DIRECTIONS

FOR

MAKING AND ADMINISTERING

NITROUS OXIDE.

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BY

S. R. DIVINE, M. D.,

AUTHOR OF "ALBUMEN PHOTOGRAPHY," "PHOTOGRAPHIC MANIPULATION, &C.

Manufacturing, Analytical, and Consulting Chemist.

ENOCH MORGAN'S SONS,

AGENTS FOR

Divine's Pure Nitrate of Ammonia.

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INTRODUCTION.

THIS little treatise was written to fulfill a promise made in an advertisement in the "Dental Cosmos," to give gratuitous information on the subject of Nitrous Oxide to those who applied. It had been my custom to write out the important details of the manufacture and use of the gas to such of my patrons as made inquiries. But the advertisement alluded to brought such a shower of letters, that it was utterly impossible to answer them in writing.

I would prefer to have made a larger volume, and given the full history of *anæsthesia;* but that would have involved too great an expense for a gratuitous work, and occupied too much time in its preparation, to meet the present urgent demand.

There can be no doubt that Nitrous Oxide will supersede all the other anæsthetic agents in a very brief period ; and, if no other hand takes up the needed task, I hope, at some future day, to offer a better volume on the subject.

I have not space to do justice to Dr. G. Q. Colton, and can only return the poor recompense of gratitude for his generous assistance in affording me information on many of the topics of the following pages. Although he never claimed the discovery of ANÆSTHESIA, I believe that but for him it would have remained unknown to this day. The names of WELLS and COLTON must ever be associated in the history of one of the greatest blessings that science has conferred on humanity.

Drs. Paddock and Slocum, of the Colton Dental Association, have made valuable suggestions. The latter gentleman, being a practicing physician, greatly aided me in the preparation of facts that I designed to publish, but are excluded for want of space. They are no less valuable, however, than those herein contained.

CHAPTER I.

NITROUS OXIDE—PROTOXIDE OF NITROGEN—LAUGHING GAS.

Nitrous Oxide, as its name indicates, is composed of Nitrogen and Oxygen. It was discovered by Dr. Priestley, in 1776, although but little was known respecting its properties until 1800, when Sir Humphrey Davy gave the results of his investigations concerning it.

It is a transparent, colorless, elastic gas, possessing a very slight odor and a sweetish taste. Its specific gravity is 1.52, air being 1, or a very little more than once and a half the weight of atmospheric air. It will be seen, also, that Nitrous Oxide is composed of the same elements as the atmosphere, but the Nitrogen and Oxygen in the former are in different proportions, and *chemically combined*, whereas in air they exist merely in the state of mixture. Thus Nitrous Oxide is composed by weight of:

	Per cent.
Nitrogen,	63.6
Oxygen,	36.4
	100.0

or in chemical notation:

	Atoms.	Equivalent.	Volume.
Nitrogen,	1	14	1.0
Oxygen,	1	8	0.5
Nitrous Oxide,	1	22	1.0

The composition of air is:

	By Weight.	By Volume.
Nitrogen,	76.90	79.20
Oxygen,	23.10	20.80
	100.00	100.00

Thus it will be seen that Nitrous Oxide contains a much larger proportion of Oxygen than exists in atmospheric air. We will next consider how chemical union affects the physical properties of Nitrogen and Oxygen, and how greatly Nitrous Oxide differs from air. By reference to the constitution of Nitrous Oxide, we see that one volume or measure of Nitrogen and half a volume of Oxygen make but *one* volume of Protoxide of Nitrogen, *i. e.*—the two elements, Nitrogen and Oxygen, are condensed one-third in bulk by being *chemically* combined. In the case of air the volume is equal to the *sum* of the volumes of the Nitrogen and Oxygen which compose it.

Nitrous Oxide is absorbed by water, the latter when cold taking up its own bulk of the gas, while air is but very slightly soluble in water; one volume of cold water dissolving about one fiftieth of a volume of atmospheric air. Both air and Nitrous Oxide are expelled from their solutions in water, by boiling.

Nitrous Oxide is a vigorous supporter of combustion; a lighted taper burning in a jar of the gas much more brilliantly than in air. If a candle with a spark of fire on the wick be lowered into the gas, it will immediately burst into a flame, the effect being analogous to that of a similar experiment with Oxygen, although Nitrous Oxide is less powerful than Oxygen as a supporter of combustion.

Nitrogen does not support combustion or respiration, and hence we attribute the energetic effects of Nitrous Oxide to the Oxygen it contains. Nitrogen, being negative in its character, serves as a diluent to the Oxygen in air, in order to adapt the atmosphere to the requirements of vegetable and animal life. In an atmosphere of pure Oxygen animals live but a very short time, because the chemical energy of Oxygen very quickly exhausts the powers of life. On placing an animal in a vessel of Oxygen, violent excitement ensues, followed by prostration and death.

Nitrous Oxide differs from air: 1st—By being copiously absorbed by water and various other aqueous fluids. 2d—By its supporting combustion more energetically. 3d—By its possessing an odor and taste. 4th—By its effect on the animal system when respired. 5th—By its being susceptible of condensation into a liquid and a solid state. The latter is a remarkable property of Nitrous Oxide. It may be condensed into a liquid under a pressure of 50 atmospheres, or about 750 lbs. to the square inch, at a temperature of 45° Fahr., and this liquid in the exhausted receiver of an air pump is frozen to a solid by its own evaporation. The cold produced in this manner is 150° below zero. If a globule of mercury is dropped into the liquid Protoxide of Nitrogen it is instantly frozen to a solid, and may be hammered like lead. Air has never been liquefied by the most intense cold and pressure yet applied.

