manchester.

As soon as the state of his health permitted, Mercer directed his attention to a subject which he had kept in abeyance for some years, waiting for the convenient opportunity —namely, the action of caustic alkalies, &c. on cotton. His experiments, and their results, will form the subject of the following chapter.

In 1851 he accepted the invitation of the Commissioners of the Great International Exhibition to become one of the Jurors of the Exhibition. Sir Lyon Playfair, who was the Special Commissioner over all the Juries, refers, in a recent letter, to 'the excellent service which Mercer rendered in that capacity, bringing into the work his practical knowledge with his usual earnestness.'

The little insight we have had of Mercer's 'inner man' has been enough to convince us that he was not one who cared for personal distinction on any selfish ground. He lived for others rather than for himself; and to him position and influence were of no account, except in bringing him increased opportunities for usefulness, and in affording gratification to his friends. We can therefore sympathise with the doubts felt by a company of *savants* who dined together one evening at the house of Professor Graham, when the question was raised—Would John Mercer like to become a Fellow of the Royal Society? Such a distinction in the case of a self-educated man, with no such facilities for acquiring learning as abound in the present day, would be a great honour. All present testified that it would be well deserved. But would he care to receive it? Would it be congenial to his retiring disposition? Dr. Lyon Playfair was deputed to write to Mercer to ascertain his feelings on the subject; which he accordingly did, and promised him such support of a large number of influential Fellows as would ensure his election, when proposed. Mercer, as might have been expected, hesitated. Dr. Playfair then placed the question before him rather in the aspect of duty; and the gratification his assent would afford to his friends and admirers. 'I think you ought,' he wrote to Mercer, 'to accept the offer of your friends moving in this matter for you. It is a great tribute to a man who has acquired a knowledge of science without the aid of academies, and under every disadvantageous circumstance.' After some pressure, Mercer gave his assent, and he was accordingly elected an F.R.S. in 1852. He was one of the original Fellows of the Chemical Society, founded in 1842; in April, 1849, he was chosen an honorary member of the Literary and Philosophical Society of Manchester; and in January, 1860, he was elected an honorary member of the Glasgow Philosophical Society.

CHAPTER X.

ACTION OF CAUSTIC ALKALIES ON COTTON; PROCESS OF 'MERCERISING.'

In accomplishing the various technical improvements which we have noticed as the outcome of his genius and perseverance, Mercer was generally led from one step to another, by experiments suggested by inductive reasoning, until he attained the object which he first had in view. It not unfrequently happens, however, in chemical researches, both practical and theoretical, that, in the course of an investigation, a by-path is presented which diverts the inquirer from his original object to another unexpected, but more promising, field. In this category may be placed the interesting discovery which Mercer made of the change which certain chemical agents effect on cotton and other fibres—a discovery as interesting in a scientific as in a technical point of view.

On being asked, on one occasion, to give an account of the various steps by which he was led to this discovery, Mercer said that he must go back to a period of several years previous to the time of its publication, when his thoughts were much occupied with questions about the constitution of solutions of substances which are capable of forming chemical combinations with water ; the existence of definite hydrates in solution ; and the differences exhibited by solutions of different strengths in viscosity and mobility. He frequently mentioned his views on this subject to his friends at the Whalley meetings (in 1843 and 1844), and suggested the experiment of transmitting such solutions through a capillary tube in the expectation of finding a variation in mobility harmonising with different degrees of chemical hydration; an idea which was experimentally proved to be correct by Graham about eighteen years afterwards.[1] 'I was much struck,' he wrote, 'with the results of Graham's experiments on the heat disengaged in chemical combinations' ('Memoirs of the Chem. Soc.' 1841 and 1843), 'particularly those on the hydration of sulphuric acid, which confirmed me in some of my views and gave me some new ideas . . . and as a good knowledge of the nature of solutions is so important to a calico-printer,' he made numerous experiments with the view of ascertaining the variations presented by solutions of the same substance of different strengths. The question of the practicability of effecting a partial separation of different hydrates by slow fractional filtration then occurred to him, and led him, among other experiments, to try the effect of filtering solution of caustic soda through cotton. 'For this purpose,' he wrote, 'I made a filter, composed of six folds of strong, fine cotton cambric, bleached, passed three times through

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[1] In a paper read before the Royal Society in June, 1861, 'On the Capillary Transpiration of Liquids in Relation to their Chemical Composition;' published in the Phil. Trans. 1861.

the calender to make it compact, and poured upon it solution of caustic soda of 60° Tw. The filtration was very slow; the liquor which passed through was of 53° Tw. (as well as I remember). But I found my filtering-cloth had undergone an extraordinary change; it had become semi-transparent, contracted both in length and breadth, and thickened or "fulled," as I then termed it. I then spotted bleached cambric with single drops of caustic soda of 60° Tw. and 50° Tw., and noticed that the central portion of each drop (about the size of a shilling) became semi-transparent and contracted; around this was a rim of a quarter of an inch, neither semi-transparent nor contracted, which evidently contained but little soda. I then spotted cloth with drops of soda solution which had been previously coloured with various colouring matters, and found that in all cases the colouring matter was transmitted to the outer portion, very little remaining in the central or contracted part. On mixing stannate of soda with the soda liquor, I found that that substance is also conveyed to the outer portion. The stannate, like the colouring matter, is retained in solution by the watery portion of the alkaline drop. The size of the outer rim is too large to be materially affected by the hygroscopic moisture of the cotton. When the spotted cloth was exposed to the air to become carbonated, the central portion became crystallised, but the outer portion showed no apparent change.'

Mercer then subjected a few 'fents' to the action of caustic soda, and showed his 'fulled cotton' to his partners and some friends as a curiosity; but the close attention which his duties at the Oakenshaw Works then required rendered it inexpedient for him to pursue the subject farther at that time (1844); it was therefore put aside as one of the subjects awaiting further experiments on the first opportunity.

After the dissolution of partnership, Mercer, having time at his disposal, brought forth his 'fulled cotton' from its resting-place, and on examination soon found that it merited full investigation. The first two questions which claimed attention were these—What is the nature of the change in the sodaised cotton; is it chemical, or only mechanical, or both? And secondly—Has the cotton undergone any change in its receptive power for materials used in dyeing and calico-printing?

After long washing the sodaised cloth was found to contain no alkali. If, therefore, a chemical combination had taken place between the cotton fibre and the alkali it must have been weak; being capable of decomposition by water. But a much longer washing appeared to be necessary to remove the soda than if it had been held merely mechanically. Mercer concluded that a definite combination is formed, but that the compound undergoes decomposition by contact with water; and also by the carbonic acid of the air. To this subject we shall return.

On exposing the sodaised cloth, freed from alkali (first with water, then with weak sulphuric acid, and lastly with warm water), to solutions of various mordants and colouring matters, Mercer observed that the receptive powers of the cotton fibre had become greatly increased by treatment with soda. When tried with all the various kinds of materials capable of being absorbed by ordinary cotton the same result was obtained, whether the material were acid, neutral, or alkaline. The increased receptive power was therefore due to a mechanical change effected in the fibre as the result of the chemical action of the alkali. Further, the alkali, instead of, as might have been expected, weakening the cloth by causing a disintegration of the fibres, had certainly done it no injury, and even appeared to have increased its tenacity. Possessing these two important characters, the fulled cotton, or, as it afterwards became designated, 'mercerised cotton,' naturally presented an aspect of practical importance, and application was soon made for a patent for its preparation.

In order to pursue his experiments with command of necessary machinery and other appliances, Mercer made an arrangement with Mr. Robert Hargreaves, of the Broad Oak

Print Works, Accrington, who afforded him facilities for carrying on his experiments, and received in return a share of the patent. For a season—that is, until the rendering of the specification—these experiments could not be carried out with the freedom and ease which would have been in conformity with Mercer's tastes and habits, from the circumstance that at the time of his application for a patent there were no less than ten other applications not yet specified, whose titles might have included Mercer's invention; 'an illustration,' he remarked, 'of the defective state of our present patent law.'

The following may be noticed as the principal results of his investigation:

He ascertained that a similar modification of the cotton fibre may be produced by other agents than the caustic alkalies; namely, sulphuric acid (within certain limits of strength) and chloride of zinc; but having reason to believe that caustic soda would prove most suitable for practical application, he gave, for the present, his attention principally to the latter. Solution of carbonate of soda, however strong, hot or cold, produced scarcely any effect on cotton fibre.

For cloth consisting of cotton only, Mercer concluded that from 45° to 55° Tw. is the best strength of solution of caustic soda for general work, at ordinary temperatures. Exposure to such liquor for a few minutes suffices to produce the change. Much weaker liquors, however, were found to be effective; but with these much longer exposure was necessary. Exposure for forty-two hours in liquor of 10° Tw., at ordinary temperatures, produced very little change. The strength of the soda liquor was found to be considerably reduced by contact with cotton, even if so strong as 65° Tw. at starting; showing that the cotton absorbed soda in larger proportion than the water corresponding to such solution. To maintain at 45° Tw. a bath of caustic liquor, through which cloth was passed, it was found necessary to supply liquor of at least 60° Tw.

The influence of change of temperature

was found to be the reverse of what usually occurs with chemical reactions. Increase of temperature, instead of facilitating the action of the alkali, retarded it. At a boiling heat the peculiar effect was never obtained. Reduction of temperature, on the contrary, facilitated the action. By artificial cooling much weaker liquors were found to be equally effective. Mercer concluded that about 60° Fahr. is the temperature best suited to prepare cloth of good texture. At a much lower temperature the cloth turned out stiffer and harder. Cloth which had been altered by treatment with cold weak liquor (40° Tw.) showed a partial return to its previous condition if immediately washed in boiling weak liquor (20° Tw.); but when the alteration had been effected with stronger liquor (50° Tw.), the cloth might be immediately washed in hot weaker liquor without injury.

Mercer's description of his process, as given in his patent specification, will be found in the Appendix (§ XX.).

The best results, both as regards texture and colour-receptive power, were obtained with cloth which had been previously bleached without being boiled in weak alkaline liquors, as commonly practised.[1] Cloth which was bleached by being first soaked for one hour in boiling water, squeezed and washed five or six times, afterwards soaked in a bath of lime and hypochlorite at a temperature not exceeding 170° Fahr., and then squeezed, soured, and washed as usual, was regarded as best for mercerising. It is very important that the cloth is in such a condition as to allow the liquor to permeate the threads uniformly and rapidly. When a difficulty presented itself from imperfect or unequal permeability of the cloth, as is the case with unbleached cotton, Mercer's remedy was to soak it in boiling water for about one hour, squeeze and wash with water five or six

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[1] It has been observed by Mr. Walter Crum, that hot alkaline solutions, although weak, mat together cotton fibres, close their pores and thus injure their absorbing powers; although strong caustic alkaline solutions open their pores. Hypochlorites in excess also open the pores of cotton fibre.

times, and treat the cloth with alkali, while still slightly moist.

The two most important changes which the cloth exhibits after this treatment have already been stated—namely, increased tenacity, in consequence of the contraction of the fibre, and increased receptive power for colouring materials. A practical illustration of the first was very soon obvious in the extra effort required from the boys whose duty it was to tear off the superfluous ends of the printed pieces. Their fingers were strained much more than when working with ordinary cloth. The increase in strength appeared to be in greater proportion than the linear contraction of the fibre would suggest. The linear contraction was found to be from one-fifth to one-fourth, according to circumstances. On a comparative trial of two narrow strips of similar cloth of the same size, one of which was mercerised, the ordinary cloth broke with a weight of 13 lbs.; the altered cloth required for breakage a weight of 22 lbs. A given number of ordinary threads, which would break with 13 oz., could sustain, when mercerised, a weight of at least 19 oz. The mercerised cotton fibre acquires a strength almost equal to that of linen. The finest cotton cloth which can possibly be manufactured may, by mercerising, be contracted and consolidated to three-fourths of the original length and breadth, or fine cotton cloth of 200 picks to the inch may be contracted to 270 picks to the inch.

Another change which the cloth presented after being mercerised was a slight increase in weight, notwithstanding every trace of soda had been washed out. This increase was found to be nearly uniform. It amounted to from 4·5 to 5·5 per cent. of the weight of the original bleached cloth, dried at ordinary temperatures. It is due to the presence of moisture in excess of the hygroscopic moisture of the unaltered cloth; either in a state of feeble chemical combination, or hygroscopic, owing to the increased absorbing power of the altered fibre. This water is capable of being expelled by a moderate heat (212° Fahr.); but on exposure to the air at ordinary temperatures, the dried cloth uniformly re-absorbs the same quantity of moisture in excess of the hygroscopic moisture absorbed by the same weight of unaltered cloth under similar circumstances.[1]

By printing the cloth with a protecting material before mercerising, very pleasing results were obtained; the protected parts, not being contracted like the rest, gave a 'puckered' design, resembling damask or cotton crape. On afterwards dyeing such cloth, the protected design, owing to its comparatively inferior colour-receptive power, presented a lighter shade. For a protecting material, Mercer gave the preference to gum solution made as thick as workable with best hard gum arabic or senegal. He observed

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[1] Mercer took two similar pieces of cambric, each weighing, after being kept at 60° Fahr., 80 oz. One was mercerised and washed; the other was washed in water. Both were thoroughly dried by being passed three times over the drying-machine at 212°. They then weighed 76 oz. each. After exposing both to the air at 60° Fahr., the mercerised cloth weighed 84 oz. and the ordinary cloth 80 oz. Frequent trials gave similar results.

that caustic liquor of 60° Tw. produced more contraction and puckering than liquor of 70° Tw.; but with the former there is more risk of the gum being loosened than with the latter. For a white puckered design he preferred steeping the cloth for two minutes in liquor of 60° Tw.; to obtain different shades of colour, he preferred using liquor of 70° Tw. The cloth was immediately washed in water or very weak liquor. In the Appendix (§ XXI.) will be found some of his observations on dyeing mercerised cloth.

In a scientific aspect, a question of considerable interest is—whether or not a direct chemical combination takes place between the cotton fibre (or cellulose) and the alkali. Mercer, as we have before observed, concluded, at the commencement of his investigations, that such a compound is formed, but so feeble as to suffer decomposition by water, and by exposure to the carbonic acid of the air. One circumstance in favour of this view is the reduction in strength which the strong alkaline bath undergoes, as already mentioned. Another is that the alkali is not so easily removed from the cloth by washing as if it were held merely mechanically; hence the necessity, in practice, of passing the cloth through a bath of weak sulphuric acid to remove all the alkali with facility. Mercer concluded that the compound which is formed consists of single equivalents of cellulose and alkali, or (according to equivalents now accepted) $C_{12}H_{20}O_{10}, Na_2O$; and that when it is decomposed by water, one equivalent of the latter takes the place of one equivalent of the alkali. To the existence of this hydrate he attributed the remarkable difference in weight which mercerised and ordinary cloth present on being dried and afterwards exposed. The average increase of weight above the hygroscopic moisture of similar ordinary cloth was 5·0 per cent.; sometimes it was found to amount to 5·5 per cent. The proportion of water required by the formula $C_{12}H_{20}O_{10}, H_2O$ is 5·5 per cent. Mercer compared the degree of affinity existing between the altered fibre and this water to that presented by crystallised yellow prussiate of potash, which parts with all its water at 180° Fahr.; but, on exposure to air, the white dried prussiate absorbs the full amount previously contained in the crystals. This he regarded as a case of chemical de-hydration and re-hydration parallel to that of mercerised cloth at similar temperatures.

On the other hand, the retention of the structure of the fibre without injury appears to be unfavourable to the view of a chemical combination. Certainly in most cases of chemical action on organic structures disintegration is a consequence. But there are exceptions to this rule, a notable one being that of gun-cotton. The microscopic appearance of the fibre is scarcely altered by the gun-cotton process.

The chemical view received a confirmation from Dr. Gladstone, who obtained a definite compound of cotton with potash by washing out the excess of alkali with alcohol. It was decomposable by water and by carbonic acid. Gladstone's compound contained one-half the amount of alkali assumed to be the full amount by Mercer.

Microscopic comparison of raw and mercerised cotton has confirmed Mercer's original view as to the change produced in the fibre, expressed in his specification as 'somewhat analogous to that which is produced on wool by the process of fulling or milling, the fibre becoming thicker and closer.' This subject was investigated by the late Mr. Walter Crum, to whom we are indebted for the following observations, published in the 'Journal of the Chemical Society,' 1863:

Ordinary cotton fibre presents, in section, the appearance of a flattened, partially twisted tube. It is not a hollow tube filled with air, but filled with apparently solid matter (like the liber fibre of flax), sometimes altogether, and at other times leaving clear passages through the centre. If unripe, the sides are so close as to appear like a blade, and sometimes adhere so firmly to each other that no line can be detected to mark a division between them. In the process of ripening the substance of the thin wall as it exists in the half-ripe fibre, and after being removed from the plant and dried, is itself capable of expansion, so as not only to give the fibre more of the cylindrical form, but to fill up a great part of the interior of the cylinder. When mature, the fibre is more cylindrical; its walls are considerably and uniformly thickened, but the complete cylindrical form is rarely to be seen except at the smaller end.

Mr. Crum states that, by the process of mercerising, the fibre undergoes a change precisely similar to that in ripening. When the half-ripe but still perfectly flat and thin dried fibre is soaked in a solution of caustic soda of sp. gr. 1·300 to 1·400, it at once assumes the round solid form of ripe cotton, differing from the naturally matured fibre only in being smaller, more generally cylindrical, and in having a larger aperture in the centre. The increase of magnitude is due altogether to an expansion of the cell-wall, or a separation from each other of the laminæ or other structure of which it must consist.

The action of the soda completes the cylindrical form of the mature fibre, at the same time greatly enlarges its volume, and fills up almost entirely the central cavity. Another effect of the alkali is to produce a twisting of the fibre to an extent sufficient to explain the contraction which takes place in the length and breadth and the thickness of any woven fabric which is made to undergo the mercerising process.

In the same memoir, Mr. Crum has shown that the colour-receptive power of the fabric is to a great degree dependent on the proper development of the internal laminæ or cells. It is the interior rather than the external membrane which has the faculty of attracting those mineral and vegetable substances which are either dyes themselves or which form dyes by attracting and combining with other bodies. They enter through the pores in a state of solution, and by various means become solidified and retained within the fibre. It is true that with many dyes a portion of the colouring matter is also attached to the exterior of the fibre, but this is only a superaddition to the greater amount of the dye which is, or ought to be, in all cases within the fibre. Hence the importance, in dyeing, of the expansion of the fibre, the loosening of the cells, and opening of the pores, which are effected by the process of mercerising.

ACTION OF SULPHURIC ACID ON COTTON.

We have already stated that Mercer discovered that a change may be produced in cotton fibre, apparently precisely similar to that produced by caustic alkalies, by means of sulphuric acid, within certain limits of strength. The use of sulphuric acid was included in his English patent for 'Improvements in the preparation of cotton,' &c., in 1850. The action of this acid, like that of caustic alkali, varies considerably with the strength, temperature, and time allowed for action. Weak acid, as well as strong, produces disintegration of the fibre; but exposure for a few minutes to acid of from 104° Tw. to 125°, at ordinary temperatures, produces a modification of the fibre without impairing its tenacity.

If the object is simply to enhance the colour-receptive power of cotton cloth without injury to the fibre, Mercer considered the best strength to be about 108° Tw. at 50° to 60° Fahr. The cloth (which should be in a condition to absorb watery liquids quickly) was passed over and under rollers, so as to be in the acid for one minute, then through squeezers, and washed by a series of rollers in water.