CHAPTER II.

COMPOUNDS OF NITROGEN AND OXYGEN.

It is necessary to consider the series of compounds formed by the chemical union of Nitrogen and Oxygen in different proportions, in order to arrive at a full understanding of the subject in hand. To present the matter in a scientific light, it will be necessary to employ the chemical nomenclature and notation. Nitrogen is represented by the symbol N, and Oxygen by that of O.

The number of compounds of Nitrogen and Oxygen is five.

		Parts Nitrogen.	Parts Oxygen.
Protoxide of Nitrogen,	NO.	14	8
Deutoxide "	NO_2	14	16
Hyponitrous Acid,	NO_3	14	24
Nitrous "	NO_4	14	32
Nitric "	NO_5	14	40

The first two, Nitrous Oxide and Deutoxide of Nitrogen, are neutral compounds, *i. e.*—they have neither alkaline nor acid properties. The latter three compounds are acids. Deutoxide of Nitrogen (NO_2) was made known in 1772, by Dr. Priestley. It is requisite to form a thorough acquaintance with the properties of this remarkable gas, in order to manipulate safely with Nitrous Oxide as an anæsthetic, for it always accompanies Protoxide of Nitrogen when the latter is first generated, and requires to be thoroughly removed by a proper process of purification. The Deutoxide of Nitrogen is a transparent, colorless gas, and has never been liquefied. Its specific gravity is 1.036, air being 1000. It is a notable fact, and one which furnishes an interesting example of the change in properties which elements undergo by chemical union, that this gas will not support combustion under ordinary circumstances, a lighted taper being extinguished when immersed in the gas; yet it contains more Oxygen than either air or Nitrous Oxide. The most distinctive property of the Deutoxide is its powerful affinity for Oxygen, with which it instantly combines when exposed to air or Oxygen, the effect becoming manifest by the formation of blood-red fumes of Nitrous Acid. It takes two equivalents of Oxygen, in this case $NO_2+2\ O$. becoming NO_4. By reason of this reaction, Deutoxide of Nitrogen is a test for the presence of air or Oxygen, and vice-versa, air or Oxygen is a test for the Deutoxide. This gas is fatal to animal life when respired, but it would be difficult to define its own specific effects in that respect, as the cells of the lungs always contain air with which the gas unites to produce Nitrous Acid, which is known to be extremely poisonous. It is but very slightly soluble in water, and this fact has an important bearing on the old method of purifying Laughing Gas by water exclusively, for it is evident that if a large volume if Deutoxide were present the water would not take it up.

When Nitrous Oxide containing Deutoxide of Nitrogen is inhaled, a hot, suffocating sensation is felt in the lungs, generally attended with short, painful and spasmodic breathing. A peculiar "coppery" taste is also experienced, and when this is the case the gas is unfit to administer. I consider the taste and sensation in the lungs as the simplest and best practical test for the presence of Deutoxide—more delicate than that of the formation of red fumes with Oxygen or air. The coppery taste is produced by the Deutoxide forming Nitrous Acid with the air in the lungs.

Deutoxide of Nitrogen is freely absorbed by a solution of Caustic Alkali, as Potash or Soda, but more abundantly by a solution of Proto-sulphate of Iron (green crystals of copperas) in water. Hence Laughing Gas may be purified by thoroughly washing it through these materials. Many other substances in solution will take up Deutoxide, but it is unnecessary to mention them, as those given above are the best, considering economy and efficacy.

Hyponitrous Acid (NO_3) requires but little attention, as it is known only in the Laboratory of the Chemist, in a free state, and is ordinarily met with only in combination with bases, the salts being hyponitrites. These salts do not stand in the way when practically dealing with Nitrous Oxide.

Nitrous Acid, (NO_4) at common temperature, is an orange-red vapor or gas, but becomes liquid about zero, and *colorless.* The color deepens as it is heated. It supports combustion, but not so well as air or Nitrous Oxide. This Acid is decomposed by water when the latter is in large quantity, as is always the case in Gasometers for Nitrous Oxide, being resolved into Nitric Acid and Deutoxide of Nitrogen. The Nitric Acid is dissolved by the water, while the Deutoxide is set free. Nitrous Acid is very destructive to animal life, and many fatal accidents have occurred by its inhalation in cases where large quantities of Nitric Acid have been spilled upon metals, wood or vegetable matter; Nitric Acid decomposes into Nitrous Acid under such circumstances. The writer came very near losing his life on one occasion, by breaking a carboy of Nitric Acid on the floor of a chemical room. The apartment was almost instantly filled with red vapors; the packing of the carboy took fire, and waiting to extinguish it before leaving, it was necessary to breathe several times before making escape. Bleeding at the lungs and severe prostration, lasting several days, ensued.

Nitric Acid ($N\,O_5$) is well known as one of the most powerful acids, and is familiar to most of those who will read this work. In an impure form it is known as Aqua-Fortis, being of an orange or reddish color from the presence of Nitrous Acid. Pure Nitric Acid is colorless. It is always combined with water as we ordinarily see it, but it has been isolated in a dry and solid state. Having now briefly considered the five compounds of Nitrogen and Oxygen, we see that they present a beautiful instance of the increase of Oxygen in a regular arithmetical series.