Sulphuric acid of 104° produces very little immediate effect. Mercer regarded the effective hydrate to be the terhydrate ($H_2SO_4+2H_2O$), of sp. gr. 125°, but acid of that strength was found to be too energetic for practical use. He made the following observations respecting the action of sulphuric acid of different strengths on cotton, paper, &c.:

'Three stages, or perhaps more, may be

recognised in the action of sulphuric acid. The first action seems to be the expansion and rupture of the fibre; to effect which the strength of the acid should be about 110°, at temperature about 50° Fahr. When washed and dried, the cloth is not stiff (as is the case with stronger acid), but very soft, and feels similar to glove leather. It is not much contracted, and can easily be stretched to its original size. It is very white, and its power of receiving colour is greatly augmented. It is to cloth of this character that my patent relates.

'The next stage is exhibited with acid of about 114° or 115°, at the same temperature. This strength causes considerable contraction of the cloth. When washed and dried under pressure between folds of bleached cloth, it is stiff and white, having the appearance of being impregnated with a dense white precipitate. It cannot be stretched to its original dimensions. If the cloth is impregnated with milk, and dried before being immersed in the acid, it looks still whiter and more beautiful.

'Sulphuric acid stronger than the above, namely, from 116° to 125° Tw., at the temperature of 50° Fahr. produces another marked effect. With this the cloth becomes semi-transparent. It is stiff, and much contracted. If a design is first pencilled or printed with a protecting paste of albumen, solution of casein, or thick gum-water, and dried before being put into the acid, the design is preserved and a very pleasing effect may be produced.

'When paper or cotton is digested for a little time in acid not stronger than 115° Tw. at common temperatures, it dissolves, forming a thick pasty liquid, which, when poured into water, gives a white precipitate something like boiled rice, very soluble in caustic soda. If the acid is stronger and allowed to act longer, the pasty character of the solution disappears; and the liquid becomes thin. This, when poured into water also gives for a time a precipitate, but differing in appearance from the above; when washed and dried, it forms a smooth coherent mass. But if the action of the acid be still further prolonged, or the temperature be slightly raised, or the acid be a little stronger, the fibre is wholly converted into dextrine, and the solution then gives no precipitate on dilution.'

The weight of the dried cloth altered by sulphuric acid was found to be the same as at first; in which respect it differs from sodaised cloth.

Through an oversight in the translator, or some other party, in the specification of Mercer's French patent the claim to use sulphuric acid was omitted. The English specification, which included the use of sulphuric acid, was soon published in this country; but a French chemist, M. Lefevre, of Thann, considering Mercer's invention to relate only to caustic alkalies, made experiments with sulphuric acid for the same object, and finding the method feasible, made an application for a French patent and introduced it as a novelty. M. Lefevre, on discovering that he had been anticipated by Mercer, wrote to him a very courteous letter, acknowledging his oversight, and withdrawing all claim to originality.

ACTION OF OTHER CHEMICAL AGENTS ON COTTON.

The only other altering material which Mercer introduced into his English specification was chloride of zinc. This was found to be effective in a state of strong solution (200° Tw.), but it presented no advantages over caustic soda or sulphuric acid. Moderate heating of the liquor (to 100° Fahr. or a little higher) was found to be necessary. The hydrate, containing 2½ equivalents of water to 1 equivalent of chloride of zinc, answered very well; with more than 3 equivalents of water there was very little action. A warm saturated solution of nitrate of zinc was without action.

Mercer found that a strong solution of chloride of calcium at a boiling heat produces a slight alteration of the fibre. He observed that bleached cotton may be improved by being passed through solution of chloride of calcium at from 90° to 100° Tw. at a temperature near boiling (290° Fahr.). A mixture of single equivalents of chloride of zinc and chloride of calcium of 165° Tw. proved much more effective than chloride of calcium. The other materials which were found to produce a similar change in cotton fibre were arsenic acid with heat, phosphoric acid, and hot protochloride of tin with three equivalents of water. Neither of these suggested any practical application.

He also, on a subsequent occasion, tried the effect of adding hydrated oxide of zinc to the soda liquor used in the mercerising process, and found that the action of the liquor was greatly increased by the presence of that oxide. Caustic soda liquor too weak to be used in the process (20° Tw.) was found to be very effective when it held oxide of zinc in solution, in the proportion of nearly one equivalent of zinc to two equivalents of soda.[1] Soda-zinc solution corresponding to 30° Tw. soda liquor 'acted very strongly when cold, but did not act while hot.'

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[1] Or, as we should now say, one equivalent of zinc to four equivalents of soda.

In memoranda on the action of soda on other textile fabrics than cotton, Mercer has observed that linen is altered thereby in a similar manner to cotton ; it shrinks, and also increases in weight by absorption of extra moisture, but the increase in weight is not so great as is the case with cotton. Cloth made from China grass was found difficult to wet, but it was altered, and in colour-receptive power became equal to cotton. He suggested the application of the process to materials for making ropes, cordage and thread.

He also made numerous experiments on the action of caustic soda and sulphuric acid on paper; and found that, by contact with either of these for a few moments and then washing, the paper could be considerably strengthened and made translucent. He states that he obtained the most translucent paper (and also cotton cloth) by dipping it in caustic soda at a very low temperature, such as he obtained by mixing 1 pint of caustic soda liquor of 70° Tw. with 20 ounces of snow or pounded ice. The temperature of the mixture was below zero (Fahr.). With sulphuric acid of various strengths, from 115° to 125° Tw. at 50° Fahr., he found the paper to be likewise made translucent and considerably strengthened. Paper may be used sized or unsized. By impregnating it with gelatine and drying previous to dipping it into the acid he obtained, after washing and drying, a 'very fine white paper, which folds quite easily.' This mercerised paper was probably regarded by him rather as an article of curiosity than of practical value; but a few years afterwards it became manufactured extensively by others as the useful material now known as 'parchment paper.'

No sooner was the interesting and important discovery which forms the subject of this chapter made public than it attracted great attention, both from a scientific and technical point of view. Among the most attractive exhibits at the Great International Exhibition of 1851 was Mercer's interesting collection of various articles in illustration of his invention. As one of the jurors of the same Class in which he exhibited, he was precluded, by the rules of the Exhibition, from receiving the ordinary mark of distinction awarded to the best exhibitors; but in the Reports of Juries of the Exhibition (p. 69) we read that ' "Mercer's process for modifying the fibre of cotton" was found to be of sufficient importance, in the opinion of the jury, to merit special commendation. This was considered so valuable and so important a discovery that the jury determined to recommend it as worthy of the distinction of a Council Medal.'

At the close of the Exhibition, so many exhibitors were desirous of making presents to the Queen, that her Majesty was compelled to decline all such proffers. A special building would have been necessary to receive them all. Her Majesty was, however, graciously pleased to make two exceptions, one of which was a present of his prepared pocket handkerchiefs from Mr. Mercer. The process was made the subject of an interesting lecture, at one of the Friday evening meetings of the members of the Royal Institution, by Dr. Playfair.

In commercial results the invention did not prove so successful as had been anticipated. It is probable that, if it had been carried out vigorously at the time of its introduction, it would have been a commercial success. A French company offered, for the purchase of the patents, the sum of forty thousand pounds, which Mr. Mercer, not having Works of his own, was disposed to accept; but his partner in the patent, Mr. Hargreaves, was not so disposed, and the negotiation failed. The invention has not yet been extensively applied for the object which Mercer had chiefly in view—that is to say, the improvement in colour and strength of printed calicos. The question will be asked—to what is this to be attributed? Certainly not to any difficulty in carrying out the processes, nor to failure in obtaining all the desired improvements. The answer is probably to be found in the change which close competition soon afterwards induced in calico-printing, as in many other industries in this country, which rendered it expedient, in the judgment of the manufacturer, to sacrifice durability and intrinsic excellence to external appearance. The contraction of the cloth which took place in mercerising, although attended with so great an improvement in quality, did not suit the purpose of the manufacturer, especially for goods intended for export. Durability of his produce oftentimes became undesirable to the producer. A good appearance at the lowest cost was the primary consideration. It is obvious that such an unwholesome condition of things must either be permanently injurious, or else in the course of time induce a reaction. Possibly such reaction, in the particular industry before us, may have already commenced, and the time may not be distant when it will be found expedient to carry out extensively the process we have been considering. That the time for this will one day arrive we have every reason to believe, especially when we consider the greatly reduced cost at which the necessary chemicals may now be obtained, as compared with their prices thirty years ago.

We have, however, in concluding the present chapter, to notice an application of mercerised cotton which has been very successful—namely, in the manufacture of calico-printers' 'blankets' for machine-printing, for which Messrs. Mercer and Hargreaves obtained a patent. The blanket consists of two plies of unbleached mercerised cotton cloth cemented by caoutchouc, capable of being easily connected at the ends, so as to make a continuous even band. Being much thinner than the old woollen and macintosh blankets, they afford a neater and better impression. They are also cheaper and more durable than the old blankets. Their superiority, which was soon recognised, led to their general adoption. They continue in general use at the present time.

CHAPTER XI.

MISCELLANEOUS NOTES ON SOME SUBJECTS IN THEORETICAL CHEMISTRY.

On thermal changes produced by admixture of chloride of zinc and chloride of calcium.—While experimenting on the modification produced in cotton fibre by chloride of zinc and chloride of calcium, Mercer made some interesting incidental observations, one of which he describes in a letter to Dr. Playfair, from which we make the following extracts. It relates to the change of temperature which occurs on the mixture of hydrates of these two chlorides.

'The terhydrate of chloride of zinc, $ZnCl+3HO$' (according to the equivalents and formula then received), 'at a temperature of 200° Fahr., acts powerfully on cotton fibre or paper, converting it into a material which has the appearance of boiled starch, but insoluble in boiling water. The terhydrate of chloride of calcium ($CaCl+3HO$), at the same temperature, or at its boiling heat of 290° Fahr., acts but slowly on the fibre. I therefore mixed these two chlorides together. The result was an immediate disengagement of a large amount of heat. Although I expected that combination of the two chlorides would take place, according to my theory of the constitution of mixed saline solutions—that is, that the two chlorides would unite to form a closer combination with each other than either chloride held with its first atom of water, and consequently some heat be developed—yet I was taken by surprise at the great increase in temperature which resulted.

'If the two hydrates are heated separately to near their boiling-points, and then mixed, the heat is such as to blow up the mixture.

'If the two terhydrates are mixed in the proportion of single equivalents, each of the temperature of 200° Fahr., the temperature of the mixture is 230° Fahr.; the increase is, therefore, 60° for one volume.

'This mixture may be concentrated by evaporation until it retains only two equivalents of water (one equivalent to each chloride). I have kept this without change at the temperature of 400° Fahr.

'The preceding mixed hydrates retained their fluidity when cooled to 180° Fahr. On the addition of water at the same temperature, violent ebullition took place.

'But the admixture of *higher hydrates* of these two chlorides gave me very different results; thus:

'On mixing $ZnCl+9HO$ with $CaCl+9HO$ (single equivalents), both at the temperature of 48° Fahr., cold was produced; the temperature of the mixture immediately became 43° Fahr., or a loss of 5° Fahr.

'On mixing $ZnCl+12HO$ with $CaCl+12HO$, both at the temperature of 55° Fahr., that of the mixture became 49° Fahr., or a loss of 6° Fahr.

'On mixing $ZnCl+6HO$ with $CaCl+12HO$,

both at the temperature of 50° Fahr., that of the mixture became 44° Fahr.—a loss of 6° Fahr.

'On mixing $ZnCl + 6HO$ with $CaCl + 18HO$, both at the temperature of 55°, that of the mixture became 50° Fahr.—a loss of 5° Fahr.

'On mixing $ZnCl + 12HO$ with $CaCl + 6HO$, both at the temperature of 80° Fahr., that of the mixture became 78° Fahr.—a loss of 2° Fahr.

'The addition of water after the two chlorides had been mixed caused increase of temperature up to a considerable degree of dilution.

'In all my experiments, when one of the hydrates contained less than six equivalents of water, however many the other contained, heat was developed; but there was a fall of the thermometer (at ordinary temperatures) on mixing hydrates both containing over six equivalents of water. In all probability no cooling would take place at higher temperatures. This I must prove. The only similar cases I am aware of are those noticed in Gmelin's "Handbook," vol. i. p. 300.'

Referring elsewhere to a kindred subject, the tendency to combination among salts in solution, he observes that the cases are very rare in which the mixture of two soluble salts, in saturated solution, possesses the exact average qualities of the solutions separately. Setting aside cases of obvious double decomposition, there is generally a change, more or less, in solubility, which is sometimes increased, as in the case of acetate and nitrate of lead (the mixture of which salts in single equivalents is so soluble as to be scarcely crystallisable); sometimes, and much more frequently, the solubilities of salts are diminished on mixture, as in a multitude of well-known cases.

A propos of such saline combinations, he remarks that 'a mixture of acetate of lead and acetate of alumina forms a strong coagulum with gum, while neither of the salts separately possesses this property.'

In the letter to Dr. Playfair above quoted he says: 'Did you arrive at any definite conclusions in your researches on the contractions on diluting sulphuric acid? I was unprepared for the diagram or curve which you sent me. For a long while I was "quite out at sea, nor saw the shore," until at length I thought I saw twelve equivalents of water as a marked progressive number; twice twelve, three times twelve, and so on. Possibly, six may be the distinctive number of equivalents.'

Note on the solubility of oxalate of lime in certain liquids.—In 1851 Mercer made the observation that solutions of the oxalates of the 'sesqui type,' namely, alumina, oxide of chromium, and peroxide of iron, afford no precipitates when mixed with a solution of chloride of calcium, nitrate of lime, or acetate of lime. He also observed that oxalate of lime is soluble in solutions of chloride of aluminium, nitrate of alumina, nitrate of chromium, and pernitrate of iron, whether the base is united with the full proportion of acid (as in the alums) or with two-thirds only. Some of these facts had already been noticed by Graham, but they were not generally known to the chemical world at that time

Ammoniacal copper solution and cotton.—Mercer appears to have been the first to notice the remarkable action which the ammoniacal solution of cupric oxide exerts on cotton fibre. He found that cotton is completely soluble in the liquid obtained by dissolving hydrated cupric oxide to saturation in ammonia of sp. gr. 0·920 and diluting with three measures of water. On neutralising this solution with sulphuric acid, the organic matter was precipitated, and the latter became freed from copper by an excess of sulphuric acid.

When a piece of cotton was soaked for one minute in the ammoniacal solution of cupric oxide, its surface became changed to a gummy or mucous substance, which could be detached from the unaltered cloth, of a fine purple colour. Excess of ammonia did not increase the effect, showing that the active agent is the compound of ammonia with cupric oxide. The solution obtained by supersaturating solution of sulphate of copper with ammonia did not act so well as that made by dissolving the washed precipitated hydrate in ammonia water.

A piece of cotton cloth spotted with drops of strong solution of nitrate of copper, and suspended in the moist state in ammoniacal gas, showed very little appearance of being acted on. But on decomposing the nitrate by dipping the spotted cloth in cold weak caustic soda, washing and partially drying, and then exposing to ammoniacal gas for a night, 'the cloth was fully acted on.' In a similar experiment, where the cupric oxide on the cloth was brought to the anhydrous state by a boiling heat, and treated similarly in other respects, 'the cloth was scarcely altered.'

To ascertain the effect of difference of temperature, Mercer took one measure of ammonia of sp. gr. 0·920, dissolved in it the full quantity of washed hydrated oxide, and added two measures of water. One portion of this was put out of doors on a frosty night and the other warmed to 100° Fahr. On dipping cotton cloth in each of these for ten minutes, the cloth in the cold solution 'was acted on very powerfully,' that in the warm solution 'was scarcely at all acted on.' Mercer observed that the difference between the action at these temperatures is even more marked than in the case of soda.

On allowing cotton to soak for a night in soda liquor of 30° Tw., to which a little ammoniacal solution of the oxide had been added, the cloth was found to have absorbed a good deal of copper, so as to become very blue and stiff, but not gummy.

On relations among the atomic weights of chemical elements, and the constitution of chemical compounds.—Among the theoretical subjects which occupied Mercer's thoughts in some of his spare moments was the grouping of elementary bodies, and the relations which exist among their atomic weights. The attention of other chemists had been drawn to the same subject, but Mercer had very little acquaintance with their views, and pursued his inquiry on a basis of his own. He brought to light some interesting relationships, not before recognised, between the atomic weights of several elementary substances, and presented a paper on this subject to the British Association at their meeting at Leeds in 1858. The published report of that meeting contains several tables showing the results of Mercer's calculations, extracts from which we give in the Appendix (§ XXII.).

The relative position of ultimate atoms in compound bodies was also a subject which often occupied Mercer's thoughts, but the notes he has left rather show the difficulties he realised than satisfactory explanations of that mysterious branch of chemical philosophy. In a memorandum, written probably in 1854, he remarks: 'I have at times thought about the arrangement of atoms, but my conjectures are not so plausible probably as those of Gmelin ('Handbook,' vol. vii. p. 30, Cavendish Soc.). Still there are, to my mind, difficulties in his arrangements. For instance, in his arrangement of monobasic, bibasic, and tribasic phosphates, it would appear as if the tribasic was the most compact (and therefore the most stable) of the three, whereas it is not neutral, but strongly alkaline. The same is the case with most bibasic and tribasic salts. Neutral tartrate of potash, and tartrate of potash and soda (now called bibasic) hold one atom of base so feebly that acetic acid or almost any weak acid will remove one atom. If the atoms of such compounds have the compact arrangement which Gmelin suggests, then, either the energy with which they are united is not according to the solidity and compactness, or else we mistake in the arrangement of the atoms. . . . . I cannot help thinking that all bodies, whether considered to include a nucleus or not, must have two extremes, corresponding to positive and negative poles, points of energy and attraction, affecting the imponderable atmosphere which surrounds the ultimate atoms. And when combination takes place, although the affinities are greatly reduced and modified, and circumstances may prevent one or both from being recognised, yet we have no reason to suppose that by the act of combination both affinities are so completely satisfied as to cease to exist. . . . The resulting compound has chemical affinities, and may have a condition of polarity.'

CHAPTER XII.

PHOTOGRAPHIC EXPERIMENTS.

In a letter to Dr. Playfair, written in May, 1857, Mercer writes: 'For the last two or three years I have occasionally amused myself with making photographic experiments, not as an artist, but rather as a chemist. Some of my results are interesting. One is a simple method of measuring the chemical power of the solar rays, different from the method of Bunsen noticed in the "Proceedings of the Royal Society," Nos. 23 and 24. I considered it not worth publishing, but when I read Bunsen's I thought I might as well ask you to be kind enough to consider mine. If you think it too simple to be worth notice, let it sleep; if otherwise, you are at liberty to make it known in any way you think proper.—J. M.'

The occasional experiments of the previous 'two or three years,' and also some made subsequently, will form the principal subject of our present chapter. But we find, in an old memorandum-book, a brief entry, made so far back as the year 1828, which may be regarded as the germ of all his subsequent experiments on this subject, namely: 'I spotted a piece of white cotton with solution of pernitrate of iron, and exposed it to the sun; on testing it afterwards with solution of red prussiate of potash it gave a blue, but it gave no blue before exposure. This is worthy of note. I have not seen it noticed by any chemical writer.' Several years afterwards, Mercer introduced the use of *peroxalate of iron* at Oakenshaw, as a mordant for both woollen and cotton goods, and then observed the susceptibility of decomposition of that compound by exposure to the solar rays; the peroxalate thereby becoming reduced to the protoxalate, with disengagement of carbonic acid.[1] It is not sufficiently sensitive to be used

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[1] $Fe_2,3C_2O_4 = 2Fe,C_2O_4$ and $2CO_2$.

in the camera, but may be used for 'printing' from a negative.

Writing to Dr. Playfair in December 1847, he says: 'I have not done much in photography yet, having been too much occupied with other things. I have, however, a few crotchets in my head which I intend to try sometime. One, which is very promising, is to produce photographic pictures on paper and on fine calico, by means of persalts of iron and red prussiate. I have expected something from this, but I now find that Hunt has already made the same suggestion. I found that if paper or cotton cloth is smeared with a solution of pernitrate or persulphate of iron with certain quantities of oxalic and tartaric acids, dried in the dark, then exposed to the light (solar), and immediately dipped in solution of red prussiate containing a little free sulphuric acid (perfectly free from yellow prussiate), where the light has caused deoxidation, the blue is fixed, and where the peroxide remains unchanged there is no colour. The cloth or paper must be washed immediately in water containing a little sulphuric acid, and afterwards in pure water. The picture is a reverse blue print. If another colour is required, the blue cloth may be steeped in lime-water or weak caustic alkali, washed, and then dyed in gall-liquor or other dyeing infusion.'

An exposure of twenty seconds on a dull rainy day sufficed to produce a good blue when the paper was passed through the red prussiate bath.

Pressing duties at the Print Works, however, compelled him to postpone further experiments on this interesting subject; and the convenient opportunity for resuming them did not occur until October, 1854. He then directed his attention not only to obtaining good pictures in blue, on paper and cloth, but (using the blue as a basis) to obtain other colours by a variety of interesting chemical reactions. We give here a summary of his principal results and conclusions, and in the Appendix a description of some of his latest processes. At first he employed as his active photographic material a mixture of pernitrate of iron with both oxalic and tartaric acids; but afterwards gave the preference to oxalate unmixed with tartrate, which he prepared by adding nitric acid and oxalic acid to the protoxalate (see Appendix). The addition of perchloride of tin was found to impart the peculiar lustre to the Prussian blue which it does in the ordinary calico-printing processes.

The paper, having been cleansed from all ferruginous and deoxidising material, was impregnated with the iron solution, dried and exposed for printing, and afterwards treated with red prussiate solution in the manner indicated in the letter above quoted, and more fully described in the Appendix.

In continuing his experiments, Mercer operated on fine mercerised cotton as well as paper, the former being better suited for producing other colours by means of various chemical agents. His earliest attempts in this direction were of the kind alluded to in the above letter; consisting, that is, in the decomposition of the Prussian blue on the cloth or paper by lime or an alkali with production of oxide of iron, and the fixation thereon of various colouring matters from the ordinary dyeing materials. For this purpose he employed fresh clear infusions of galls, valonia, quercitron bark, sumac, &c., made with boiling water. The paper or cloth was dyed at a temperature of from 120° to 130° Fahr., and afterwards soaked in weak acetic acid. Infusion of galls with a little logwood gave a nice black. It was not Mercer's practice to discharge the Prussian blue in all cases before dyeing the cloth with a vegetable colouring matter. In dyeing it with madder to obtain a purple picture, which he made the subject of numerous experiments, he preferred to allow the blue to remain until the cloth was dyed.[1]

By various ingenious devices he succeeded in producing a great number of transformations on the exposed paper or cloth, and thus obtained pictures in a variety of pleasing tints. When not intended for dyeing with galls or

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[1] A description of his latest process for obtaining madder-purple photographic pictures on cloth will be found in the Appendix.

similar dyeing materials, his usual practice was to soak the paper or cloth, immediately after the exposure, in a solution of arseniate of soda, whereby the soluble oxalates are replaced by corresponding arseniates, insoluble in water but soluble in acids, and the paper is no longer sensitive. In the acid solution of red prussiate the ferric arseniate dissolves, and the ferrous arseniate gives place to a ferricyanide. Besides the transformations of Prussian blue already mentioned, two others may be noticed, namely—one by means of an ammoniacal solution of cupric oxide (saturated), which gives a fine purple blue picture; and another by soaking the blue paper in acid solution of nitrate of silver, whereby the Prussian blue is replaced by ferrocyanide of silver. By means of the latter compound Mercer obtained pictures on paper in various colours, including purple of cassius, for a description of which we must refer the reader to the Appendix.

Interesting results were also obtained by substituting for the red prussiate developing bath a mixture of a cupric salt with sulphocyanide of potassium,[1] which afforded, whereever it came into contact with the protoxalate or corresponding arseniate, a dense white deposit of cuprous sulphocyanide. All the iron compounds were then removed by soaking the paper or cloth in weak sulphuric acid, in which the cuprous sulphocyanide is insoluble. By means of that substance, as another basis, several other metallic compounds, possessed of colour, were fixed on the paper or cloth, of which the following are examples.

1. Pictures in the brown red of ferrocyanide of copper were obtained by soaking the paper in a mixed solution of red prussiate of potash and sal-ammoniac. The transformation proceeds gradually, and the shades are at length well developed. The ferrocyanide of copper afforded another means of obtaining the ferrocyanide of silver, by soaking the

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[1] The mixture preferred by Mercer for this purpose contained copper in the state of tartrate of copper and soda, with a little excess of soda, at a temperature of 160° Fahr. For his method of preparing this, see Appendix.

paper in solution of nitrate of silver and afterwards in dilute nitric acid.

2. By adding a little ferric salt to the red prussiate bath, a mixed deposit was obtained of ferrocyanide of copper and Prussian blue, giving a colour similar to logwood purple.

3. By soaking the cuprous sulphocyanide paper in a solution of stannous arseniate in tribasic arseniate of soda, washing in water, and then soaking for some time in neutral dilute chloride of gold, finishing with dilute hydrochloric acid and water, it afforded a picture of fine dark purple of cassius.

4. A picture which he describes as 'still more beautiful' than the preceding was obtained by soaking the cuprous sulphocyanide paper in dilute neutral nitrate of silver, then clearing in dilute ammonia, soaking in the above stannous solution, washing, drying, and aging one day, and then steeping in dilute chloride of gold with excess of acid.

At the meeting of the British Association at Leeds, in 1858, Mercer exhibited a number of these coloured photographs, some on paper, others on cambric, and gave a brief account of his processes. The subject excited considerable interest, and his friends pressed him to continue the experiments. A professional photographer, in acknowledging some specimens presented to him by Mercer, says: 'I have never in any kind of paper photography seen anything so beautiful as the Prussian blue seems in softness and gradation. If there is any method of getting the right tone in black from the Prussian blue, it would be all that can be desired, and far superior to anything at present known. The madder purples on cloth are very rich in colour, and one of them is remarkably delicate, which shows what the process is capable of.' Having sent some specimens of his photographs on cambric to the Photographic Society of Vienna, Mercer received from the secretary of that Society a letter of thanks, expressing the great admiration which his photographs elicited in Vienna, and the request that, if agreeable to him, his processes might be published in the Society's journal. He pursued his photographic experiments occasionally, but no further account of them was published. From his memoranda, however, we are enabled to extract and place on record his principal observations, which will be found in the Appendix.

At the same meeting of the British Association Mercer also showed how paper impregnated with the ferric oxalate might be used as an actinometer. It was to this he referred in a letter already quoted, written to Dr. Playfair in May, 1857 (p. 220). In the meantime, however, a similar suggestion had been published by Dr. Draper. Mercer's plan consisted simply in placing a slip of the prepared peroxalate paper between the leaves of a book, and pulling it out half an inch at a time every five seconds. After 'raising' in the red prussiate bath it could be compared with a graduated standard.

CHAPTER XIII.

LECTURES AT CLAYTON-LE-MOORS—HIS VIEWS ON SOME PHYSICAL SUBJECTS.

It was not often that Mercer complied with requests sometimes made to him to give a public audience the gratification of hearing him deliver a lecture, though he delighted in bringing forth out of his own 'treasure things new and old' for the edification of all with whom he came in contact; but it was more congenial to him to do this in his own quiet way, by his fireside, than to appear as a lecturer in public. Sometimes, however, he consented to deliver popular lectures at Clayton-le-Moors on subjects adapted to his audience, embracing the atmosphere, water, food and aliments, and the chemical changes which occur in vegetable and animal life.

The notes he has left of these discourses show that he always kept two objects prominently in view—first, to exemplify, by natural phenomena, the power, wisdom, and beneficence of God; and secondly, to take every opportunity of giving useful practical advice, especially in matters connected with bodily health. The harmonious adaptations of the various forces in nature to produce certain desirable results, the universal law that every force has its purpose to fulfil, and every substance its position to occupy and influence to exert, with a view to 'one harmonious whole,' were subjects which he tried to impress upon his audience. These he, of course, dealt with in the elementary way suitable to his hearers; but now and then he gave expression to interesting thoughts, the outcomings of his own meditation, and therefore, so far as he was aware, original; some of which we may here notice.

After dwelling on the exact suitability of our atmosphere to our requirements, in composition, weight, and other properties, 'so beautifully and wonderfully adjusted and adapted to our present wants as to produce in us astonishment and admiration,' he remarked that the earth was once surrounded by a very different atmosphere. In all probability the atmosphere of the preadamite world at one time contained an enormous excess of carbonic acid gas, in which only the lowest forms of animal life could exist. But certain vegetables grew then most luxuriantly, and became the means not only of purifying the air and rendering it fit afterwards for human life, but also of transferring the carbon from the air to the earth, and laying up a store of the invaluable mineral that now contributes so largely to our comforts and prosperity. He dwelt on the importance of pure dry air as an exhilarant; and remarked that by a slight alteration of the composition and properties of the air we breathe our lives might be made a grievous burden. The nitrogen of the air he called the principal mechanical agent, oxygen the principal chemical agent, and carbonic acid the agent for building up, first, vegetables, and thereby, indirectly, animals. The air is the first external agent essential for maintaining the life of the new-born infant. The functions of vegetables in transforming inorganic bodies of simple constitution into complex materials adapted for producing blood (which Mercer called 'the whole man in solution, and his life') were made occasions of illustrating the wisdom and goodness of the Almighty Designer.

When describing the change of arterial to venous blood, he remarked that 'as chemical action in a galvanic battery developes electricity, so the chemical action which takes place in the capillaries produces not only heat, but also another force which is capable of being collected by the nerves. These (the nerves) I may compare to the wires of the galvanic battery. They collect this force and convey it to the centre of sentient and motor influence.' When lecturing on food he took the opportunity of giving to his younger friends a word of advice respecting the preservation of their teeth. 'If you wish to keep your teeth in good condition, give them hard usage; press them well down into their sockets so as to keep good contact and circulation. For this purpose there is no food better than our hard oat-cake and crusts. People who accustom themselves to soft food soon have no teeth for anything else.' Another word of practical advice in the same lecture relates to the nutritive value of skimmed milk, which some persons are apt to overlook. 'Although the most agreeable constituent of the milk has been removed, the skimmed milk is not to be lightly esteemed; since a quart of it contains as much nitrogenous aliment (in the form of casein) as about half a pound of moist flesh; besides saccharine matter and wholesome saline ingredients.'

We may take this opportunity of noticing Mercer's views on some physical subjects, which we obtain from his memoranda and letters. Though not now possessing novelty, they are interesting illustrations of his independence of thought, and of his habit of looking beneath the familiar surface of things to the occult interior.

'In the various phenomena taking place around us we see that the potent agencies or forces of this world, as gravitation, electricity, chemical affinity, heat, light, and even magnetism, are nearly all concerned to a greater or less extent. In the living animal and vegetable there are also secondary forces dependent on organic structure. Like a complex mathematical process, in which every number has its influence on the product, so these various forces operate, sometimes harmoniously, sometimes apparently antagonistically, modifying the result.

'Such forces produce different physical qualities, which may vary, to some extent, in the same substance under different circumstances, without interfering with identity. Thus weight or mass, as determined by gravitation, is only a quality or expression of relative force between different bodies, without anything positive as to real solidity, or what we understand by the expression "mass." The weight of a body varies according to circumstances.[1] Herein we perceive the essential difference between gravitation and chemical affinity. The property possessed by certain bodies of uniting chemically in certain definite proportions is inherent and essential under all circumstances. It establishes identity.' Mercer regarded chemical affinity as 'probably a surface power, closely related to or dependent upon the shapes of the ultimate particles. When the forms of two or more bodies admit of their combining compactly, the resulting compound exhibits nothing whatever of the chemical qualities of its constituents; it is devoid of marked chemical qualities.'

In a note on gravitation, Mercer suggests that the gravitic influence may be dispersed throughout space by means of the ethereal

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[1] And the same change of circumstances may affect the weight of one body without affecting that of another. A pound of iron, for example, will appear to weigh more than a pound if weighed over a magnet.

medium in the same way as light and heat (*i.e.* by undulation). 'Strictly speaking, distance causes no diminution of the force of gravitation: the same amount of force exists, but it is diffused over a larger area; and if it could be concentrated, it would have the same power, however great the distance.'

Under the head 'Sources of Heat,' he remarks that 'combustion, friction, frictional electricity, galvanic electricity, and chemical action may all be resolved into friction or motion.[1] The influences we derive from the sun are also produced through motion. It is probable that around the body of the sun there is a distinct shell of highly electric matter in a state of intense agitation, and that the shell moves round the internal sphere. The force, as it exists in the sun, may be of a character different from anything we are now acquainted with. We have no proof that it is either light or heat when it leaves the sun; but the phenomena of light and heat take

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[1] This observation was made by Mercer long before the kinetic theory had attracted much attention.

place when the emissions (from electric or other source) enter our atmosphere; like the meteorite which then becomes luminous . . . . Not only heat, light, and chemical action, but electricity and magnetism, and probably other forces, are produced on the earth by the influence of the sun. This is a mysterious subject; but the greatest mystery of all is the maintenance of solar heat and light, without, so far as we can ascertain, any appearance of diminution.'

CHAPTER XIV.

HIS VIEWS ON TECHNICAL EDUCATION.

A MOVEMENT having been made with the object of establishing technical chemical schools in this country, Mercer was requested to give the promoters his views on the subject. His answer related chiefly to the connection of his own art with chemical education. Though written in 1853, it contains observations which are worthy of reproduction. 'I entirely concur with you,' he observed, 'that, for the preservation and benefit of the British arts and manufactures, the masters, managers, and skilled artisans ought to be better instructed in the *rationale* and scientific principles involved in their operations. Chaptal remarked that "practice is better than science" (*i.e.* abstract principles), "but when it is necessary to solve a problem, to explain some phenomenon, or to discover some error in the complicated details of an operation, the mere artisan is at the end of his knowledge, he is totally at a loss, and would derive the greatest assistance from men of science." Probably no person would, from his own experience, confirm the above remark, as regards the art of calico-printing, more heartily than myself. When I became connected with calico-printing in 1818, the only printing firms in this country who employed a man possessing a knowledge of chemistry were the Thompsons of Clitheroe and the Hargreaves of Accrington. I had begun to study chemistry, and pursued it diligently. The practical applications I was enabled to make proved of great advantage to our firm, and conduced to prosperity up to the time of dissolution of our partnership.'

Although the importance of having an educated chemist at print-works, chemical works, and bleach-works was then generally recognised, yet Mercer considered that, at the time he wrote, there was great room for improvement, and oftentimes much loss through spoilt goods or bad work was the result of imperfect acquaintance with the chemical principles of the operations. He observed that, 'as regards good practical men, no district could excel Lancashire; but in all the process, from the grey piece to the finished print, embracing thirty to forty operations, both the science and practical experience of the cleverest are requisite to keep all things straight and to detect the cause of, and rectify, mishaps.'

The want of chemical knowledge was most obvious among the managers of smaller works of the kind referred to. 'I might give,' wrote Mercer, 'many amusing cases of misjudgment and misconstruction, bad and spoilt work, from ignorance even of first principles. Let one suffice. I once met with a blue dyer who was exuberant at having obtained a supply of copperas admirably suited to his operations. He showed me what an excellent blue vat he had made with this copperas. He then showed me his highly prized copperas.

It looked like a mass of iron-rust. Scarcely half of it could have been effective for deoxidising. I then told him to make another vat, for comparison, with pale bluish-green copperas, and use only half the quantity he had used of the rusty. The fact was he had been accustomed to use double the proper quantity of copperas, so that when he got the rusty copperas his error was avoided. Similar mistakes are of every-day occurrence to a greater or less extent. An amusing volume might be written about ludicrous mistakes, and equally ridiculous attempts to rectify them.'

'I do not consider,' he continues, 'that the present chemical schools are well adapted for the sons of print-masters, managers and colourmen. During the two or three years they can spare for such training they ought to receive instruction not only in general principles, but in subjects related to their intended labour in the future. They should be fully instructed in the nature of the various substances used in their arts. If this is neglected, and other novel and more interesting subjects pursued, the young man returns to the print-works unprepared for his intended occupation, and brings both himself and his school into disrepute among practical men.

'I do not, however, undervalue abstract chemistry. I am well aware that from that source we have derived many of our most important improvements in the arts. But I maintain that, in the limited time the young man of the class referred to generally has for study, he should be initiated in such principles as he can apply *at once*, and leave to his future and higher progress the attempts to discover new applications. I remember the case of a son of a manager of print-works who was sent to one of the chemical schools to prepare himself for a situation in the print-works. While there, instead of applying himself to subjects connected with printing and dyeing, he took up other subjects, and wrote a paper on building materials. On his return to the print-works the principal expressed his dissatisfaction and declined his services.

'The majority of managers and colourmen in print-works, being practical only, are so jealous of, and offer such decided opposition to, "the chemical man," as they term him, that the principal is compelled to give way when sometimes he would gladly engage such a person. A case of this kind which occurs to me was that of a young man named Fletcher, who came to visit me from one of the chemical schools of London, with the object of obtaining a situation in print-works. I endeavoured to obtain a situation for him, and he himself tried at various places, but all failed through the opposition of the managers or colourmen. Yet this young man, in my estimation, was one as likely to succeed in a chemical or print-works as any I ever met with. He saw, to his regret, that his chemical education at the school had not been sufficiently directed to the situation he sought to fill. The young men who, having had judicious training, would find no opposition to their appointment are the sons of masters, managers and colourmen. But at present they have no suitable schools where they can obtain the special instruction desirable to fit them for their future work.

'It appears to me that the time is come when something ought also to be done to give the rising generation, generally, more instruction in rudimentary scientific subjects than is afforded in our ordinary country schools.

'Of proper technical schools there ought not to be many; say one at Manchester, one at Leeds, another at Sheffield, and another at Glasgow; with a central parent school in London. These would be quite sufficient; each of the country schools should have a speciality, and in that take precedence of the others.'

In some of the preceding observations there is reference to the want of harmony which sometimes existed between the practical man and the scientific. Doubtless there is far less of this at the present day than there was thirty years ago. When circumstances admit of its application to chemical arts, true science is always practical; that which is not practical can hardly be called scientific. But in all such industries a vast number of useful practices, especially in details, have been learned by long experience, instead of by the application of science; some of which even now are not satisfactorily explained on scientific principles; but experience has proved them to be advantageous. While, on the one hand, the practical man has often erred in attaching too little importance to scientific explanations and improvements, the scientific man, on the other, may sometimes have erred in attaching too little importance to useful practices, the scientific accuracy of which he may not yet perceive.

In the present day, however, the absolute necessity of the application of science in such arts is so fully recognised, that we may consider the discordance referred to by Mercer has almost disappeared.

CHAPTER XV.

'THOUGHTS ON MOULD,' AND PREPARATIONS FOR THE CHOLERA.