CHAPTER III.

PREPARATION OF NITROUS OXIDE—PURIFICATION —APPARATUS REQUIRED.

Nitrous Oxide for practical use is always prepared by subjecting *Nitrate of Ammonia* in a glass flask or retort, to a strong heat over a lamp or gas flame. The heat should not greatly exceed 410° Fahr. to insure a proper decomposition and to render the process manageable. This point is easily accomplished after a little experience, and it will never be necessary to employ a thermometer, as the indications to be governed by are plainly perceptible. Crystallized Nitrate of Ammonia melts at 228°—at 356° it boils; but does not decompose into gas. Above 390° and below 410° it decomposes into Nitrous Oxide and water. Dry Nitrate of Ammonia, or that which has been fused until the water of crystallization is expelled, has a higher melting point, and begins to generate gas very soon after it enters the state of fusion. If the heat rises much above 400° the decomposition is different, and variable quantities of Deutoxide of Nitrogen and Hyponitrite of Ammonia are formed, and the former, being volatile, will go over with and contaminate the Nitrous Oxide. The normal decomposition may be chemically explained thus:— Nitrate of Ammonia is Nitric Acid combined with Ammonia; one equivalent of water being present, or symbolically, $N H_3$, $H O$, $N O_5$, ($H O$ being the equivalent for water,) decomposing by heat $N H_3, H O, N O_5 = 2 N O + 4 H O$ That is, two equivalents of Nitrous Oxide and four equivalents of water are produced, or, by absolute weight, 80 parts Nitrate of Ammonia give 44 parts Nitrous Oxide and 36 parts Water. This decomposition is only theoretically correct; practically there is always a minute quantity of Deutoxide of Nitrogen produced, which renders the gas impure. The nearer the heat is kept at the lowest point of decomposition, the purer will be the gas as it leaves the retort. The heat must be abated when copious white fumes are generated in the retort, for they are an indication that the proper temperature has been exceeded, and that other products are forming. The heat may sometimes become so great as even to liberate the red fumes of Nitrous Acid in the retort. Besides making an impure gas, there is danger of bursting the retort if the heat is too high, and the Nitrate of Ammonia decomposes too rapidly.

In the chemical reaction given above, we have supposed the Nitrate of Ammonia to be *fused* and dry, or deprived of its water of crystallization, by heat, before being used. (This has no reference to the one equivalent of water necessary to the constitution of Nitrate of Ammonia, under all circumstances.) Crystallized Nitrate of Ammonia contains another equivalent of water, and hence 89 parts of it only equal 80 parts of the fused. Thus at the same price per pound, fused Nitrate of Ammonia is more than 10 per cent. cheaper than the crystallized. *Granulated* Nitrate of Ammonia is prepared by stirring the melted salt until cold, when it becomes fine, like crushed sugar. It may be made dry, or may retain the full amount of water of crystallization, at the will of the manufacturer.

One pound of dry Nitrate of Ammonia will make about 37½ gallons of Nitrous Oxide.

Glass is the only material which has yet been found to answer for a retort, for making Nitrous Oxide. Platinum might be used if the Nitrate were always pure, but even in that case such a retort would be too expensive. The ordinary metals will not answer at all, for the Nitrate of Ammonia speedily destroys them, besides corrupting the gas. Nitrate of Ammonia thrown upon hot Iron, Zinc, Copper and many other metals, causes them to burn up with a flame.

The apparatus for collecting and purifying the gas for use may be made in a variety of forms. The old plan, which is still in use by those who care not for economy in the saving of gas, is to fill a tight barrel, connected with a hydrant, with water, and displace the water with gas, let in at the bottom through a large tube 8 or 10 inches long, pointing upwards at an angle of 45°, to prevent the air from gurgling in and letting the water out, as would happen if the tube were entered straight or inclined downwards. There is a pipe with a stopcock at the top of the barrel, for drawing off the gas into bags when wanted for use. The tube at the bottom for letting in the gas is larger than the pipe from the retort which enters it, in order to leave room for the water to flow out between the tube and the pipe. The pipe from the retort is a piece of rubber hose, slipped over the beak of the retort, so as to make a tight joint, and when all things are ready the hose is thrust in the large tube in the barrel, entering far enough to discharge the gas inside the cask. Heat is now applied to the retort, and as the gas enters the barrel the water will flow out, and may be conducted away by a suitable drain. The barrel should have a water gauge, or glass tube connecting with the top and bottom, to show the height of water within. The flow of gas must be stopped before the water descends to the level of the large tube, to prevent admixture of air, and the hose is then drawn out, and the tube plugged. When it is desired to draw out gas, the bag is connected with the pipe at the top, and the cock opened. Water is now let in at the bottom of the barrel, through the hydrant, and it displaces the gas and drives it into the bag. The water-cock is closed as soon as the bag is filled. When the gas is all drawn out the barrel is full of water, and ready for a new operation. The gas is purified by standing six to twelve hours over the water left in the bottom of the barrel.

I heartily disapprove of this plan, for the following reasons: 1st—As water by prolonged contact absorbs its own bulk of gas, there is a large quantity of Nitrous Oxide needlessly wasted, making a much greater expense for Nitrate of Ammonia. 2d—There is too much time required in purifying the gas by water alone, without always being certain of purity in the end. The latter difficulty might, of course, be overcome by interposing washing bottles, containing Caustic Potash or Sulphate of Iron solution, between the retort and the barrel, but it must be borne in mind that every wash-bottle adds to the pressure on the interior of the flask.