SOME interesting 'thoughts on mould' which we find in Mercer's memoranda, and in a letter which he wrote to Dr. Playfair in 1843, must not be overlooked. His attention was particularly directed to this subject by serious damage having occasionally occurred through mildew to extensive shipments of printed calicos made by the Oakenshaw firm to South America, which caused the discharge of the colours during the voyage. After some investigation, Mercer came to the conclusion that the mildew was closely connected with the quality of the starch used for stiffening; badly prepared starch, which retained a little gluten, being much more productive of mildew than well-made starch, free from gluten. He made a large number of samples of starch-paste containing different proportions of gluten, and allowed them to stand for several days in shallow earthen pots, covered, but not air-tight. In the samples which contained most gluten mould appeared in four days, other samples stood free from mould for a longer time, up to nearly a fortnight, in the reverse order of their proportion of gluten.

Of the various substances with which Mercer experimented in order to discover a suitable preventive of mould in the printed calicos during a long voyage, he considered bichromate of potash to be the most convenient and effective. By using the best starch, and adding a little bichromate, no further inconvenience was experienced.

Having surmounted the technical difficulty, most people, probably, would have allowed the matter to drop, or thought little more about it. But Mercer's observations led him to contemplate a wider field, although pressing duties at the print-works at this season prevented him from doing more than giving his thoughts and suggestions to others. He was much impressed by two of his experimental observations, which were these: When a solution of pure tartaric acid, in distilled water, after being boiled, is allowed to stand for some time in a vessel not absolutely air-tight, mould at length makes its appearance on the surface. Mercer rightly concluded that in such a case the originating fungoid germ (which, no doubt, contains nitrogen as well as carbon and hydrogen) must have been floating about in the air, and thus obtained access to the tartaric acid. He also noticed that in the experiments above referred to, with starch-paste, the mould in the various pots did not appear to be uniform; in some it was of a greenish colour; in others, yellow; and in others, red; suggesting the thought that there might have been a variety in the germs derived from the air.

Writing on this subject to Dr. Playfair, Mercer asks: 'If starch-paste, immediately after being boiled, were placed within a bell-jar containing air which had been passed through oil of vitriol, or through earthen pipes heated to whiteness, would moulding or any such action take place then? Mould seems to be a species of vegetable; is it not? I am not acquainted with anything written on this subject. Are there many different kinds of mould? If it be, as I suppose, a vegetation, there must have been a germ. Must not this have been supplied by the air? It would be interesting to ascertain whether starch or flour-paste, well boiled to destroy any ready-formed ferment or diastasic substance, would afford mould in an atmosphere deprived of all organic germs. If nothing of the kind appeared, then I would admit air from a fever room, or other infected atmosphere, or put in infected clothing, or a little saliva, blood, or discharge from a person having an infectious disease, to ascertain whether anything like mould would then be produced, and whether such mould would present differences when derived from different diseases. A simple method of trying this would be to daub a piece of board or paper with paste and expose it over the sick person or in an infected place, then scrape off the paste and put it aside in the pots. Or charge the pots with paste and put them in a small perforated tin box or cage, to be kept for a little while in the unhealthy place, and afterwards in a convenient place, to see what mould appears. I keep my pots in a rather confined place, protected from direct sunlight. I am occupied a little with these things at present, but I despair of doing much, owing to the pressure of my business. I should like to add to the starch when cold a little of the virus from small-pox; scurf from ring-worm heads; saliva, blood and urine from fever patients, &c., to see if I can discover any difference in the mould produced. . . . . The deleterious matter in infected air must, I think, be a nitrogenous body, and at least as highly organised as ferment and that class of substances. It may have the structure of a low vegetable or an animal. And even though starch fails to show a peculiar mould, yet other substances may be found suitable for the purpose. The subject is worthy of careful experiment. . . .

'We had our Whalley meeting at the usual time, but it passed off with very little that was interesting. We wanted the Lyon of the former meetings.

'Yours truly,

'JOHN MERCER.'

Surely these 'thoughts on mould' of Mercer's, written in 1843, derived wholly from his observation of the few facts here recorded, may be called a *thought-germ*, which, in a congenial environment, would not have taken long to develop the microbe doctrine of disease enunciated many years afterwards by Professor Pasteur, Dr. Koch and others. But, obviously, the congenial environment was not to be found at Oakenshaw. It must have included the physician, the microscopist and the naturalist. Hence we find no further reference by Mercer to the subject. It will be scarcely necessary to remark that Mercer was unaware that a similar idea as to the origin of some diseases had just before been suggested by Sir Henry Holland.

As somewhat connected with the same subject, we may here notice some contents of another letter which Mercer wrote to Dr. Playfair a few years later (1847), when fears were entertained in this country of the approach of the cholera. Dr. Playfair had been appointed on the Commission of Health of Towns.

Mercer writes: 'Do the functions of your Commission extend to inquiry into the prevention of the cholera? You see it is approaching. Are there any meetings of medical and other scientific men to discuss the best means of resisting it when it has come? There ought to be such discussions now, while they may be held deliberately. All will be hurry and bustle when the disease arrives, and the people will be dying. At the previous visitation of the cholera in this country, scarcely any preparations were made to resist it, and there was great diversity of opinion as to the best mode of treating the disease. It was not without reason that I was much alarmed, as there were nearly three thousand persons residing in our district, and the same number at Harwood, without a resident medical practitioner. The nearest doctor resided two or three miles from us, and three or four miles from Harwood. From seven to eight hundred of the people were our own servants. I therefore determined to make myself as well acquainted with the nature and treatment of the disease as I possibly could. I read all the medical journals of the time, and every other source of information on the subject I could obtain, so as to be able in some feeble way to do my best among our servants and the people around. I decided on a mode of treatment, and prepared a large quantity of magnetic oxide of iron. I also procured a large supply of chloride of lime, intending to have some placed in every house in our township. I have for a long time had the floor of our print-shop sprinkled with this when any epidemic has prevailed in our neighbourhood. However, the cholera came no nearer than Sykeside, a small village two miles and a half distant. A Pole, who was travelling from York to Manchester, was attacked with the disease, and had to be taken to an old empty house in that village. He soon died; an old woman who waited on him was attacked and died, and her daughter and another attendant also died in rapid succession. As soon as I received intelligence of this I sent to Mr. Becker, a manufacturer of chloride of lime in the vicinity of the village, requesting him to send a cask there immediately, with men to dust and drench the corpses, all the clothing, and every house in the village. This was done promptly, just when the fourth death occurred. There was a complete fumigation of chlorine, but without the use of acid. There were no more cases of the disease in the village.

'I see that a letter has just been sent to "The Times" by Herapath of Bristol, in which he recommends chlorine fumigation as a preventive of cholera.'

CHAPTER XVI.

EXAMINATION OF WATER FOR USE IN DYEING.

The last laboratory work of Mercer, of which we have any record, consisted in the examination of a large number of samples of water, with reference to their suitability to dyeing and calico-printing. A very heavy claim for damage having been made by the proprietor of the Horwich Vale Print Works against the Corporation of Liverpool, on the ground of alleged inferiority in the quality of the water supplied to their works by that body in 1860, as compared with the previous supply, Mercer was requested by the Corporation to investigate the subject and give his report. It was not without some reluctance that he complied with the request. To be mixed up with such legal proceedings at his advanced age was anything but agreeable to him; but, having consented, he applied himself to the work with his usual devotedness and conscientiousness, and rendered to the Corporation important services, which were duly appreciated. The special results and aspects of the investigation have ceased to possess interest, but among Mercer's notes of his experiments we find some observations which have a wider application than the case of 'Chippendall *v.* The Corporation of Liverpool,' and deserve to be placed on record.

A large number of his experiments consisted in dyeing pieces of calico with madder, in different samples of water, all other circumstances being precisely identical. For this purpose he made use of a water-bath fitted with eight similar vessels, each large enough to manipulate with one pint of water. Pieces of cloth were printed in large stripes, with mordants for red and purple, and prepared in the usual way, of which either three or six inches, across the whole width of the cloth, were taken for each experiment. The dyeing was commenced at 80° Fahr., the heat was increased 10° every ten minutes for two hours, when it reached 200°, which temperature was not exceeded. For each three-inch piece of cloth 60 grains of Turkey madder were taken for full-dyeing and 30 grains for half-dyeing; or for full-dyeing 20 grains of garancin, or half that quantity for half-dyeing.

In these experiments, Mercer generally used three-inch pieces of cloth of full width, and madder or garancin for half-dyeing. The proportion of water in such cases was five times and a half as much as would be used on the large scale (*i.e.* eight gallons to one piece). As only one-half the full quantity of dyeing material was used, the injurious influence of impurity in the water would therefore be exhibited in such tests to an extent probably ten times greater than would be experienced on the working scale. A slight difference in the chemical composition of the waters, especially in respect of carbonates of lime and magnesia, showed a decided difference in the depth of the colour of the dyed samples.

Sulphate of lime, when not in unusually large proportion, produced very little injurious influence. Of sulphate of magnesia, twenty-four grains (cryst.) to the gallon produced very little change, as compared with distilled water; but twice that quantity proved very injurious.

Carbonates of lime and magnesia acted injuriously, whether introduced in the solid state or held in solution by carbonic acid. But the results were not uniform with different varieties of madder. With matured Turkey madder, and with garancin, the smallest quantity of the carbonates proved injurious, when compared with distilled water. Carbonate of lime, added to the extent of one-tenth the weight of the madder, diminished the dyeing power at least one-third. But in the case of unmatured Dutch madder, the addition of a very small quantity of carbonate of lime, not exceeding one-fortieth part of the weight of madder, was found to be an improvement. The colour was deeper than that obtained with the distilled-water test. More than that proportion acted very injuriously, as in the case of Turkey madder and garancin. Mercer considered that the beneficial action of a very small quantity of carbonate of lime was attributable to its combining with some of the pectic acid contained in unmatured madder, which otherwise, as when distilled water is used, would have acted injuriously on the alizarin.

It is probable that in dyeing with artificial alizarin, which has to a large extent taken the place of the root, the desirability of avoiding the presence of earthy carbonates is as great as when madder is employed. In the course of his experiments, Mercer ascertained that the injurious action of the earthy carbonates on madder and garancin may be entirely prevented, so far as red dyeing is concerned, by the addition of a small quantity of sumac.

A test which Mercer often used qualitatively for ascertaining the presence of earthy carbonates in water was protosulphate of tin, which he prepared for this purpose by agitating one ounce of crystallised sulphate of copper and one ounce of feathered tin in two ounces of distilled water, until all the copper was precipitated. The solution was kept without exposure to air, to avoid the formation of stannic sulphate. If pure, no cloud appears when the protosulphate is dropped into distilled water; but a turbidity does appear if oxidation has taken place. According to Mercer, this test produces a cloudiness when dropped into water containing one part of lime or magnesia in 500,000; one part of caustic soda liquor of 70° Tw. in 1,000,000; one part of ammonia liquor (0·915) in 1,000,000; and one part of arseniate of soda in 1,000,000.

CHAPTER XVII.

HIS CLOSING YEARS.

For many years, Mr. Mercer's domestic circle was a scene of sunshine and happiness. The cloud, however, came at length in the illness and death of the fondly loved wife of his youth, in the year 1859.

For a few years previously, Mrs. Mercer had been indisposed; but this occasioned no anxiety among her friends, until the close of the year 1858, when her suffering became severe and alarming. The occurrence, however, of seasons of relief and rallying led her friends and medical attendants to expect her recovery; but she herself seemed fully persuaded that the end of her earthly existence was approaching, and looked forward to the change with the peace and calmness which harmonised with her life of Christian faith and devotedness. In the prospect of 'the rest which remaineth,' she bore her severe suffering with exemplary fortitude and patience. A few days prior to her decease she had an attack of partial paralysis, after which she was unable to speak, but apparently free from pain. She was fully conscious of all that was transpiring, and, with her bright smile and intelligent eye, showed her lively appreciation of the prayers and attentions of her friends. 'What an enviable position to be in!' exclaimed a lady friend who saw her on the day before her death, 'ready to clap her glad wings and soar away!' She departed on December 2, 1859, aged seventy-four years.

Miss Mercer, to whom we are indebted for this account of her mother's last days, thus describes an interesting incident: 'After the attendants had performed the usual offices for the body, my father took us all to the bedside, raised the cover from her face, took her cold hand in his, and said, "I bless thee, O God, for having given me so good a wife;"

and, turning to his children, he said, "and I call upon you, my children, each to thank Him also, for having given to you such a good mother." We were all deeply moved.' . . . 'But I cannot describe the grief we all felt at losing so estimable a mother.' This amiable woman was truly a helpmeet to Mr. Mercer in his battle of life; we have before seen the testimony to this which he himself gave to his children. But her praise was on the lips of all who knew her. The rule of her life was to do good to others, not only in outward acts of charity, but in tokens of loving sympathy. Thus the disinterestedness and generosity of Mr. Mercer himself were encouraged by his wife; and we can well imagine the thought of her example prompted him on one occasion, as we are told, when, walking in company with his sons, he suddenly stopped, and, looking earnestly on them, said, 'Oh, my sons, do all the good you can to everybody!'

In 1861, Mr. Mercer was placed on the

commission of the peace for the county of Lancaster. It is probable that, in his awards when on the bench, the claims of justice to the community were not unfrequently outweighed by his feelings of pity and compassion for the offender. Oftentimes the question in his mind as to the claims of justice on the one hand and mercy on the other was evidently very trying to him, and the award of strict justice cost him a struggle. Sometimes he manifested great uneasiness on leaving the bench, when he considered his brother-magistrates had imposed too severe a penalty. I have heard the saying, which probably expressed the truth, 'Mr. Mercer was too merciful for a magistrate.' Frequently the friends of an offender came to him to ensure his being present at the court at the time of trial.

At the great International Exhibition of 1862 his services were again in requisition as a juror, in which office he rendered important assistance, as on the previous similar occasion in 1851.

It need hardly be stated that the deep religious convictions of his youth and manhood remained unshaken to his last days. With advancing years he could realise more and more fully the 'vanity' of earthly things, and the certainty, in the gospel of Christ, of a glorious eternal future. He always loved to recognise and trace the wonderful evidences of the Almighty Designer exhibited in the 'Book of Nature,' not only in the grand and majestic, but in the minute details with which we are familiar in the daily walk of life. Writing in 1860 to his friend Mr. Richard Fort, who was then on the Continent, and who had informed Mr. Mercer that his reading of Bishop Butler's 'Analogy' had been of great help in leading him to a conviction of the truth of the Christian religion, he writes: . . 'I have never read Butler's "Analogy," but I intend to do so, and expect I shall find that, in the course of my long life of active thought, I have hit upon something similar to what I shall find there. I have long been convinced that the visible is as inscrutable to us as the invisible; that all nature is an aggregate of, so to speak, miraculous adaptations, compensations, restraints, adjustments, provisions, &c., all of which belong to the department of immateriality; that all the active and passive changes which take place in this world, and in the universe, are produced by forces which cannot be proved to be material; and the mysterious and profoundly inscrutable character of the common phenomena of this world, with which I am familiar, only deepens my conviction of the reality of the invisible world.'

Mr. Fort had referred to his having passed through 'many forms of scepticism,' and 'had to struggle with difficulties' during a season of protracted illness; but having become convinced of the truth of the Christian religion, he then found his 'views of the future wonderfully brightened and cheered by the consolation it affords.' Mr. Mercer wrote in reply: 'Your letter gives me so much pleasure; especially as it shows how clear your ideas were, and how vigorous your mind was, when you wrote it; with such tranquillity and self-possession—a most desirable state to be in. While reading your letter, before I came to your own statement, I felt sure your "health had made great progress," and I was glad to find my expectation confirmed. Dear Richard, allow me to say that, in every case, to produce and maintain an even, placid, tranquil state of mind and feeling there is nothing like true religion; but this is particularly so in your form of illness. As you have learned from experience the wholesome influence of certain kinds of reading and study, so I have no doubt that, by strict attention to your own experience and the exercise of your best judgment, your health will continue to progress.'

Living in an age of great political excitement, and in a part of the country where political enthusiasm often led to extreme demonstrations, Mr. Mercer, as might have been expected, held decided political views. He was a supporter of the Reformers and the advocates of liberal measures; but without making himself prominent as such, and without making any uncalled-for obtrusion of his views. He was a great admirer of Richard Cobden. That great statesman, to whom, more than any other, our nation is indebted for the repeal of the duty on corn, was in the employ of Messrs. Fort Bros. and Co. in 1830; he occasionally 'took the road' as their commercial traveller, and afterwards became a partner. The connection did not continue long, but the intercourse was sufficient to produce in Mr. Mercer a great esteem for Cobden, and sympathy with his political principles.

During the last two years of Mr. Mercer's life he experienced severe bodily suffering, which he bore with becoming fortitude and resignation. His illness was induced by an accident which happened to him in the year 1864, while examining the progress which was being made in the construction of a water reservoir in his neighbourhood. His foot slipped, and he fell a few feet into the water. Some time elapsed before he could put off his wet clothing; the immediate consequence was a severe cold, which soon developed into an internal disease of a very painful character. This eventually proved fatal. With a readiness and a desire to depart and 'go home,' as he used to say, he sought for and obtained help, patiently to wait until the right time arrived. A few days before his decease he said to a friend, 'Christ is all in all to me.' Thus testifying to the last the power of the faith which had exercised so much influence on him throughout his career, this remarkable man departed this life on November 30, 1866, in his seventy-sixth year. Not only was his loss deeply felt by his two sons and two daughters, all of whom, being unmarried, still resided under the paternal roof, but by a large number of friends to whom he had endeared himself by his sympathy, catholicity of spirit, and uniformly unselfish life. Among the inner circle of his personal acquaintance many could bear witness to the good influence exerted on themselves by his example; and though since his day times have changed, and the surroundings of the readers of this memoir may differ largely from those of Mercer, yet we do indulge the hope that our endeavour to make known his character and aims, his difficulties and successes, may render Mercer's example a wholesome influence to an outer circle, and enable him, though he died nearly twenty years ago, yet to speak words of wisdom. His remains were interred in the family vault, St. Bartholomew's Church, Great Harwood.

APPENDIX.

§ I. LIQUID MEASURES USED AT THE OAKENSHAW WORKS.

THE peculiar division of the gallon introduced by Mercer, to which we shall have frequent occasion to refer, is the following:—

1 gallon=16 'gills,' g = 10 oz
1 'gill' =16 'spoons,' ·6 oz = 10

and the spoon was further subdivided into 16 parts.

No doubt this system, from its simplicity and easy subdivision, would be found very convenient.

§ II. EXTRACT FROM A LETTER TO MR. ROBERT WARINGTON.

The letter from Mercer to Warington, in which he describes some experiments with antimony orange, and indigo, referred to page 29, was written in 1847.

'I remember being remarkably struck at that time by the fact that if I had used too much sulphur in making the orange, when it became mixed with the blue ("deoxidised indigo" in alkaline solution), the whole became "oxidised" or dark blue. I then tried the effect of adding sulphur to the mixture of indigo with red arsenic (and alkali), and found that no solution or "deoxidation" of the indigo could be effected. I then took the calico-printer's blue-vat liquor (made with indigo, copperas, and lime) and added a little "red sulphuret of lime," and found that in a short time all the indigo was precipitated of a blue colour. This effect does not take place by the addition of simple sulphuret, but only when there is excess of sulphur; as $Na\ S_2$ or $Na\ S_3$ &c., not $Na\ S$. I concluded at the time that when indigo blue is changed to white indigo it does not lose some of its oxygen, but that it gains hydrogen; and that in the above case the excess of sulphur above the simple sulphuret combines with that hydrogen. Indigo precipitated in this way differs from common indigo in density. I have had it sometimes as light as magnesia, of a very fine colour.'