A better plan is to have a gasometer of tin or zinc, contained in a cistern of a somewhat larger size, after the plan of the large gasometers for containing illuminating gas in cities. The gasometer is open at the bottom, and when counterpoised with a pulley and weight, rises easily when gas is let in, which may be beneath or through the top; when the gas is drawn from a cock in the top, the gasometer sinks in the cistern, and is filled with water. The same water being used repeatedly, becomes so saturated with gas that it will take no more, and hence there is not that waste that occurs in taking new water with each change of Nitrous Oxide.

This apparatus always requires the interposition of washing-bottles, containing solution of Potash or Sulphate of Iron, when the water in the cistern is not changed, in order to purify the gas before it reaches the gasometer. With a series of Wolfe bottles, containing the solutions named above, the gas may be generated of sufficient purity to collect immediately in a large rubber bag, *provided the* *heat is kept low and the gas generated very slowly.** A series of five or six one gallon bottles will render the gas perfectly pure, when flowing at the rate of 1½ gallons per minute. The arrangement of the bottles is fully described in another chapter.

The writer devised an apparatus which rendered gas perfectly free from impurity, flowing at the most rapid rate. It consisted of a rectangular tin box, 6X6X20 inches, with tubes entering at the ends. The box was filled with small fragments of coke, and a solution of Sulphate of Iron poured in and shaken, to saturate it. The very large surface to which the gas was exposed, immediately purified it, and no pressure was exerted on the interior of the flask. The tin, however, rapidly corroded, and proved that a non-corrosive material was necessary. Having taken steps to procure a patent, the apparatus may be placed before the public.

It is a fact well known to those who have had experience with Nitrous Oxide as an anæsthetic agent, that the gas rapidly deteriorates when kept over water, or in a rubber bag, and some dentists want "fresh" gas, in order to insure effect. Now every chemist knows that Nitrous Oxide is very stable, and that it never becomes "stale;" then why should it lose its effect in two or three days, when kept in a rubber bag? The reason is this:—There is a law of diffusion of gases, in obedience to which, different gases will rapidly mix when brought in contact. Thus, Hydrogen, being 14 times lighter than air, may be collected in a jar with the mouth downwards, but in a very short time it will be found to be mixed with air, as may be proved by exploding the mixture with a match. Next, take Carbonic Acid, which, being heavier than air, may be placed in a jar in the upright position; that will quickly mix with air, also, as will become evident by the proper tests. Another law must now be considered, in connection with the foregoing, to fully explain the subject; *Endosmose* and *Exosmose* (flowing inward and outward through membranous pores.) In the case of Hydrogen, cited above, if we tie a piece of bladder or sheet of caoutchouc over the mouth of the jar, the air will still get in and mix with the Hydrogen; so, also, in the case of Carbonic Acid. Now neither bladder nor caoutchouc will leak air by a direct pressure, but if a vessel containing a different gas be tied over with either material, the air will get in and the gas will get out. We understand, therefore, why Nitrous Oxide, in a rubber bag, loses its virtue—it becomes diluted

*A very beautiful and ingenious automatic arrangement for regulating the heat under the flask, and preserving a uniform flow of gas, was patented by Mr. A. W. Sprague, of Boston. It is attached to an apparatus sold by him, and is much used and very highly commended.

with air. This law holds good with animal or vegetable membranes, but not with metals. Nitrous Oxide contained in a tight metallic reservoir will keep good for an unlimited time. With regard to gas contained in a gasometer, it will become slowly diluted with air through the water in the cistern. There being a surface of water exposed to the air, between the gasometer and cistern, and the water being saturated with Nitrous Oxide, will give out gas and take up air. This dilution goes on very slowly, and gas thus kept will remain good for a fortnight or longer. I discovered that a film of limpid oil, on the surface of the water between the gasometer and cistern, would entirely prevent the admixture of air with the gas. I also found that salt dissolved in water to saturation would prevent the absorption of Nitrous Oxide.

CHAPTER IV.

PHYSIOLOGICAL EFFECTS OF NITROUS OXIDE.

Protoxide of Nitrogen, when respired in moderate quantity, produces a pleasing species of intoxication, attended generally with considerable mental and muscular excitement. A train of vivid ideas flash in succession across the mind, and there is a disposition to sing, dance, laugh or weep, as the case may be. Some desire to display their extraordinary powers of oratory, while others (not a few in number) assert belligerent rights, and make a pugnacious foray on anybody within reach. The first sensation on breathing the gas is that of slight giddiness, and there seems to be heard a buzzing sound, somewhere in the distance. Staggering often ensues just after these sensations, and then follows mental, emotional or muscular excitement. If more gas is administered, a state of quietness and insensibility results, and the patient breathes stertorously, when no more gas must be given. This is the state of anæsthesia.

The anæsthetic state does not usually continue longer than from thirty seconds to a minute, and the patient generally returns to the normal condition in two to three minutes after ceasing to breathe the gas. If the operation to be performed is long and severe, more gas can be given, whenever the patient seems to be recovering sensibility to pain, and he may be kept in an unconscious state for ten or twenty minutes; as has been proved by trial in capital operations. Probably by judicious management a subject might be kept in the anæsthetic state for a much longer time. Whenever Nitrous Oxide has been tried for amputations and other severe operations of surgery, it has proved perfectly satisfactory. For minor operations, such as teeth extracting, it is incomparably superior to Ether or Chloroform. Nausea scarcely ever ensues; and the other distressing symptoms that follow Ether and Chloroform, such as headache, prostration, &c., rarely occur. Ether and Chloroform taint the breath for hours after their inhalation, while Nitrous Oxide never does.

To return to the mental and physical manifestations that follow the administration of Nitrous Oxide, it should be said that these depend in a great measure upon the previous mental preparation of the subject, by the operator. For instance, when the gas is given for the purpose of exhibiting its ludicrous effects, we request the subject to fix in his mind something he would prefer to do. If he thinks he would like to make a speech, he will be sure to do it after taking the gas, and he will introduce the principle of "action" to an extent that Demosthenes never contemplated. So with other ideas, the subject may fix in his mind previously. Now in giving the gas for anæsthesia, the patient must be kindly assured, and be prepared to sit down and sink into unconsciousness. With this resolve in his mind, he remains passive and breathes the gas to insensibility. On awakening, he is informed that all is right and the operation is over. His astonishment and gratitude can hardly find expression. Still, there are subjects who are difficult to keep in subjection. Some will push the attendant violently away on experiencing the first sensations produced by the gas, and will refuse to take it beyond that stage. Others will scream, and, in occasional instances, a subject will exhibit erotic desires, which will embarrass the operator as well as himself, if he retains any recollection of his thoughts and actions. The utmost endeavors should be used to dissipate all apprehensions of fear from the mind of the subject, for this is one of the greatest requisites of success.

The question now arises, How does Nitrous Oxide operate to produce such results? We have seen that the gas is absorbed abundantly by water. The blood being for the most part water, also absorbs the gas through the cellular membranes of the lungs by endosmotic action. A similar phenomenon obtains in the respiration of atmospheric air. The oxygen of the air passes into the blood, and is distributed by circulation through every part of the system. While in the blood it combines with the carbon of that fluid, producing carbonic acid, and the latter is thrown out through the lungs by exosmosis. This consumption of carbon is the main source of animal heat, and is, in fact, a slow combustion, comparable to the burning of fuel in a stove to warm a dwelling. We have stated the fact that Nitrous Oxide is a powerful supporter of combustion, and when we consider its copious absorption by the blood, we can readily understand why the pulse rises and the complexion changes. Indeed, it often causes profuse sweating in consequence of the rapid oxidation of the blood, generating more than the normal quantity of heat.

The countenance generally assumes a livid hue, and the lips turn to a dark purple. Rapid respiration of air will cause slight giddiness, proving that a superabundance of oxygen acts like a small dose of Nitrous Oxide. Pure oxygen acts more decidedly in the same way, but the blood will not absorb enough of it to produce anæsthesia. Persons who have consumption, but not the advanced stage, that would render the inhalation unsafe, might experience great benefit by the judicious employment of Nitrous Oxide. When the lungs have partially wasted away, they have not the capacity for air to properly aerate the blood, and by giving Nitrous Oxide, which is so readily absorbed, we might counterbalance the diminished functions of the lungs.* It has been observed that consumptives who have taken the gas have sometimes experienced great improvement. In asthma, it has been given with beneficial results in numerous instances.

Nitrous Oxide tends to the urinals, acting as an efficient diuretic, and has been proposed for various diseases of the urinary and reproductive organs.†

* I am not so sanguine on this point as some other writers, for it seems to me that the excess of *carbonic acid* generated in the system would require *more* lung surface to eliminate it.

† See Ziegler, on Nitrous Oxide for medicinal applications.

CHAPTER V.

MODE OF ADMINISTERING NITROUS OXIDE.

At first sight the operation of administering Nitrous Oxide might not furnish the most agreeable study for a fastidious mind. We will attempt to describe what we have often witnessed. A person bordering on distraction with toothache, enters the office of some respectable dentist, who "extracts teeth without pain." He hesitatingly takes his place in the huge chair, when it suddenly occurs to him that his tooth does not ache, and he is half inclined to abandon his preconceived intention. Then, after more or less argument and persuasion on the part of the philanthropic dentist, he summons all his courage and consents. A bloated india-rubber bag is brought before him, he is at once gagged with a cork, and, before he can realize his terrible situation, the mouthpiece is thrust between his jaws; the assistant compresses his lips tightly with both hands, while the dentist seizes his nose, and effectually prevents any unnecessary waste of gas in that direction. "Will he or nill he," breathe he must; and, imagining all the horrors of pandemonium, he slowly inflates his lungs and exhales again into the bag. He breathes more freely next time, and no longer fears. Quicker and faster now he respires, for he cannot get enough, and would gladly take in bag and all if he could. But he is falling asleep—and now he snores. The bag is quickly removed, and in another moment the offending molar is grasped by the forceps, and, with a wrench and a twist, the muscular dentist draws it forth in triumph. The patient is awaking, and asks: "Why didn't you pull it?" "It's all right," replies the dentist, "here is the tooth;" and the happy individual, seeing blood flowing from his mouth, realizes in astonishment that something has been going on while he was gone.