§ III. PREPARATION OF COCHINEAL LIQUORS.

Having discovered (in 1825 or thereabouts) that neutral oxalate of potash possesses a remarkable solvent power for the colouring matter of cochineal, or rather for that portion of it which is scarcely soluble in water, Mercer made use of that salt for preparing cochineal liquors with great advantage. The following method was practised at Oakenshaw for preparing a fine liquor of moderate strength:—

The cochineal was digested three times: first with 'weak liquor' obtained from the second digestion; next with 'red washings' obtained from the third digestion; and lastly with water.

Eight lbs. of unground silver cochineal were put into 24 gallons of 'weak liquor' previously heated to 190°, kept for about a quarter of an hour at that temperature, and then filtered, with pressure. The liquor thus obtained was fit for use.

The bottoms were put into 24 gallons of 'red washings' containing oxalate of potash, previously heated to 190°, kept at that temperature for about a quarter of an hour and then filtered. This 'weak liquor' was used with fresh cochineal.

The bottoms were next put into 10 gallons of hot or boiling water, again placed on a filter, and washed with 12 gallons of hot water, added in several successive portions. In the 'red washings' thus obtained 3 lbs. of oxalic acid were dissolved, and carefully neutralised with solution of carbonate of potash.

Another method practised for making stronger liquor (suitable for black merino discharge work) was the following:—

Twenty-four lbs. of good cochineal were boiled for a quarter of an hour in 10 gallons of 'weak liquor,' and one gallon of oxalate of potash liquor of 36° Tw. The liquor squeezed through a hair-cloth filter-press was of 14° Tw.; it was either used in that state, or, for most purposes, concentrated by evaporation to 22° Tw. The bottoms were then boiled for half an hour with 10 gallons of 'red washings' and again pressed (giving 'weak liquor'), and lastly boiled with 10 gallons of water for half an hour (for 'red washings').

Cochineal '*crimson liquor*,' used for black merino discharge, was made thus:—

Four lbs. of cochineal were mixed with 1 gallon of 'crimson washings,' and 2 quarts of ammonia (medium strength), and allowed to stand, with frequent stirring, for about ten days. There was then added, by degrees, a solution of 2 lbs. of oxalic acid in 2 quarts of 'weak liquor'; the quantity necessary for neutralising the ammonia was observed, but the whole was added. The mixture was heated to 180°, and then filtered and pressed to obtain liquor for use.

The bottoms were washed, in the first place, with 2 quarts of water and pressed, to obtain the above 'weak liquor'; next with 2 quarts of water and 4 'spoons' of ammonia; and lastly with 2 quarts of water; the last two washings, mixed, formed the 'crimson washings' used with the raw cochineal.

§ IV. MERCER'S TEST FOR BLEACH LIQUORS.

The following method was found convenient, at the Oakenshaw Works, for testing strong bleach liquors. The standard for this liquor was taken at

1 lb. of bleaching powder of 50 p.c. 'pure chloride of lime' (or 28 p.c. available chlorine) in one gallon. The liquor to be tested was put into a '4-spoon vessel' graduated into 100 parts, and added gradually to a solution of 182 grains of yellow prussiate of potash, with a little acid, until the mixture ceased to give a blue precipitate with a solution of ferric salt.

If the liquor was of the exact standard above mentioned, 50 measures would have been necessary.

Calling the number of measures used a, then

$\frac{800}{a}$ = the number of ounces of bleaching powder of 50 p.c. pure 'chloride of lime' (28 p.c. of chlorine) per gallon.

$\frac{225}{a}$ = the number of ounces of chlorine per gallon.

And if the liquor had been made with 1 lb. of bleaching powder per gallon, then

$\frac{2500}{a}$ = the percentage of pure 'chloride of lime' in the bleaching powder; and

$\frac{1400}{a}$ = the percentage of chlorine in the bleaching powder.

The weak 'chemic' liquors used for 'chemicking' delaines, which required frequent examination and adjustment, were tested as follows:—

The standard strength required was 1 gallon of the above strong liquor (containing 1 lb. of 28 p.c. to the gallon) to 100 gallons of water.

The yellow prussiate solution was made by dissolving $5\frac{1}{4}$ ounces in 1 gallon of water; 4 'spoons' of this solution correspond to 1 pint of the above dilute 'chemic' liquor. One pint of the liquor to be tested was slightly acidified by nitric acid, a few drops of solution of 'red nitrate of iron' were added, and then the yellow prussiate until the mixture became blue. If more than 4 'spoons' were necessary, more of the strong bleaching liquor was added to the tank, in proportion.

This was found a very convenient and ready test for maintaining the proper strength of the chemicking cistern.

§ V. ON THE ACTION OF A MIXTURE OF RED PRUSSIATE OF POTASH AND CAUSTIC ALKALI UPON COLOURING MATTERS.[1]

'About ten years since I discovered, and used extensively in calico-printing, the oxidising properties of a mixture of red prussiate of potash and caustic alkali. For many years I have been in the habit of communicating to my friends several applications of this interesting reaction, among whom I may mention Mr. Crum of Glasgow, and Dr. Lyon Playfair. Since then Boudalt has directed attention to the oxidising

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[1] From the *Memoirs of the Chem. Soc.* vol. iii. p. 320. 1847.

power of the same mixture, as far as relates to metallic oxides, but has not shown any important practical application of the knowledge thus acquired.

'There are but few processes known in the arts for bleaching indigo, the principal of these being that in which chromic acid, liberated from the bichromate of potash, is used. In certain cases this process is attended with various disadvantages, and the cloth requires to be subjected to a clearing process to remove the oxide of chromium. The topical application of a mixture of red prussiate of potash and an alkali at once effects the same purpose, and in a most complete manner, leaving a brilliant white on the spot where the colour is discharged, without rendering any injury to the fabric. The manner of applying this discharge may be arranged to suit the conditions of the calico-printer. As a class experiment for a lecture-table it is convenient to impregnate the indigo-blue calico with a solution of red prussiate of potash, and then dip it into a weak solution of alkali.

'This action is a beautiful illustration of those double affinities which we frequently find at play in combinations or decompositions. Thus, though neither chlorine nor charcoal can decompose alumina *per se*, the same gas passed over a mixture of alumina and charcoal combines with the metallic radical; the charcoal in this case having aided the combination by withdrawing the oxygen. It is the same kind of action in the case under consideration. Red prussiate of potash, $Fe_2\ Cy_6\ 3K$, differs from the yellow prussiate, $Fe_2\ Cy_6\ 4K$, by containing one atom less potassium. When potash is presented to the former, this deficient atom of potassium is supplied, but the affinity is not strong enough to liberate the oxygen. When, however, a second body having an attraction for oxygen, such as litharge or indigo, is presented to the potash and red prussiate, this second affinity acting in a different direction withdraws the oxygen and allows the potassium to unite with the compound radical ferrocyanogen; thus $Fe_2\ Cy_6\ 3K + KO + PbO = Fe_2\ Cy_6\ 4K + PbO_2$, the decomposition being of the same kind when an organic matter is substituted for the oxide capable of further oxidation. Soda and ammonia may be substituted for potash in the above decomposition, producing the oxidation or discharging the indigo. This is curious in the case of ammonia, for it cannot be explained by any other than by the ammonium theory, and shows the complete analogy between the oxide of ammonium and the oxide of the simple metallic radicals, potassium and sodium. It is interesting also to observe that the last member in the formula $Fe_2\ Cy_6\ 4R$, may be substituted by any alkaline base. Thus, that it may either be $Fe_2\ Cy_6 + K_3K$, or $Fe_2\ Cy_6 + K_3\ Na$, or $Fe_2\ Cy_6 + K_4\ NH_4$. This circumstance points to important theoretical considerations in the atomic constitution of the prussiates, which would be foreign to the present paper, the principal object of which is to furnish a means of discharging indigo, and thus supply a process much wanted in the art of calico-printing, and which I have followed for many years with success.'

§ VI. THE RIBBON-ROLLER.

We have occasionally referred to the use made by Mercer of the 'ribbon-roller,' as a means of producing some pleasing styles. This was not an invention of his, but for the information of some of our readers we may mention that it was used for the purpose of producing a continuous colour lengthways of any desired breadth, with softened edges; being simply a wooden roller of about six inches in diameter, with the blanks grooved out to about $\frac{5}{8}$ of an inch; underneath the cylinder was the colour trough, the projections of the cylinder just dipping into the liquor; the cloth by passing over the upper part of the rotating cylinder became impregnated with the colouring material or mordant. Three such rollers, supplying different colours, were often placed together for the cloth to pass over them in succession; and to produce certain effects, the second or third roller was so placed that its impression overlapped that of the preceding roller. The colours applied in this way were not thickened as for ordinary printing; so that the edges became shaded off by absorption, and effects obtained similar to what is called 'rainbow-printing.'

§ VII. DOLE YELLOW.

The receipt referred to page 59 is the following:

Dissolve	Nitrate of lead	4 lbs.
and	White acetate of lead	4 ,,
in	Water	6 quarts.
Dissolve	Bichromate of potash	$4\frac{1}{2}$ lbs.
in	Water	6 quarts.

Add three-fourths of the bichromate solution to the lead solution, then thicken with

Starch	4 lbs.

Apply heat, and add the remainder of the bichromate solution; when of the right consistency remove from the source of heat, and add

Nitrate of alumina liquor (from 4 lbs. alum, and 4 lbs. nitrate of lead to the gallon)	2 quarts
and Salammoniac	1 lb.

§ VIII. DISCHARGES FOR MERCER'S 'MYRTLE GREEN.'

The following are receipts referred to page 62:—

1. Blue discharge.

Gum liquor of 40° Tw.	5 pints,
Dil. Sulphuric acid (1 O.V. 2 water)	$1\frac{1}{2}$ gills,
Protochloride of tin liquor of 100° Tw.	$1\frac{1}{2}$ pints;

to which add

Tartaric acid	8 ozs.

previously dissolved in

Water	$1\frac{3}{4}$ pint.

2. Yellow discharge.

Dissolve	Sulphate of copper	8 ozs.
in	Water	2 quarts;
add	Sulphate of zinc	5 lbs.
	Pipe-clay	10 ,,
Next add	Gum liquor of 40° Tw	1 quart,
and (previously mixed together)		
	Nitric acid	1 pint,
	Water	1 ,,

3. 'Discharge resist white,' for printing on and discharging the orange, and for acting as a resist when the cloth is afterwards dyed in the blue vat.

Mix	Pipe-clay	8 lbs
with	Sulphate of copper	2 ,,
previously dissolved in		
	Water	2 quarts.
Next add	Gum liquor of 40° Tw.	1 quart,
and lastly	Protochloride of tin liquor of 100°	1 ,,

§ IX. DISCHARGES FOR BLACK MERINO.

The following are the discharges referred to page 63:—

A. White discharge (for 'solids').

Dissolve	Oxalic acid	4 ozs.
and	Oxalate of ammonia	4 ,,
in	Water	3 pints.
With a portion of the solution, beat up		
	Pipe-clay	3 lbs.

Mix the remainder with

Gum liquor of 40° Tw.	5½ pints,
Gum liquor of 20° Tw.	2 ,,
Oxalic acid	4 ozs.
and Oxalate of ammonia	12 ,,

Warm, if necessary for solution, and mix with the pipe-clay. Place in the bottom of a pan

Tin crystals	21 ozs.

to which add the above mixture by degrees; strain for use.

A similar discharge was used for 'shapes' containing more pipe-clay and less gum.

B. Standard deep yellow discharge.

In one pan mix well together

Pipe-clay	3 lbs.
'Quercitron bark precipitate' (described elsewhere in this Appendix)	1 quart
and Tin crystals	20 ozs.

In another pan mix

Ground Barbary gum	4 lbs.
'Quercitron bark precipitate'	2 quarts,
Oxalic acid	12 ozs.
Oxalate of ammonia	12 ,,
and Water	1 quart.

Stir well, cold at first; afterwards warm a little, and when the crystals are dissolved add the mixture by degrees to the above paste. Strain twice through a coarse and afterwards through a fine cloth.

C. For a lighter yellow (for 'pegging') mix

2 measures of A with 1 measure of B.

D. Another yellow discharge, containing no insoluble ingredient, consisted of:—

Tin crystals	19 ozs.
Oxalate of ammonia	29 ,,
British gum, No. 4	$3\frac{1}{2}$ lbs.
Water	2 quarts,
Quercitron bark liquor of 12° Tw.	2 ,,

E. Green discharges for black merinos:—

First make a mixture of

Fustic liquor of 8° Tw.	3 quarts
and Persian berry liquor of 7° Tw.	1 quart

Mix 1 pint of this 'yellow liquor' with

Pipe-clay	3 lbs.
Extract of indigo	1 'gill.' (Mercer's)
and Tin crystals	6 ozs.

To this add

Ground gum	$4\frac{1}{2}$ lbs.,

and also, by degrees, 3 pints of 'yellow liquor,' in which have been previously dissolved

Oxalic acid	6 ozs.

Heat the mixture, and then add, previously dissolved in 4 pints of 'yellow liquor,'

Tin crystals	12 ozs.
Oxalate of ammonia	18 ,,

F. Another shade of green:—

Mix	Pipe-clay	3 lbs.
and	Extract of indigo	1 'gill'
with	Water	1 pint ;
add	Ground gum	$4\frac{1}{2}$ lbs.

and	Oxalic acid	4 ozs.
previously dissolved in		
	Water	1 pint.
Lastly add	Tin crystals	15 ozs.
and	Oxalate of ammonia	20 ,,
previously dissolved in		
	Persian berry liquor of 7° Tw.	2 quarts.

G. Red discharge for black merinos :—

Cochineal liquor of 22° Tw.	3 quarts,
Oxalic acid	9 ozs.
Oxalate of ammonia	7 ,,
Tin crystals	18 ,,
British gum, No. 4	$2\frac{3}{4}$ lbs.

Heat, and afterwards, when cold, add

Cochineal liquor of 22°	1 quart.

H. Another standard red discharge :—

Oxalic cochineal liquor of 22° Tw.	7 pints,
Tin crystals	20 ozs.
Gum	$4\frac{1}{2}$ lbs.
Oxalic acid	9 ozs.
Oxalate of ammonia	8 ,,
Pipe-clay	2 lbs.
Water	1 pint.

Mix together the pipe-clay, tin crystals and 1 pint of water ; when well mixed add half of the gum ; then 1 pint of the cochineal liquor and the remainder of the gum ; next a solution of the oxalic acid and oxalate of ammonia in 3 pints of the cochineal liquor, and, lastly, the remainder of the liquor.

To make a paler tint, dilute with A.

I. Gum crimson for black merinos :—

'Crimson liquor' (from cochineal, described elsewhere in this Appendix)	1 gallon,
Oxalate of ammonia	16 ozs.
Oxalic acid	8 ,,
Gum	4 lbs.
Tin crystals	21 ozs.

For pale crimson, take 1 measure of I with 5 of A.

K. Standard blue discharge for merinos :—

Dissolve	Oxalic acid	4 ozs.
and	Oxalate of ammonia	4 ,,
in	Water	3 pints.

Mix this solution with

	Pipe-clay	6 lbs.
	Extract of indigo	3 gills.
Then add	Tin crystals	42 ozs.
Dissolve	Oxalate of ammonia	28 ,,
and	Oxalic acid	12 ,,
in	Gum liquor of 40° Tw.	5½ quarts,
and	Water	1 pint.

Mix with the above, and add lastly,

Gum liquor of 20° Tw.	2 quarts.

L. Olive brown discharge for merinos :—

Mix together

Cochineal precipitate (described elsewhere)	1 quart,
Ground gum	2½ lbs.
Standard yellow discharge B	1 quart.

Dissolve	Oxalic acid	4 ozs.
and	Oxalate of ammonia	8 ,,
in	Water	1 quart.

Add half of the latter to the colour mixture. Put into an empty pan Tin crystals 10 ozs., add to it all the colour mixture by degrees, and lastly the remaining portion of the oxalic liquor.

Among the mixtures of the preceding discharges, used at Oakenshaw, the following may be noticed :—

Dark brown :—1 measure of G, 2 measures of E, and 2 measures of C.

Pale brown :—2 measures of the preceding, 1 measure of C, and 1 measure of A.

A good pale drab :—1 measure of C, 1 measure of H, 6 measures of K, and 40 measures of A.

Strong scarlet :—1 measure of B, 3 measures of H, and 4 measures of G.

Orange :—1 measure of G, 1 measure of H, and 14 measures of C.

Primrose :—1 measure of B, and 16 measures of A.

Drab :—4 measures of preceding primrose, 1 measure of H, 4 measures of K, and 4 of A.

Orange :—1 measure of G, with 4 measures of C.

Pale orange :—1 measure of the preceding with 4 of A.

Buff :—1 measure of H, 1 measure of C, with 14 measures of A.

A good weak scarlet for solids :—1 measure of H with 1 measure of C.

Purple :—1 measure of I, 3 to 5 measures of K, and 5 measures of A.

Deep purple :—1 measure of H with 1 measure of K.

Salmon or orange to go between red and yellow in rainbow work :—1 measure of H with 1 measure of C.

Orange in regular use :—1 measure of G with 4 measures of C.

A 'protecting paste' used in conjunction with the preceding discharges was made by dissolving

Binarseniate of soda	12 ozs.
Alkaline arseniate of soda	12 „
In water sufficient to make	5 'gills,'
And thickening, when dissolved, with	
Finely ground British gum	1½ lb.

§ X. REMARKS ON THE IMPORTANCE OF ATTENDING TO TEMPERATURE IN DYEING OPERATIONS.

In 1829 Mercer made some interesting observations respecting the importance of attending to temperature in dyeing operations, which ought to be recorded. In making experiments to ascertain the best tin solutions for mordants for logwood, peachwood, and other colours, he observed that if cotton cloth, mordanted with a persalt of tin, is 'done off'[1] cold, it dyes far better than if 'done off' hot. This influence of the higher temperature is not nearly so great with a mixture of protoxide and peroxide as with the latter by itself; hence he preferred generally for such purposes a mixture made by dissolving one

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[1] By 'doing off' is meant the removal of the loosely attached mordant by means of a bath containing bran, size, or other similar materials previous to dyeing.

pound of metallic tin in one gallon of perchloride of 100° Tw. He found that the solution best adapted for dyeing was the worst for 'preparing,' or even printing, if steam colours are to follow. He was led to draw the following conclusions:—

For 'preparing,' for steam colours, use perchloride made alkaline;[1] dry the cloth hard; then pass it through boiling solution of sal-ammoniac; or through cold sal-ammoniac liquor, and afterwards through boiling water. The oxide of tin aggregates so as not to take the colour.

For dyeing, the cloth should be printed with liquor made by dissolving one pound of tin in one gallon of perchloride, thickened with gum tragacanth, starch, or British gum, according to the colour; 'done off' under 100° Fahr. (not passed through hot water), and then dyed cool. If too hot before contact with the colouring matter, the oxide of tin becomes too much aggregated to take the colour properly. After dyeing it may be boiled.

For padding for dyeing, use liquor made with one pound of tin to one gallon of perchloride of 100° Tw., to which add caustic potash until the precipitate is just redissolved, and then sulphate of zinc. The oxide of zinc prevents the oxide of tin from assuming the aggregate form.