The foregoing practical operations may still be witnessed in many dental operating rooms; but I am happy to say that there are many dentists sufficiently progressive to employ more scientific methods, and those which do not combine so much of the ludicrous and disgusting. With a properly constructed mouthpiece, one man can alone administer the gas, without the necessity of applying two hands, or even one, to the lips. With the double-valved inhaler (one valve opening from the bag, and the other in the air), the subject takes in pure gas at each inhalation. The ungainly bag may be concealed from the sight, and the gas conveyed through flexible tubes through a partition, or the tubes may lead direct from the gasometer, thus dispensing with the bag entirely. Breathing in and out of a bag used by hundreds of patients is shocking and repulsive to that portion of the public cognizant of the practice, and such antipathy is just, so far as it reaches the dentists who do not *wash and disinfect* the bag every time it is used. The valved inhaler is certainly unobjectionable on that score, for no expirations from the lungs go back to the bag.

But so far as poisoning or asphyxiating with carbonic acid from the lungs is concerned, I think there is no great danger, unless the quantity of gas in the bag is too small, or the inhalation is continued too long with a patient who is difficult to subdue. Carbonic acid exists constantly in the blood, because it is generated there, and is carried to the lungs to be thrown out. *Expired air* contains, on the average, about three and one-half per cent. of carbonic acid, by measure. Twenty per cent. of carbonic acid in air renders it destructive to life. Such a mixture will first cause drowsiness, then total loss of muscular power, and afterward insensibility, coma and death. There can be no doubt that in some cases where a small quantity of gas has been used that the patients have been *asphyxiated* with carbonic acid, instead of *anæsthetized* with Nitrous Oxide. The quantity of Nitrous Oxide that is converted into carbonic acid in the blood is probably quite small, but still, the expirations contain a larger amount of carbonic acid, than when air is breathed.*

The amount of gas consumed by the use of the valved inhaler, which allows the exhaled products to escape into the atmosphere, is very much larger than when it is breathed back and forth, ten to fifteen gallons being often used. Dr. Vanderweyde patented an arrangement for removing the carbonic acid, and still preserving the unconsumed Nitrous Oxide for inhaling again. The inhaler has two valves, one for admitting gas from the bag, the other conveying the expired gas through a solution of caustic alkali to absorb the carbonic

* A series of analyses of the products of respiration, during and after anæsthesia by Nitrous Oxide, were commenced by the writer, but they are as yet unfinished. He hopes to publish them at no distant day.

acid. The device is admirable in principle, but is rather too complicated for convenient use.

The inhaling bag may be disinfected from all taint of the exhalations by using a dilute solution of permanganate of potash, and afterward rinsing with water.

For anæsthesia, it is advisable to remove the bag when the patient arrives at the state of stertorous breathing, and oftentimes it will not be necessary to proceed thus far. Some allow the subject to "snore" for fifteen or twenty seconds. Prudence should always be observed, and the effect carried no further than strictly necessary. The closing of the glottis, causing a suspension of breathing, may sometimes happen, in which case the patient should be thrown forward, and his chest suddenly compressed to drive out the contents of the lungs and open the air passage. Sometimes the tongue falls back and stops the air passage, in which case it must be pulled outward.

There should be no timidity on the part of the operator in administering the gas; but care and watchfulness should be exercised, and every difficulty must be met with its prompt remedy. The dose of Nitrous Oxide varies from half a gallon with a child to eight or ten gallons with some men. When breathed in and out, six gallons of gas will generally suffice for teeth extracting. In a case of surgery, where the subject requires to be kept in the anæsthetic state for a longer time, fifteen to thirty gallons may be required, being given at short intervals, as circumstances indicate.

The best mouthpieces are made of ivory, hard rubber, or ebony. They should have an opening of at least one-half inch in diameter, to afford opportunity for free breathing. They should be of hard and firm material, for prying the subject's jaws apart if he should clench them while in the unconscious condition. Before taking the gas, the patient should throw the air out of his lungs, that the gas may not be diluted thereby.

The operations should be performed as quickly as consistent with proper care, for the anæsthetic state does not usually last longer than from thirty to forty-five seconds with one administering. It has, in a few instances, been known to last for several minutes.

The cases in which Nitrous Oxide is contra-indicated should be borne in mind to guard against accident, and the subject should be scrutinized, and sometimes questioned respecting his bodily condition. It should not be given in cases of heart-disease, apoplexy, cerebro-spinal disease, advanced consumption, or in any case where the vital functions are greatly impaired. The conditions that forbid the use of ether or chloroform will generally apply to Nitrous Oxide. Although this agent has, up to the present time, proved the safest of all anæsthetics, still, prudence is necessary if we would have no more deaths laid at its door. More than one hundred thousand people have taken it within the last three years, and yet only two deaths are in any way attributable to its effects, and those under circumstances that do not weigh much against it. One was that of Miss Bell, of St. Albans, Vt., who died three or four days after taking the gas for sport, and who was affected with cerebro-spinal meningitis. The other was that of Mr. S. P. Sears, of New York, who was at the time far advanced in consumption, and died about two hours after taking Nitrous Oxide for the purpose of having a tooth extracted.

The Colton Dental Association have refused to give the gas in but *one* instance out of seventeen thousand patients, which is an argument of *fact* for the safety of Nitrous Oxide, too strong to be controverted.

Mr. Sprague, of Boston, informs me that he has taken Nitrous Oxide to the state of insensibility over *three hundred times*; and Dr E. P. Howland, of Washington, has tried it quite as often. However, the effects must be considered abnormal, and the human system would, without doubt, be impaired by a long and habitual use of Protoxide of Nitrogen.

CHAPTER VI.

NITROUS OXIDE COMPARED WITH ETHER AND CHLOROFORM.

ETHER has the chemical formula $C_4 H_5 O$, or, taking the weights of its elements, it is composed of 24 parts carbon, 5 parts hydrogen, and 8 parts oxygen. It is called (improperly) sulphuric ether, from the fact of sulphuric acid being used in the process of manufacture, although no such product exists in it. Ether being exceedingly volatile, the vapor of it can be rapidly inhaled; but an admixture of air is necessary to support respiration. Ether alone would quickly suffocate a patient, because it does not oxygenate the blood. However, it is absorbed in considerable quantity by the blood, and thus produces anæsthesia. A person who has inhaled ether will emit it by the breath for ten or twenty hours afterward, as is perceptible by the odor. Ether undergoes decomposition in the system, a portion of it going to form acetic acid, as has been proved by taking blood from the vein of an etherized patient and subjecting it to analysis.

The dose of ether for anæsthetic effect varies from a fluid ounce to a pint or more, with different subjects. The symptoms that usually follow etherization are headache, giddiness, nausea, and depression—one, or all combined. Ether cannot be regarded as very dangerous to life, as but few cases of death from its use are on record.

Chloroform (C_2HCl_3, or 12 parts carbon, 1 part hydrogen, and 105 parts chlorine) was first brought into use for anæsthesia by Dr. Simpson, of Edinburgh. From its potency it was rapidly adopted in surgical practice, and extended until the the fearful record of deaths caused by it excited caution in its use. Chloroform acts more rapidly than ether, and a much smaller dose suffices. From a drachm to a half ounce is commonly employed. Chloroform is rapidly transformed in the blood, formic acid being produced in a quantity to admit of detection.

Air is necessary to sustain respiration while inhaling chloroform. The symptoms that follow the anæsthetic effect of chloroform are much the same as those of ether, but generally more aggravated.

The pulse lowers during the inhalation of both ether and chloroform, falling sometimes to forty a minute, which is considered the utmost limit of safety.

With the data now before us, we can institute a comparison between the merits of the three principal anæsthetic agents.

Nitrous Oxide supports respiration, and exalts the functions of the animal system. It is composed of the same elements that constitute the air we breathe, and hence must be most nearly normal. It produces *carbonic acid* by decomposition in the circulation; but this is not a foreign substance, for the air generates it there also. It is the most harmless in its effects.

Ether will not support respiration. It sickens and depresses the patient. It introduces acetic acid (vinegar) in the blood, which is unnatural, to say nothing of its own foreign nature and hurtful tendency.

The same may be said of chloroform as of ether, with regard to distressing effects. It produces formic acid in the blood, which is a rank poison. Lastly, chloroform is dangerous to life.

There are very many substances that will produce anæsthesia, as, for instance, many of the ether series, and a number of other hydrocarbons. Oil of turpentine has been used at sea by a ship surgeon for various operations.

I will venture a theory as to the primary cause of anæsthesia. I have supposed it to be the introduction into the blood of a foreign substance (or, in the case of Nitrous Oxide, carbonic acid beyond the normal quantity). Possibly it is essential that the substance be carbonaceous, as is the case, directly or indirectly, with all known anæsthetics. I am of opinion that Nitrous Oxide owes its anæsthetic effect to the formation of carbonic acid in the circulation faster than is is eliminated.

CHAPTER VII.

PRACTICAL SUGGESTIONS.

A recapitulation of the practical points in the generation and management of Protoxide of Nitrogen, with some additional observations, may not be out of place.

The nitrate of ammonia should be pure, white, and free from chlorides, sulphates and organic matter, to guard against irrespirable products. *Fused* nitrate of ammonia, all circumstances considered, is the best. This is free from water, and consequently it is not necessary to boil the product for a time before gas is given off. The fused nitrate is in lumps somewhat resembling loaf sugar, but which are easily broken into fine fragments. *Granulated* nitrate of ammonia may or may not be free from water when first made, but its state of comminution causes it to speedily absorb water and gain weight when exposed to air. Crystallized nitrate contains the full amount of water, or a little more than 10 per cent. This is when the salt is not deliquesced. In the latter case it contains still more water. All the foregoing varieties of nitrate of ammonia are deliquescent, and if in bulk, should be kept in a closely corked stone jar, to exclude the air.*

Fused nitrate of ammonia, broken into fragments about the size of a wheat grain, endangers the retort less than the finely granulated; it distributes the heat more rapidly and uniformly through the interstices on first applying the lamp. Retorts or flasks of Bohemian glass are most esteemed for generating gas, although I have seen those of American manufacture quite as good as the best imported.

The heat may be supplied by means of a Bunsen or other suitable gas burner, or when gas is not at hand, an alcohol lamp, or kerosene stove may be used.

The nitrate will slowly melt, and soon afterwards send off bubbles of gas in abundance. The retort must be watched, in order that the heat may not become so great as to endanger it, by the violent ebullition of the contents. But the regulation of the heat is of more

* To avoid this inconvenience I am packing nitrate of ammonia in hermetically sealed tin cans of 5 lbs. each.

importance, on account of the danger of making impure gas, by too high a temperature. Sometimes, with a charge of three pounds or more, of nitrate in the retort, after decomposition has commenced briskly the heat may be entirely withdrawn, and the gas will go on generating until the charge is almost wholly exhausted. Practically, one pound of nitrate of ammonia should be put in the flask for every thirty-five gallons of gas wanted.