'A great change seems to take place in the condition of the oxides merely by heat; and when

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[1] This was, of course, previous to his introduction of the stannate made in the dry way.

in this changed state they can never properly combine with colouring matters, so as to produce good shades. There are means, however, of restoring the colour-absorbing powers of such oxides. Thus, if cloth with iron-buff is boiled in water, it takes only a very pale blue when dyed with prussiate of potash and acetic acid; but if previously passed through very dilute hydrochloric acid, it dyes a fine full blue. Again, in producing drabs, olive, &c. if the cloths are done off hot, or boiled afterwards, they give poor colours when dyed; but if such cloth, after being boiled, is spotted with a weak acid before dyeing, the spots take twice as much colour as the other parts. Probably, an advantage of the addition of sumac in dyeing with madder and logwood proceeds from its disintegrating power on the oxides or earth. Again, if cloth with red liquor is dunged or done off hot, it never gives a good yellow. It is probable that a great cause of bad purples and pale reds is from making use of too high a temperature.

'Of the same character is the action of heat on lemon chromate of lead, which thereby becomes bright yellow, and much more durable; but after this change it cannot be so easily converted to chrome-orange by caustic alkali.'

Experiments which he made on the same subject some years afterwards led him to conclude that by the addition of 'farina preparation' (page 93) this aggregation of the mordants by heat may be prevented. He found that if cotton printed with red liquor thickened with British gum is steamed, 'done off' at a moderate heat, and dyed in garancin at 180° Fahr., it takes the colour very badly, owing to the aggregation of the alumina during steaming. Similar cloth aged without steaming dyed very well indeed. But if 'farina preparation' is added to the red liquor mordant it may be steamed twice, if necessary, without the colour-absorbing power of the mordant being at all impaired. The addition of farina preparation to iron liquors was found to give corresponding results.

§ XI. DUNG-SUBSTITUTE PATENT.

Specification of patent for '*Certain improved processes to be used in the printing, dyeing, or colouring of cotton, woollen, silk, or other cloths and yarns,*' granted to John Mercer, John Dyneley Prince, and William Blyth, Aug. 1, 1839.

'In the first process, which is applicable to silk or cotton goods, we use a substitute for what is commonly called dunging. The pieces, after being printed with different strengths of what is commonly called iron liquor, or pyrolignite of iron, and different strengths of what is commonly called red liquor, or sulpho-acetate of alumina, each thickened with flour, starch, or some kind of gum in the usual way, are aged or exposed to the air as usual for a few days, less or more according to the kind of mordants they are printed with, or the condition or state of the atmosphere. When they have been properly aged, we put six gallons of phosphate of soda liquor (prepared from bones), each imperial gallon weighing 10½ lbs., into a cistern containing 600 gallons of water, and furnished with a series of rollers in the usual way; and having the liquor nearly boiling, the pieces are passed through at such a speed that every part of each piece may be in thirty seconds, and the pieces to go through at the rate of thirty yards in a minute. We then wash the pieces and rinse them in a separate vessel from fifteen to thirty minutes, charged with 300 gallons of water, one gallon of phosphate of soda liquor weighing 10½ lbs., and two quarts of size from bones weighing eleven pounds the imperial gallon, and kept nearly boiling. When the superficial mordant and starch, or other thickening, is removed, the pieces are washed and are then ready for dyeing. We renew the first, or 600 gallon cistern, with one gallon of phosphate of soda liquor to every fifty pieces; and the second, or 300 gallon cistern, with one quart of phosphate liquor and one pint of size for every fifty pieces; and in this way we go on renewing until we have done from fifteen hundred to three thousand pieces of light work, or one thousand pieces of heavy work before we empty the cisterns and set them afresh.'

§ XII. OBSERVATIONS ON PREPARING DELAINES.[1]

1. 'It is difficult to charge woollen goods with tin without the application of heat.

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[1] Referred to page 89.

2. 'By running the cloth through stannate of soda there is not much tin fixed in the wool, although quite sufficient for the cotton.

3. 'Chlorine prepares wool for receiving colours, but if there is no tin with the colour the shades are dull and heavy, although sufficiently deep.

4. 'If the delaine is padded in strong solution of protochloride of tin, with a large excess of muriatic or sulphuric acid, both the wool and the cotton become charged with tin. Chemicking then changes the protoxide of tin to peroxide, and also effects the necessary modification of the wool by oxidation.

5. 'By heating the delaine in solution of bisulphate of potash before padding in the sulpho-muriate, the absorbing power of the wool for tin is much increased. The cloth must then be chemicked.

6. 'Or, if the delaine is heated in a mixture of perchloride of tin with as much oxalic acid as is necessary to form a binoxalate, the wool also becomes sufficiently charged with peroxide of tin. The cloth should next be padded in stannate of soda and afterwards soured and chemicked. No doubt peroxalate of tin (made by oxidising the protoxalate by chlorate of potash with addition of more oxalic acid, at a very moderate heat)[1] might be advantageously used instead of the perchloride and oxalic acid.

7. 'I believe that if the wool of the delaine is

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[1] Another method practised by Mercer for preparing oxalate of peroxide of tin will be found elsewhere in this Appendix.

well charged with tin by the peroxalate, then padded with stannate and well soured, only a little chemicking will suffice to produce good work.

8. 'But if the sulpho-muriate of tin has to be used, more chemicking is necessary, this being requisite for peroxidising the tin as well as for modifying the woollen fibre.'—J. M.

In a subsequent memorandum he observes :—

'If the delaines are padded in stannate of soda, soured, and then chemicked, they receive colours (or wet) very fairly; but I have found that they receive such colours (or wet) far better if a considerable quantity of free acetic acid is added to the colour mixtures.'

§ XIII. PRINTING MIXTURES MADE WITH COLOUR PRECIPITATES OR LAKES.

The precipitates referred to are those, the preparation of which is described page 90, *et seq.*—

Black, for machine work :—

Logwood precipitate	4 gallons
Oxalate of ammonia	1 lb.
White British gum	4 lbs.

Brown.—Brazil wood precipitate	1 quart
Quercitron bark precipitate	3 quarts
Oxalic acid	6 ozs.
Caustic ammonia	12 'spoons'
Starch	10 ozs.
British gum, No. 2	10 ,,

Chocolate.—Brazil wood precipitate	8 quarts
Logwood precipitate	2 „
Quercitron bark precipitate	2 „
Oxalic acid	19 ozs.

Heat to 130°, then neutralise with ammonia; when dissolved, filter through calico and thicken with

Starch	1½ lb.
and British gum	1½ „

Purple.—Logwood precipitate	1 gallon
Oxalate of ammonia	10 ozs.
Oxalic acid	2 „
Gum liquor of 40°	1 gallon

Amaranth.—Brazil wood precipitate	3 gallons
Logwood precipitate	3 'gills'
Oxalic acid	19 ozs.

Heat to 130°, neutralise with ammonia, and thicken, if for block rainbow work, with

Ground gum	11 to 12 lbs.

or if for 'blocking,' with 1½ lb. of starch, and 1½ lb. of British gum, No. 2.

§ XIV. SPECIFICATION OF PATENT GRANTED TO JOHN MERCER AND JOHN BARNES IN 1842, FOR ASSISTANT MORDANT LIQUOR,

'which when combined with ordinary mordants renders them more effective and useful' (page 93).

'To 100 lbs. of potato starch we add 37½ gallons of water, 12½ gallons of nitric acid of commerce, of 1·300 sp. gr., and 4 ounces of oxide of manganese.

The chemical action which takes place among these ingredients is allowed to proceed until the nitric acid is destroyed. To the residuum thus produced we add 50 gallons of pyroligneous acid, and the compound is the assistant mordant liquor in a fit state to add to the various mordants used in printing and dyeing. The proportion in which the assistant mordant liquor must be added to produce the various improved mordants will vary according to the chemical properties and nature of the mordant to which it is applied, but according to our present experience we have found the following proportions to produce a greatly improved article (either thickened or not, according to the mode in which it is to be applied). We take

	Iron liquor (pyrolignite of iron).	Assistant mordant liquor.	Water.
For black	1 gallon	1 gallon	1 gallon
For purple	1 ,,	2 gallons	6 gallons
Paler	1 ,,	3 ,,	12 ,,
Still paler	1 ,,	4 ,,	20 to 30 ,,

'These improved articles or mordants are applied in the usual way.' A similar course is recommended for aluminous mordants and tin. 'For dyeing silk or woollen we add the assistant mordant liquor along with the tin, iron, or aluminous mordant, either with or without colouring matter, in the same boiler; but this and other practical arrangements must depend on the judgment of the operator.'

'Our aim is to carry on the decomposition as far as possible without forming oxalic acid, and as little as possible of carbonic acid, in the process. This is greatly aided by the manganese, which, by its catalytic action prevents the formation of oxalic acid. Although we have found potato starch to answer well in the process, we are aware that all starchy, saccharine, or gummy substances will answer the same purpose; indeed, all such like substances may be used as contain little nitrogen, and where the oxygen and hydrogen are, or are nearly, in the proportion to form water.'

§ XV. SPECIFICATION OF PATENT FOR STANNATE AND STANNITE OF SODA GRANTED TO MERCER, GREENWOOD, AND BARNES, 1845.

'To make stannate of soda we take 22 lbs. of caustic soda liquor (one gallon weighing 13½ lbs., or 1·350 sp. gr.), and put it in an iron crucible heated to low redness by a fire underneath. When evaporation has proceeded so far that watery vapour ceases to be evolved, we then add 8 lbs. of nitrate of soda and 4 lbs. of chloride of sodium. When the mixture is at or near the fluxing heat, we add 10 lbs. of feathered block tin, and mix the materials well together with an iron stirrer; the mass becomes dark coloured and pasty, and ammonia is given off, the tin decomposing both the water of the hydrate of soda and part of the nitrate of soda. The stirring is continued as well as the heat under the crucible, until ignition or deflagration takes place, when the whole mass becomes red or white hot, and of a pasty consistence: it is then stannate of soda. We then take it out of the crucible, and when cold grind it into powder: it is then ready to be packed for delivery to the printer and dyer. But if it is required in a more pure state, we merely dissolve the dry stannate of soda in water, allow any impurity it may contain to settle, and evaporate the clear liquor down to crystallisation in an iron boiler; as the crystals form at the bottom of the pan we take them out and dry them on hot iron plates, or we evaporate all down to a pasty state, not quite dry, but so dry as not to let any liquid run from it.'

'Should stannite be required in the place of stannate, then we take 4 lbs. of chloride of sodium, 1 gallon of caustic soda liquor, weighing 13½ lbs., 1 lb. of nitrate of soda, and 4 lbs. of feathered block tin; we put all these at once into a hot iron crucible, over a fire, and stir and boil to dryness, and continue stirring the dry powder as long as any ammonia is given off. When the ammonia is no longer disengaged we consider the process finished and remove the contents from the crucible. This is what we call stannite of soda, which differs from stannate, inasmuch as the tin in the former is combined with only half as much oxygen as in the latter.'

'In order to obtain tin preparing liquor we take the stannate of soda and dissolve it in boiling water, about 3 lbs. to 1 gallon, and add that to 3, 4, or 5 gallons of cold water to form the strength required for the different styles of work according to the discretion of the printer. We make a solution of stannite of soda in a similar manner.'

A few years later a patent was granted to Messrs. Mercer and Blyth for the preparation of a mixture or combination of arseniate or phosphate of soda with stannate of soda, which for some purposes appears to possess advantages over the simple stannate. These compounds are known as the arsenio-stannate and phospho-stannate of soda. The patent process for making the former, which is the most important, consists in dissolving in 1 gallon of stannate of soda liquor of about 50° Tw., $1\frac{1}{2}$ lb. of arseniate of soda (made by fluxing together equal weights of arsenious acid and nitrate of soda) and evaporating the liquor in an iron pot until it forms a firm solid on cooling, when it is transferred to a suitable iron receptacle. The solution of this material was used in dyeing and printing cottons and delaines in the same way as that of the common stannate.

So far back as 1828 Mercer had used a somewhat similar compound, prepared by adding arseniate of potash to perchloride of tin, and then adding excess of carbonate of potash. The precipitate at first produced is redissolved by the alkaline carbonate, forming a perfectly clear liquor, which stands any degree of dilution without becoming turbid. He considered the best proportions for dyeing to be one equivalent of arseniate to two equivalents of tin. Acetic acid precipitates the whole of the peroxide of tin. Either that acid or sulphate of zinc was used for 'fixing.'

§ XVI. LETTER TO DR. PLAYFAIR DESCRIBING EXPERIMENTS ON BLEACHING-POWDER.

In answer to a letter of inquiry from Dr. Playfair relating to his experiments on bleaching-powder, Mercer wrote (Nov. 11, 1841): . . . 'I have been repeating my old experiments on solutions of chloride of lime and nitrate of copper. I used a solution of nitrate of copper of sp. gr. 12·5° Tw., or one equivalent[1] per gallon. This I prepared by mixing a solution of 16 ounces of crystallised sulphate of copper with a solution of 20 ounces of nitrate of lead; the liquor, with washings of the precipitated sulphate of lead, being made into one imperial gallon. This liquor stood at 12·5° Tw. The acetate of lead is not quite equivalent to the copper, but the presence of a little sulphate does not affect the result. I then took a solution of chloride of lime of 13° Tw., ascertained its proportion of available chlorine by yellow prussiate of potash, and diluted it so that one gallon oxidised 53¼ ounces of yellow prussiate; or one gallon contained one equivalent (4·5 ounces) of available chlorine. Its specific gravity was 10·5° Tw. In respect of available chlorine and salt of copper, the two solutions are therefore equivalent. The muriate of lime, of which common bleaching powder always contains more or less, may be disregarded. Now, on

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[1] That is, the number of ounces of the atomic weight, taking oxygen as 1·0.

the old theory, or Millon's, all the lime (with the exception of a little free lime, and muriate from imperfect manufacture) is united with chlorine thus, CaO, Cl. If so, the decomposition by nitrate of copper, added by successive portions, ought to give similar results throughout from first to last, until equal volumes of the two liquids have been mixed. But if Balard's views are correct, namely, that the lime is divided equally between hydrochloric acid and hypochlorous acid, or $CaCl + CaO, ClO$, then a difference ought to be perceptible on the addition of the first and second equal portions of the nitrate of copper. Well, I took a gill (10 ounce measure) of the above chloride of lime solution, diluted it with 3 measures of water, added 10 or 12 drops of nitrate of copper solution for the free lime, and then added gradually half a gill (5 ounce measure) of the nitrate of copper. Oxide of copper was precipitated of a greenish colour, but on the addition of more nitrate of copper there was no further precipitate; all the additional copper remained in solution. This shows that the hypochlorite of lime is decomposed by the nitrate of copper; oxide of copper is precipitated, because hypochlorous acid does not retain it in solution. The liquid acquires only a feeble odour, which is not that of free chlorine.

'Decomposition of the free hypochlorous acid, with disengagement of oxygen gas, soon takes place, through the catalytic influence of the precipitated oxide of copper; but on testing the clear liquid I found that it retained five-sixths of the bleaching property of the original liquor. By adding excess of nitrate of copper, the catalytic decomposition is retarded, and the top liquor acquires a fine pale purple colour. But if there is no copper in solution, and lime is added to combine with the hypochlorous acid, and also a slight excess, the catalytic decomposition proceeds vigorously, and the green coppery precipitate becomes black or dark brown. The green precipitate, after being washed on a filter, was not altered by hot water, nor by a mixture of lime and cold water, but it immediately became black when mixed with hypochlorous acid and lime. I believe the green precipitate contains very little chlorine or hypochlorous acid. When mixed with dilute sulphuric acid, it acts very feebly on indigo-dyed cotton. There is a little disengagement of gas and smell of chlorine. But the dark brown copper compound contains no chlorine in any state. It contains more oxygen than the black oxide. When it is dropped into dilute sulphuric acid, a strong effervescence takes place of oxygen gas: this mixture does not bleach indigo-dyed cotton. But when dropped into dilute muriatic acid, it disengages chlorine and bleaches indigo, after first showing the peculiar buff colour. Ammonia dissolves this copper compound partially; what remains undissolved is rather lighter in colour; it is probably an amide of some sort.

'The following is a very striking experiment. Mix four ounces of bleaching powder well with water in a mortar; then add three or four "gills" of warm water and half a "spoon" of nitrate of copper solution (12·5° Tw.). The mixture assumes a beautiful purple colour, and pure oxygen gas comes off in abundance. With a little more copper the action is still more rapid. This action must be what is called "catalytic." It may be started by even a few drops of nitrate of copper solution, or by a few grains of black oxide of copper, or copper turnings when oxidised.

'I have other reasons for adopting Balard's theory besides what I have described.

'If we add to bleaching-liquor just enough nitrate of copper, or nitrate of alumina, or some acid, to unite with the lime of the hypochlorite, so as to set free hypochlorous acid without any free muriatic acid, could we not obtain hypochlorous acid from such a mixture by distillation?'

§ XVII. ON BASIC CHLORIDES OF ALUMINUM.

To obtain basic chlorides of aluminum, Mercer began by preparing normal chloride, free from sulphate, by decomposing solution of potash alum with chloride of barium. From two measures of the chloride liquor he precipitated all the alumina by carbonate of ammonia; and after washing the precipitate dissolved it in one measure of the chloride liquor. This solution (A) therefore contained one-third the normal proportion of acid.

To a portion of A he added ammonia (as carbonate) sufficient to combine with one-half the acid of the chloride; and obtained a perfectly transparent solution, containing, therefore, one-sixth the proportion of acid in normal aluminous salts (B).

To another portion of A he added ammonia (as carbonate) equivalent to two-thirds the acid present as chloride. The precipitate was completely redissolved. The proportion of acid to base was therefore one-ninth that of the normal salts (C).

Each of these solutions retained its transparency when heated, even after dilution with pure water. Their most remarkable property observed by Mercer consisted in affording a white flocculent precipitate on the addition of a solution of a sulphate, even in very minute quantity, whether the liquid were hot or cold. No change appeared on adding nitrate of potash.

Neither potato starch nor British gum formed any precipitate or muddiness in A, B, or C, whether hot or cold, strong or weak; but gum-water produced flakes in each of the solutions.

A solution of isinglass produced no apparent change in A. In B it produced a muddy and curdy appearance, which disappeared on applying heat. In C it formed a strong white solid clot, which was not dissolved by heating.

Oxalate of soda produced in each of these solutions a very white precipitate, which was not redissolved by heating, nor by large dilution with water.

When added to weak Brazil-wood liquor, neither A, B, nor C produced a precipitate. When the mixture of Brazil-wood liquor with A was spotted on calico, the colour ran very nearly as far as the liquid, but with B and C the colour was absorbed by the cloth, not running far, and giving a well-defined edge.

§ XVIII. SPECIFICATION OF PATENT GRANTED TO JOHN MERCER AND JOHN GREENWOOD FOR 'CERTAIN IMPROVEMENTS IN DYEING AND PRINTING TURKEY RED AND OTHER COLOURS.' 1846.

'Our invention relates, first, to preparing oil for, and applying the same to, fabrics in the process of dyeing and printing Turkey red. Secondly, our invention relates to improvements in applying oil to goods or fabrics which are to be afterwards oxidised. Thirdly, our invention relates to improvements in the means used in oxidising goods or fabrics which have been oiled for the processes of dyeing or printing Turkey red; and such means of oxidising fabrics are applicable in the processes of dyeing and printing other colours when a process of oxidising is required. Fourthly, our invention relates to the preparation of an oil mixture to be used with blocks or machines, as hereinafter described. And, fifthly, our invention relates to the use of a preparation of silica in dyeing and printing, as hereinafter described.