The apparatus may be arranged in the following manner: A beaked retort (1 quart capacity to each ¾lb. nitrate, which will be a guide as to size,) is set in the ring of a lamp furnace. A piece of india rubber hose three feet long and about one inch internal diameter, slips over the beak of the retort, making a tight joint, and connects by a glass tube with the first of a series of five or six Wolfe bottles. The first tube in connection with the hose reaches very nearly to the bottom of the first bottle. The exit tube from the same bottle only just enters (so as to be above the surface of the fluid inside,) and descends nearly to the bottom of the next or second bottle. Then another tube from the second bottle (above the surface of the fluid) is connected with the third, and so on through the series. With this arrangement it is easy to see that gas, in passing through, will be compelled to bubble through the liquid in each bottle. The exit tube from the last bottle is connected by flexible hose with the gasometer. The bottles should not be of less capacity than ½ gallon each, and gallon bottles are preferable. The gasometer is such as we have before described. The pressure on the retort will be that of a column of water equal to the sum of the depths through which the tubes dip, added to the height of water the gas has to overcome in entering the gasometer. Thus, if six tubes each dip six inches under water in the bottles, and the gas has to rise through three feet of water in the gasometer, the aggregate pressure will be equal to that of six feet of water, or nearly three pounds to the square inch on the interior surface of the flask.

The first two bottles may contain solution of caustic potassa (½ pound potash to one gallon water,) and the next two solution of sulphate of iron, (pure copperas, ½ pound to one gallon water.) The iron and potash must never be mixed in the same bottle, for they are incompatible. The last two bottles may contain pure water. If desired, copperas solution alone may be used in each bottle. So with potash. All things being in readiness, introduce the nitrate of ammonia into the flask and apply the heat underneath, very gradually at first, to prevent fracture of the glass. Do not let the gas generate faster than two gallons per minute, to be certain of a pure product as it enters the gasometer. If a great quantity of white fumes arise, or the smallest quantity of red vapor is visible in the retort, it is a sign that an improper decomposition is taking place, and the gas will contain a large portion of deutoxide of nitrogen, and will require to stand in the gasometer a time for purification.

It should be observed that the flask may be heated until the nitrate melts, before the hose is slipped over the beak. In this way most of the air which fills the flask may be expelled.

When the requisite quantity of gas is made, and the heat withdrawn, the hose should be removed from the first bottle, to prevent the liquid in the bottle from sucking back and breaking the retort.

It is advisable to put a glass safety tube—open at both ends, and a little longer than the total water pressure indicates—in the first bottle just dipping under the surface of the fluid inside, to guard against bursting in case of stopage of any of the tubes. This will also prevent water from drawing back into the retort, as the safety tube will let in air to supply the partial vacuum created by the flask in cooling. After the gas is made, breathe a little of it and observe whether there is a coppery taste, or hot sensation in the lungs. If not, the gas may be relied upon for purity. But if it appears to be impure it must stand in the gasometer until it can be breathed pleasurably.

In giving the gas, it is generally desirable to stop the patient's nose to prevent him from breathing air, or the inhaler which fits over mouth and nose at the same time must be employed.

The anæsthetic state comes on in from thirty seconds to a minute and a quarter. When the patient breathes stertorously, give him no more gas, and perform the operation as quickly as possible; for in thirty seconds more he may be sensible to pain.

Dr. Howland informs me that when the patients sit erect they do not "snore" in more than one case out of five, and he considers it injudicious to let them recline backwards in the chair.

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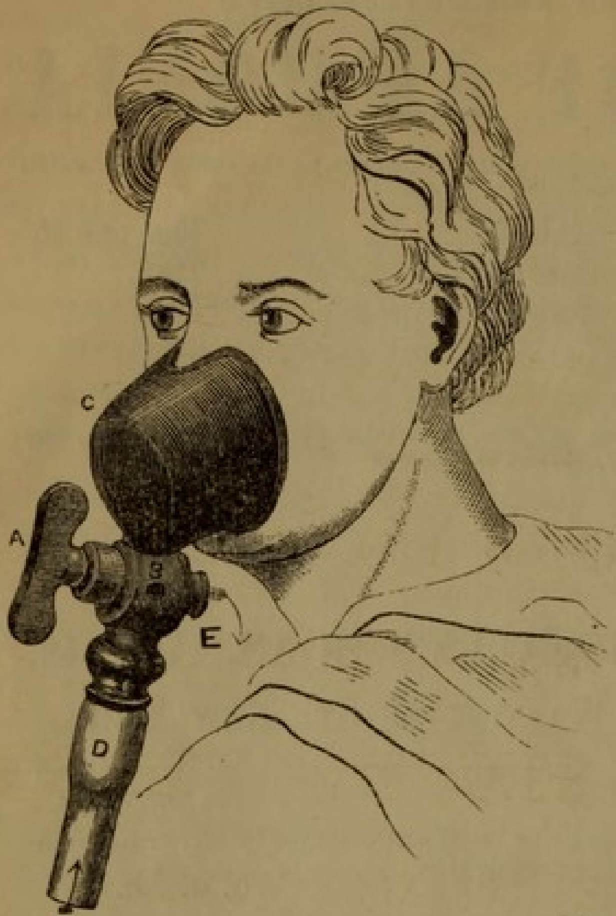

DESCRIPTION.

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c. Face-piece, covering both the mouth and nostrils.

d. Inhalation Valve, to admit the gas.

e. Exhalation Valve, to throw off the impure gas and breath.

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