'Heretofore, when dyeing and printing Turkey red, it has been usual to prepare the fabrics or goods with oil, and the goods or fabrics have been then subjected to alkali and then oxidised; and, in other cases, the oil has been combined with alkali and then applied to the goods or fabrics, and the same have then been oxidised; all which processes are well known, and therefore do not require to be further noticed in this our specification. The first part of our invention, as above stated, relates to preparing oil for, and applying the same to, goods or fabrics in dyeing or printing Turkey red. The oil we prefer to use in carrying out the first part of our invention is olive oil, though other vegetable oils produce (when treated according to our invention) a similar effect; but their use is not, so far as we are informed on the subject, so useful as olive oil.

'The first part of our invention consists in preparing what we call *sulphated oil*, and applying the same to the processes herein mentioned. For this purpose we take at the rate of one part by measure of sulphuric acid of commerce for every eight measures of olive oil; we mix the same and stir them frequently during ten days; we then add three or four gallons of water, stir the mixture well, adding three or four pounds of common salt, and then allow the whole to stand; the oil will separate and may be drawn off clear: this for convenience of description we will call *sulphated oil A*. For each gallon of this oil we take nine gallons of solution of hypochlorite of soda, which we prepare in the following manner.

We take sixteen pounds of crystallised carbonate of soda of commerce, dissolved in two quarts of water, and ten gallons of chloride of lime (bleaching-powder) liquor at 12° Twad.; we mix these materials well together, and after allowing the same to stand, we draw off the clear liquor, which we employ as above mentioned. We heat the mixture of sulphated oil A and chloride of soda by any convenient means, preferring a pipe heated by steam, and boil the mixture until the same ceases to bleach a piece of cotton dyed of a pale blue colour by indigo; or in place of applying heat, we use a diluted acid (preferring sulphuric, diluted in the proportion of one measure of concentrated acid to twenty-four measures of water), and we add and stir in the diluted acid, in portions, at intervals, allowing time to prevent as much as possible the escape of free chlorine; and when the mixture no longer bleaches a piece of cotton dyed light blue by indigo, the process will be complete. Or we treat the sulphated oil A with atmospheric air and steam, for which purpose we mix at the rate of one gallon of the oil with one gallon of water, and force streams of heated atmospheric air through a suitably perforated pipe or other suitable apparatus, such as are well understood and have before been used when applying streams of heated air or steam to fluids for other purposes. We prefer that the air should be heated to 220° Fahr., and keep up the process for ten days. We find that the process is quickened by adding one gallon of cow-dung water and one gallon of bran water made with two pounds of bran; or instead thereof one-eighth of a gallon of linseed oil; or we use eight ounces of sulphate of copper and eight ounces of common salt. When using cold atmospheric air we employ steam by a perforated tube, so that the agitation of the surface favours the action of the atmosphere on the oil; but this process of oxidation is slow when compared with forcing heated air through the oil; or when compared with alternately causing streams of steam and cold air alternately to pass through the oil. The oil, instead of being first sulphated as above explained, may be treated in the same manner, and we find it desirable to prepare both sulphated oil, and oil without that process, as above explained, and we use them as hereinafter described. The first we call *sulphated oxidised oil*, and the other we call *oxidised oil*.

'Another mode of manufacturing sulphated oxidised oil, according to our invention, is as follows. We mix at the rate of one part by measure of strong sulphuric acid with eight measures of olive oil, and stir the mixture often during twenty-four hours; to this mixture we add at intervals twenty ounces of chlorate of potash dissolved in two quarts of boiling water, to each gallon of oil, and stir until the action ceases; we then wash away the acids and salts by water by stirring in two gallons of water for each gallon of oil, then allow them to stand, and draw off the water; and repeat the washing in the same manner with two more gallons of water. Or (instead of the chlorate of potash above mentioned) we employ forty ounces of bichromate of potash dissolved in five pints of water, and proceed in the same manner as before described; or in place of the above we employ forty ounces of nitrate of soda or of potash in the state of powder, and one pint of water, and proceed in the manner above described. By either of the above processes we obtain a preparation of *sulphated oxidised oil*, and having prepared the oils as above explained, they are to be used when dyeing and printing Turkey red; for which purpose we take two quarts of either of the sulphated oxidised oils above described, and two quarts of oxidised oil, and to these we add twelve gallons of pearlash liquor of 2° Twad. The goods or fabrics are to be impregnated with this oil liquor four times, and dried after each time in a hot flue or stove; the goods or fabrics are then to be impregnated twice with pearlash liquor of 6° Twad., and dried in a hot stove or flue after each time of impregnating; then finishing at the temperature of 180° Fahr. for upwards of three hours; the goods or fabrics are then to be rinsed in pearlash liquor of 1° Twad., then washed and afterwards dried at about 140° Fahr.; the goods are then ready for the usual mordants and after processes as well understood.

'We will now proceed to describe the second part of our invention, which relates to improvements in applying oil to goods or fabrics, to be afterwards oxidised for the processes of dyeing and printing

Turkey red. We take at the rate of one pint of either carbonate or caustic potash or soda liquor at 70° Twad.; we prefer the carbonate and caustic in equal parts; we heat the same until watery vapours cease to be evolved; to this we add two gallons of olive oil and heat the mixture to about 300° Fahr., and keep the same so heated until the oil has dissolved all the alkali and the watery vapours and carbonic acid have been driven off, as will be indicated by the subsidence of all froth on the surface, and the mixture becoming clear. The mixture is then allowed to cool below 212° Fahr., and we then mix therewith two gallons of water. We would here remark that we find that time may be saved in the above process by removing the scum in the early part of the process, and returning it towards the end of the process. This preparation of oil is to be applied to goods or fabrics, and may be oxidised in the ordinary manner, as is well understood, but we prefer the oxidising process to be carried on according to either of the processes hereafter described. When we wish to employ this preparation of oil for printing, then we use a calico printer's padding pin slash or other engraved cylinder, and dry the goods in the way usually practised by calico printers. The goods are then to be impregnated with pearlash liquor of 6° Twad. three or four times, drying after each time in a hot stove or flue. They are then to be oxidised, which we prefer doing by either of the two processes hereafter described. The goods are then to be impregnated with pearlash liquor of 6° Twad., and dried in a hot stove or flue, finishing at a temperature at or above 180° Fahr. for three hours; then rinse the goods in pearlash liquor of 1° Twad., wash them in water, and dry them at about 140° Fahr., when the goods will be ready for the usual mordants and after processes. When this oil is to be applied to impregnate goods or fabrics in substitution of the old oiling process, we take two gallons of this oil mixture and mix therewith ten gallons of pearlash liquor of 1° Twad., and impregnate the goods with this liquor three or four times, drying after each time in a hot stove or flue. The goods are then to be oxidised, which we prefer to be done by either of the processes hereafter described, after which the further processes are to be pursued, as just described. Or we employ the sulphated oil A, and mix one gallon of the same with nine gallons of pearlash liquor of 2° Twad., and impregnate the goods therewith three or four times, drying after each time in a hot stove or flue, and proceed precisely as last above described; but we prefer to combine the sulphated oil A and the prepared oil above described in equal quantities.

'We will now proceed to describe the third part of our invention, which relates to a mode of oxidising goods or fabrics which have been oiled according to the means heretofore practised, or when prepared with oil according to the means described in the second part of our invention. One mode of oxidising consists in the use of an oxidising chamber, which, we believe, may be best built of stone. We hang or suspend the goods in a chamber which can be closed, and into this chamber we cause an oxidising vapour to pervade, and for which purpose we take one gallon of solution of chloride of lime of 9° Twad. for every pint of oil in the goods, and to this solution for each gallon we add five ounces of muriate of ammonia dissolved in a pint of boiling water; we place these matters in a suitable vessel with a suitable pipe into the chamber; we close the vessel and heat it to 150° Fahr.; the vapours will flow into the chamber and oxidise the goods. We have found that the vapour of water aids in this process, for which reason we have the floor of the chamber wet; or we admit steam into the chamber, taking care that the goods are not rendered wet thereby. This process of oxidising will be found to take about six hours.

'Another mode of oxidising goods according to this part of our invention is to use atmospheric air and steam, either together or forced into contact with the goods alternately. This may be performed in a chamber such as above described, allowing a vent for the egress of the air and steam; or what we prefer is to employ perforated cylinders or rollers, such as those used by calico printers, and the goods (eight or ten pieces thereof) are to be wound round such rollers or cylinders; then by a fan or other blowing apparatus we cause air to pass into a suitable heating apparatus, so as to heat the same to 160° to

200° Fahr., as is well understood, and then into the interior of such rollers or cylinders in such manner as to pass through the goods thereon; we keep up such flow of heated air for ten minutes, then apply steam to the interior of the rollers or cylinder for ten minutes, then heated air, and so on for two hours. The goods oxidised by either of these two methods are then to be impregnated with pearlash liquor of 6° Twad. as before explained. We would remark in respect to this part of our invention that besides oxidising goods which have been treated with oil for dyeing and printing Turkey red, the means herein described may be applied for oxidising fabrics in the processes of dyeing and printing other colours in those cases when the process of oxidising is necessary, such as steam colours in cotton and silk printing.

'We will now proceed to describe the fourth part of our invention, which relates to a preparation of oil for printing fabrics with blocks or machines. For this purpose we take one gallon of the sulphated oil A (or equal parts of such sulphated oil A and either of the oxidised oils above described), and we take two gallons of calico printer's red liquor at 18° Twad. and one quart of pearlash liquor at 64° Twad.; we mix one-half of the pearlash liquor with the red liquor, and then mix as much of this red liquor with the oil as it will take; when it will not take more we add the remainder of the pearlash liquor to the mixture; then the remaining red liquor by portions at a time; and when it will not take more we add one quart of oil of turpentine. This mixture will be of a nice consistency for printing, and we use it with blocks or machines; hang the goods in a warm room two or three days, then dung off in a mixture of dung and sumac, valonia or quercitron bark at 180° Fahr., as is well understood; the goods are then to be washed and dyed with quercitron bark, then exposed on the bleach fields three or four days; the fabrics are then to be dried at about 100° Fahr., and afterwards dyed with madder and quercitron bark; the fabrics are then to be cleaned after the manner of Turkey red, except that we use no alkali with the soap; we then brighten in a mixture of soap and tin material in the usual manner.

'We will now describe the fifth part of our invention. We take silicate of potash or soda, made by fluxing together three pounds of pearlash and two pounds of silica or powdered flint, and make a solution in water in the usual way. We take one gallon of solution of such silicate of potash at 12° Twad., and add to it half a pint of sulphuric acid of 68° Twad. and one and a half pint of acetic acid of 8° or 9° Twad.; this forms a clear solution, and will keep six or eight days without becoming gelatinous. We apply such silicate by impregnating the goods or fabrics therewith and dry them; then run the goods or fabrics through a solution of muriate of ammonia containing from three to four ounces of that substance in each gallon of water, and then wash in water; the goods when dried are ready for the mordant. Or the goods or fabrics are impregnated with the solution of silica and hung up for a day, after which they are ready for the mordant, or steam colours.'

§ XIX. SPECIFICATION OF ANOTHER PATENT GRANTED TO MERCER AND GREENWOOD IN 1852 FOR IMPROVEMENTS IN THE OILING PROCESS IN TURKEY RED DYEING.

'We take cotton cloth or other fabric in the usual partially bleached state, and wet it with water or with a watery solution of carbonate of potash or soda containing four to five ounces per gallon. We prefer wetting the cloth or fabric by the padding machine, and whilst in this wet state we pass it through olive oil at a heat below that of boiling water, preferring from 140° to 160° Fahr. The oil is contained in a cistern having a series of rollers, and at the end a pair of padding bowls; the wet cloth is made to pass through the oil and under and over the rollers immersed therein, then through the padding bowls. The cloth or fabric is then taken to the stove and dried at 160° to 180° Fahr.; afterwards it is alternately acted on with dilute solution of carbonated alkalies and stoved in the usual well-known manner. Or in place of using the oil at a temperature below that of boiling water, it may be heated above that degree, in which case we prefer to raise it to a temperature from 240° to 300° Fahr., and proceed in all other respects as above described. We prefer olive oil in which have been dissolved six to eight ounces of carbonate of potash or soda to the gallon; similar to what is stated in the second part of the specification of the patent granted to us in 1846.'

§ XX. SPECIFICATION OF PATENT GRANTED TO JOHN MERCER IN 1850 FOR 'IMPROVEMENTS IN THE PREPARATION OF COTTON AND OTHER FABRICS AND FIBROUS MATERIALS': THE MERCERISING PROCESS.

'My invention consists in subjecting vegetable fabrics and fibrous materials, cotton, flax, &c. either in the raw or manufactured state, to the action of caustic soda or caustic potash, dilute sulphuric acid or chloride of zinc, of a strength and temperature sufficient to produce the new effects and to give the new properties which I have hereinafter described.

'The mode I adopt of carrying into operation my invention to cloth made from any vegetable fibre, and bleached, is as follows. I pass the cloth through a padding machine charged with caustic soda or caustic potash of sp. gr., say, 60° to 70° Twad., at the common temperature, say, 60° Fahr. or under, and without drying the cloth wash it in water, then pass it through dilute sulphuric acid and wash again; or I run the cloth over and under a series of rollers in a cistern with caustic potash or soda of sp. gr. from 40° to 50° Twad., at the common atmospheric temperature; the last two rollers being so set as to squeeze the excess of potash or soda back into the cisterns; the cloth then passes over and under rollers placed in a series of cisterns charged at the commencement of the operation with water only, so that at the last cistern the alkali has been nearly all washed out of the cloth; when the cloth has either gone through the padding machine or through the cisterns above described, I wash the cloth in water, pass it through dilute sulphuric acid, and wash again in water.

'When I adapt the invention to grey or unbleached cloth made from vegetable fibrous material, I first boil or steep the cloth in water so as to have it thoroughly wet, and remove most of the water by the squeezer or hydro-extractor, and then pass the cloth through the soda or potash solution, &c. and proceed as before described.

'I apply my invention in the same way to warps, either bleached or unbleached, but after passing through the cistern containing the alkali the warps are either passed through squeezers or through a hole in a metallic plate to remove the alkali, and then passed through the water cisterns, soured, and washed as before described.

'When thread or hank yarn is operated on, I immerse the thread or yarn in the alkali and then wring out, as is usually done in sizing or dyeing them, and afterwards wash, sour, and wash in water as above described. When I apply my invention to any fibre in the raw state, or before it is manufactured, I first boil it in water and then free it from most of the water by the hydro-extractor or a press. I then immerse it in the alkaline solution, and then remove the alkali by the hydro-extractor, or I press the alkali out with a press and then wash in water, sour in dilute sulphuric acid, wash again, and then remove the water by a press or hydro-extractor.

'When cloth made from vegetable fibre, cotton, flax, &c. has been subjected to the action of soda or potash, as above described, by padding, immersion, or any other way, and then freed from alkali by souring and washing according to my said invention, the cloth will be found to have acquired certain new and valuable properties, the more remarkable of which I here describe. It will have shrunk in its length and breadth, or have become less in its external dimensions, but thicker and closer, so that by the chemical action of soda or potash I produce on cotton and other vegetable fabrics and fibres effects somewhat analogous to that which is produced on wool by the process of fulling or milling. It will have acquired greater strength and firmness, each fibre requiring greater force to break it. It will also have become heavier than it was before it was acted on by the alkali, if in both cases it be weighed at the temperature of 60° Fahr. or under. It will have acquired greatly augmented and improved powers of receiving colours in printing and dyeing. The effects of the application of my invention to the vegetable fibre in any of its various stages before it is manufactured into cloth will be readily understood by reference to its effects upon cloth composed of such fibres.

'Secondly, I employ sulphuric acid diluted to 105° Twad., and at 60° Fahr., or under; I use this acid instead of soda or potash, and operate in all respects the same as when I use soda or potash, except the last souring, which is here unnecessary.

'Thirdly, when I employ solution of chloride of zinc, instead of soda or potash, I use the solution of sp. gr. 145° Twad., and at 150° to 160° Fahr., and operate the same in all respects as when I use soda or potash.

'When I operate on mixed fabrics, partly of vegetable and partly of silk, wool, or other animal fibres, such as delaines or leans, &c. I prefer the strength of the alkali not to be over 40° Twad., and the heat not above 50° Fahr., lest the animal fibres should be injured.

'I may, in conclusion, remark that the construction of the apparatus or machinery, and the strength and temperature of the soda or potash, sulphuric acid, or chloride of zinc solution may be varied to a considerable extent, and will produce proportionate effects without at all deviating from my invention. For instance, caustic potash or soda may be used even as low as 20° Twad., and still give improved properties to cotton, &c. in receiving colours in printing and dyeing, particularly if the temperature be low, for the lower the temperature the more effectively the soda or potash acts on the fibrous material. I do not, therefore, confine myself to any particular strength or temperature of the substances I employ, but the particular strengths and temperatures here described are those which I have found best and prefer.'

§ XXI. ON DYEING MERCERISED CLOTH.

As the increased receptive power of the altered cloth appeared to be uniform for all kinds of materials employed in dyeing, the ordinary processes could generally be used with but little modification. We must not, however, omit some of Mercer's notes on this subject. He states that 'an excellent dark blue vat, suitable for contracted cloth, is obtained by dissolving white indigo (precipitated from the common blue vat by protochloride of tin and hydrochloric acid) in solution of caustic barytes. With the assistance of heat, the white indigo may be dissolved to a large extent in barytes liquor. Twelve seconds' immersion in that liquor suffices to give a deep blue. Any weak resist colour will be effective.'

'Indigo liquor made with red arsenic and lime also gives a very rich blue on contracted cloth. I have observed that if the cloth while yellow is rinsed in water, and then oxidised in a bath of sal-ammoniac and chloride of lime, the blue is much deeper, but not quite so bright.'

'If contracted cloth is padded with red liquor, and then printed with archil liquor, the colour is fixed as well as if prepared with oil, or by Broquet's plan.'

'Contracted cloth may be dyed a fine black by soaking it in logwood liquor of 1° Tw. for some time, then wringing, then soaking in cold iron liquor of 10° Tw. Wring, expose to the air for a little, and wash in hot water.'

'For sapan red, first steep in the liquor, then pad in weak red liquor, and steam.'

§ XXII. ON RELATIONS OF ATOMIC WEIGHTS OF ELEMENTS.

Reference has been made to a paper which Mercer contributed to the meeting of the British Association in 1858, on the grouping of elementary bodies, and on relations which exist among their atomic weights. The following are the groups, and the equivalents then generally accepted, of their several members. Since Mercer made his calculations, chemists have been led to double the equivalents of each of the members of two of these groups, namely, the oxygen and the magnesium: this change, however, does not affect the principle of the relationships which he pointed out, but only the manner of expressing it.

OXYGEN GROUP.

O . . . = 8
S . . . = 16
Se . . . = 40
Te . . . = 64

FLUORINE GROUP.

Fl . . . = 19
Cl . . . = 36
Br . . . = 81
I . . . = 126

MAGNESIUM GROUP.

Mg . . . = 12
Ca . . . = 20
Sr . . . = 44
Ba . . . = 68
Pb . . . = 104

NITROGEN GROUP.

N . . . . = 14
P . . . . = 31
As . . . . = 76
Sb . . . . = 121
Bi . . . . = 211

LITHIUM GROUP.

L . . . . = 7
Na . . . . = 23
K . . . . = 39

Assuming that these so-called elementary bodies may possess a compound character, the members of the same group are supposed to consist of two common constituents, varying in proportion in the different members.

The lithium group may be viewed thus:

$L = (4 + 3)$ or L . . . . $= 7$
$Na = (4_5 + 3)$ or $Na = 16 + 7 = 23$
$K = (4_9 + 3)$ or $K = 16_2 + 7 = 39$

The magnesium group may be viewed thus:

Mg . . . . $= 8 + 4$
Ca . . . . $= 8_2 + 4$
Sr . . . . $= 8_5 + 4$
Ba . . . . $= 8_8 + 4$
Pb . . . . $= 8_{12} + 4_2$

The nitrogen group thus:

N . . . . $= 5_2 + 2_2$
P . . . . $= 5_5 + 2_3$
As . . . . $= 5_{14} + 2_3$
Sb . . . . $= 5_{23} + 2_3$
Bi . . . . $= 5_{41} + 2_3$

The fluorine group thus:

Fl . . . . $= 15 + 2_2$
Cl . . . . $= 15_2 + 2_3$
Br . . . . $= 15_5 + 2_3$
I . . . . $= 15_8 + 2_3$

The members of the oxygen group have a very simple relationship, O being 8 (or 16 on the scale now adopted), and all others multiples of that number: $O=8$; $S=8_2$; $Se=8_5$; $Te=8_8$.

Mercer pointed out that a relation also exists between the atomic weights of members of different groups. This is seen by subtracting the weights of members of one series from those of another; the remainder is in many cases the same number.

The members of the nitrogen group deducted from the corresponding members of the fluorine group leave 5: $Fl-N=5$; $Cl-P=5$; $Br-As=5$; $I-Sb=5$.

The difference between corresponding members of the oxygen and magnesium groups is 4 (or 8 according to the equivalents now used): $Mg-O=4$; $Ca-S=4$; $Sr-Se=4$; $Ba-Te=4$.

When members of other groups are thus examined, the remainders are not identical, but show a simple relationship. Thus, with the oxygen and lithium groups we obtain

$O - Li = 1$
$S - L = 9 - 1 = 8$
$Se - Na = 17 - 9 = 8$
$Te - K = 25 - 17 = 8$

So with the lithium and magnesium groups:

$$\begin{array}{llll}
\mathrm{Mg} - \mathrm{L} & = 5 & & \\
\mathrm{Ca} - \mathrm{L} & = 13 - 5 & = 8 & \\
\mathrm{Sr} - \mathrm{Na} & = 21 - 13 & = 8 & \\
\mathrm{Ba} - \mathrm{K} & = 29 - 21 & = 8 &
\end{array}$$

In the nitrogen group, Mercer recognised a blank between antimony and bismuth—an 'assumed or expected element,' having for its equivalent 166, which is designated x in the following illustrations:

Relations between the lithium group and the nitrogen group:

$$\begin{array}{lll}
\mathrm{N} - \mathrm{L} & = 7 & \\
\mathrm{P} - \mathrm{Na} & = 8 - 7 & = 1 \\
\mathrm{As} - \mathrm{K} & = 37 - 8 & = 29
\end{array}$$

$$\begin{array}{lll}
\mathrm{P} - \mathrm{L} & = 24 & \\
\mathrm{As} - \mathrm{Na} & = 53 - 24 & = 29 \\
\mathrm{Sb} - \mathrm{K} & = 82 - 53 & = 29
\end{array}$$

$$\begin{array}{lll}
\mathrm{As} - \mathrm{L} & = 69 & \\
\mathrm{Sb} - \mathrm{Na} & = 98 - 69 & = 29 \\
x - \mathrm{K} & = 127 - 98 & = 29
\end{array}$$

$$\begin{array}{lll}
\mathrm{Sb} - \mathrm{L} & = 114 & \\
x - \mathrm{Na} & = 143 - 114 & = 29 \\
\mathrm{Bi} - \mathrm{K} & = 172 - 143 & = 29
\end{array}$$

Relations between the lithium group and the fluorine group:

$$\begin{array}{lll}
\mathrm{Fl} - \mathrm{L} & = 12 & \\
\mathrm{Cl} - \mathrm{Na} & = 13 - 12 & = 1 \\
\mathrm{Br} - \mathrm{K} & = 42 - 13 & = 29
\end{array}$$

$$\begin{aligned}
&\mathrm{Cl} - \mathrm{L} = 29\\
&\mathrm{Br} - \mathrm{Na} = 58 - 29 = 29\\
&\mathrm{I} - \mathrm{K} = 87 - 58 = 29
\end{aligned}$$

Relations between the magnesium and nitrogen groups:

$$\begin{aligned}
&\mathrm{N} - \mathrm{Mg} = 2\\
&\mathrm{P} - \mathrm{Ca} = 11 - 2 = 9\\
&\mathrm{As} - \mathrm{Sr} = 32 - 11 = 21\\
&\mathrm{Sb} - \mathrm{Ba} = 53 - 32 = 21
\end{aligned}$$

$$\begin{aligned}
&\mathrm{P} - \mathrm{Mg} = 19\\
&\mathrm{As} - \mathrm{Ca} = 56 - 19 = 37\\
&\mathrm{Sb} - \mathrm{Sr} = 77 - 56 = 21\\
&x - \mathrm{Ba} = 98 - 77 = 21
\end{aligned}$$

$$\begin{aligned}
&\mathrm{As} - \mathrm{Mg} = 64\\
&\mathrm{Sb} - \mathrm{Ca} = 101 - 64 = 37\\
&x - \mathrm{Sr} = 122 - 101 = 21\\
&\mathrm{Bi} - \mathrm{Ba} = 143 - 122 = 21
\end{aligned}$$

Relations between the magnesium and chlorine groups:

$$\begin{aligned}
&\mathrm{Fl} - \mathrm{Mg} = 7\\
&\mathrm{Cl} - \mathrm{Ca} = 16 - 7 = 9\\
&\mathrm{Br} - \mathrm{Sr} = 37 - 16 = 21\\
&\mathrm{I} - \mathrm{Ba} = 58 - 37 = 21
\end{aligned}$$

Relations between the fluorine and phosphorus groups:

$$\begin{aligned}
&\mathrm{P} - \mathrm{Fl} = 12\\
&\mathrm{As} - \mathrm{Cl} = 40 - 12 = 28\\
&\mathrm{Sb} - \mathrm{Br} = 40 - 40 = 0\\
&x - \mathrm{I} = 40 - 40 = 0
\end{aligned}$$

$$
\begin{aligned}
\text{As} - \text{Fl} &= 57\\
\text{Sb} - \text{Cl} &= 85 - 57 = 28\\
x - \text{Br} &= 85 - 85 = 0\\
\text{Bi} - \text{I} &= 85 - 85 = 0
\end{aligned}
$$

In a communication to Dr. Frankland a few years later,[1] Mercer pointed out the relationship of cæsium and rubidium with other metals of the lithium group. Taking 135 as the equivalent of cæsium, and 87 that of rubidium, the complete group may be represented thus:

Lithium . . . . $= 7$
Sodium . . . . $16 + 7 = 23$
Potassium . . . . . . $16_2 + 7 = 39$
Rubidium . . . . . . $16_5 + 7 = 87$
Cæsium . . . . $16_8 + 7 = 135$

Although the atomic weights which Mercer adopted (pp. 322, 323) are not in some cases precisely the same as those which are now received (he having omitted decimals) yet it can hardly be doubted that some relationship does exist. Possibly future investigation may lead to the recognition of another factor which may account for the slight divergences. As to the fundamental source of the numerical coincidences, Mercer did not publish any views beyond, first, the obvious assumption before stated that the different members of the same group may be made up from two constituents, in varying proportions; and, secondly, that the same body may enter into

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[1] *Chemical News*, vol. viii. p. 18.

the constitution of more than one group. From unpublished memoranda it appears, however, that he was disposed to go a step further. He regarded one of the two constituents as being itself compounded of two elementary bodies, of exactly opposite characters (corresponding to the zincous and chlorous of Graham) which saturate and neutralise each other, and form a neutral compound. This combines in different proportions with the other constituent; and the latter being somehow in a state of tension, is the active principle which determines the chemical properties of the resulting body. But it is right to add that Mercer was always alive to the fact that such deductions concerning the constitution of so-called elements are very speculative; being, with our present means of research, incapable of demonstration.

§ XXIII. PHOTOGRAPHIC PROCESSES RELATING TO PEROXALATE OF IRON.

Preparation of the paper.—In order to ensure the absence of every trace of iron, and of deoxidising material, Mercer's practice was to soak the paper first for some hours in weak sulphuric acid (8° Tw.), and afterwards for a few minutes in very weak chlorine water (1 'spoon' of hypochlorite solution of 10° Tw. to 8 quarts of water, with a slight excess of sulphuric acid). After careful washing in clean water, it was dried between folds of clean bleached calico fents. He preferred paper which had been sized with starch to that sized with a more soluble material.

Preparation of the solution of peroxalate of iron.—The solution to which Mercer gave the preference for general use was made as follows:—To a solution of 17 ounces of protosulphate of iron in 1 quart of water was added a solution of oxalate of soda, made by dissolving 8 ounces of oxalic acid and 1 pound of soda crystals in 1 quart of water. To the precipitate, after being washed a few times by subsidence and decantation, were added 4 ounces more of oxalic acid, and by degrees 6 'spoons' of nitric acid of 60° Tw. The nitric acid was added so slowly that the mixture did not become hot; if this were not attended to, peroxalate of iron was deposited, and not easily re-dissolved. The peroxidation must be complete, as ascertained by the red prussiate test. A slight excess of nitric acid was found rather beneficial than otherwise. The solution was made into 1 quart with water. It was carefully protected from sunlight. In the dark, it suffers no decomposition. When used for impregnating paper, the solution was generally mixed with an equal volume of water. The addition of a small quantity of chlorate of potash (12 grains to a pint of the diluted liquor) was considered to be an improvement.

Charging the paper with the iron solution was of course done in artificial light. The dry cleared paper was brushed for a minute uniformly with the solution, and then dried between folds of paper in a covered box, or between two black fents. Careful drying was found to be of importance. It was then exposed for printing.

The *fixing bath*, in which the exposed paper was next soaked, to convert the oxalates of iron into arseniates (insoluble in water and unalterable by light), was made by dissolving 3 ounces of tri-arseniate of soda in 1 quart of water, with the addition of 1 'spoon' of sulphuric acid (80° Tw.). Soaking in this for about one minute was found to suffice at the temperature 150° Fahr. After washing, the colour was raised in

The *prussiate bath*; which was a solution of 8 ounces of red prussiate of potash in 2 quarts of water, with the addition of $\frac{3}{4}$ of a 'gill' of sulphuric acid (of 80° Tw.). To ensure the absence of the smallest trace of yellow prussiate, Mercer used to add a few drops of hypochlorite solution, just sufficient to give a faint odour. After a few minutes' immersion in this, the paper was soaked for a quarter of an hour successively, in water mixed with $\frac{1}{2}$ a 'gill' of sulphuric acid (80° Tw.) to a gallon, then in water with half that quantity of sulphuric acid, and then in two waters. The protected parts were perfectly white. By slightly raising the temperature of the red prussiate bath, and the two dilute acids, Mercer considered he obtained a finer blue. But too high a temperature in the prussiate bath, and also too long immersion, gave a greenish shade, to remove which he used to dip the paper in a deoxidising bath, as protochloride of tin, or protosulphate of iron with free acid.

The attempt to simplify the operation by using, as the photographic agent, a mixture of the peroxalate with red prussiate, did not give satisfactory results, the protected parts never coming out perfectly white.

To obtain the *cuprous sulphocyanide* by the means indicated (p. 227), the copper solution preferred by Mercer, after numerous experiments, was made in the following manner:—3 'spoons' of nitrate of copper solution of 96° Tw. were added to solution of neutral alkaline tartrate; and the precipitate, after being washed by decantation, was gradually added to a boiling solution of alkaline tartrate made from 1 ounce of bitartrate of potash and $\frac{3}{4}$ oz. of soda crystals in half a pint of water. When the tartrate of copper was dissolved, half an ounce more of soda crystals was added by degrees, and the solution diluted to 1 quart with cold water; after which were added 10 'spoons' of solution of sulphocyanide of potassium of 20° Tw. Most other copper salts, mixed with sulphocyanide of potassium, gave a precipitate on standing, which was not the case with the above. When taken out of this bath, the paper was soaked in dilute sulphuric acid to remove all iron and superfluous copper.

The best red prussiate bath for transforming the cuprous sulphocyanide to ferrocyanide was a solution of one ounce of red prussiate, one ounce of yellow prussiate, two ounces of sal ammoniac, and half an ounce of sesquicarbonate of ammonia, in three pints of water.

. . . . .

Very fair pictures in silver were obtained by dipping the exposed oxalate paper successively (with intermediate washings) in the arseniate fixing bath, neutral solution of nitrate of silver, and weak hydrochloric acid; the chloride of silver thus formed being afterwards reduced by an alkaline deoxidising agent.

But much better results were obtained by means of the *ferrocyanide of silver*, which admitted of several interesting transformations by various reagents. That compound was produced by soaking either the Prussian blue picture or the ferrocyanide of copper picture in a rather acid solution of nitrate of silver. Mercer gave the preference to the ferrocyanide of copper. He also considered that the presence of nitrate of copper, mixed with nitrate of silver, facilitated the decomposition of Prussian blue. After being washed in dilute ammonia, the ferrocyanide of silver was 'raised' by means of an alkaline deoxidising agent, for which purpose he used, with good results, a mixture of his 'sugar preparation' (p. 93), with an excess of caustic soda. Occasionally he employed the alkaline sugar preparation, holding in solution a little ferrous oxide; and sometimes a solution of stannous oxide in caustic soda (stannite of soda). By either of these the ferrocyanide could be decomposed, and the oxide of silver reduced to suboxide or dioxide.

Finished pictures could thus be obtained in black or brownish-black; but Mercer preferred going a step further, and giving the picture a dip in a bath of dilute *chloride of gold*, containing a little free hydrochloric acid. The tint was thereby much improved. The chloride of silver on the paper was removed by washing in dilute ammonia; or, if a darker tint was desirable, it was made the means of imparting this by further successive treatment with the alkaline sugar preparation and chloride of gold.

But a more interesting application of gold was for the production of pictures in *purple of cassius* by the intervention of a material containing tin. This was found to be feasible in various ways; the method selected was to use a solution of stannous oxide in caustic soda as the reducing agent for ferrocyanide of silver. A beautiful purple colour was obtained by soaking the picture impregnated with ferrocyanide of silver for three minutes at the temperature 160° F. in a solution containing, in one quart, one 'spoon' of caustic soda liquor of 70° Tw., and half a 'spoon' of protochloride of tin solution of 120° Tw.; after being washed in distilled water, the paper was soaked in very dilute chloride of gold with excess of hydrochloric acid, and washed successively in dilute acid, ammonia (to dissolve out the chloride of silver), and water. Or, instead of removing the chloride of silver by ammonia, it could be treated with various reagents for deepening or modifying the tint. By soaking the paper in solution of yellow prussiate of potash, the chloride could be replaced by ferrocyanide.

Mercer discovered that the ferrocyanides of copper and silver might be replaced by stannous ferrocyanide, by soaking in a dilute solution of protochloride of tin; then for a few minutes in sulphuric acid (60° Tw.), and washing in water. The stannous compound might then be decomposed, and the oxide made use of as a mordant.

He also observed the susceptibility of decomposition of ferrocyanide of silver by chloride of lead and by chloride of zinc, both of which reactions he made available for dyeing with murexid.

Madder-purple photographs on cloth.—For these, Mercer made use of the finest cloth procurable; it was first boiled for an hour in solution of carbonate of soda, washed and soured, and then mercerised either by sulphuric acid or caustic soda. He obtained the best shades by using an iron solution containing more nitric acid and less oxalic acid than that before prescribed (p. 329). A solution which gave very satisfactory results was prepared by adding 7 'spoons' of nitric acid of 60° Tw. to protoxalate made from 8½ ounces of protosulphate; and (after complete oxidation) diluting to one gallon. After the usual operations of soaking in the iron solution, squeezing out excess, drying in the dark, and exposure for three minutes or longer according to the intensity of the light, he soaked the cloth for about one minute in the arseniate of soda 'fixing bath,' made as before described (p. 330), at the temperature 180° F.; whereby the oxalates of iron gave place to the corresponding arseniates. After washing the cloth in hot water, the blue was raised in the prussiate bath, made by dissolving six ounces of red prussiate of potash with four 'spoons' of sulphuric acid (80° Tw.) in one quart of water (with the addition of a few drops of solution of hypochlorite), at a temperature of from 100° to 110° F. Next came the 'clearing,' or removing all *ferric* compounds by means of the weak sulphuric acid washing liquors before mentioned; after which the cloth was again put into a solution of red prussiate of one-third the strength of the first prussiate bath, without any free acid. By the use of this second prussiate bath after clearing, the blue was found to be more firmly attached to the fibre.

After being washed, the cloth was dyed in the madder bath without previous decomposition of the blue by lime. This bath was made by boiling in water, with the addition of a little chalk, madder which had been previously washed two or three times with cold water. Mercer recommended that the cloth should be kept for an hour in the bath at a temperature not exceeding 110° F., and for about one hour longer at a temperature gradually increasing to 160° F. When washed, it was of a rich bluish purple colour. It was branned at 160° F. until the whites were perfect. The addition of isinglass to the dyeing bath (amounting to one-sixth the weight of the dry madder) was found to be helpful in preserving the whites.

§ XXIV. SUNDRY RECEIPTS FOR PREPARATIONS OF CHROMIUM AND TIN.

Among the latest of Mercer's receipts we find the following:

1. Solutions of Oxide of Chromium for Moderating.

(*a*) *Aceto-nitrate of chromium.*—Dissolve 19 ounces of bichromate of potash in 1 quart of water; put the solution into a 6-quart earthen pot, and add to it first 6 ounces of sugar, and afterwards 42 'spoons' of nitric acid of 60° Tw. When the action has ceased, make up to 1 gallon with acetic acid of 8° Tw., and boil for five minutes. The sp. gr. should be 36° Tw.

(*b*) *Aceto-tartrate of chromium.*—Dissolve 19 ounces of bichromate of potash in 1 quart of water; to this add, first, six ounces of sugar, then by degrees 42 'spoons' of nitric acid; next add 18 ounces of soda crystals, and afterwards 19 ounces of tartaric acid. Make this into 1 gallon with acetic acid (8° Tw.), and boil for five minutes. The sp. gr. should be 46° Tw.

(*c*) *Aceto-sulphate of chromium for Fr. Grey.*—Dissolve 38 ounces of bichromate of potash in 2 quarts of water; add, first, 12 ounces of sugar, then 1 pint of sulphuric acid of 60° Tw., and 42 'spoons' of nitric acid of 60° Tw. Allow the mixture to stand until the deoxidation of the chromic acid is complete; then add 6 quarts of acetic acid, and boil for five minutes.

2. PREPARATIONS OF TIN.

(*a*) *Bichloride of tin.*—To 3 gills of protochloride of tin liquor of 120° Tw. add 1 gill of hydrochloric acid, heat in a water-bath, and when hot add slowly 6 'spoons' of nitric acid (60° Tw.). This should make 1 quart of 106° Tw.

(*b*) *Solution of peroxalate of tin.*—Mix and dissolve 8 ounces of oxalic acid and 18 ounces of soda crystals in 2 quarts of water; add this solution to a mixture of 1½ gills of protochloride of tin liquor of 120° and 2 quarts of water; wash the protoxalate by affusion and decantation, and allow it to settle in as small a bulk as possible; decant, and peroxidise by adding 7½ 'spoons' of nitric acid (60°); add water to make 1 quart.

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