

tion of the fumes of a bowl of boiling water charged with a few drops of carbolic acid may allay pain and cough considerably. So, again, irritability of the stomach may be quieted by this agent, and carbolic acid in small doses ranks among the standard means for arrest of vomiting. As an *antipyretic* carbolic acid is undoubtedly powerful, but its poisonousness will probably always defeat it in competition with such potent and at the same time innocent antipyretics as sodium salicylate, the cinchona alkaloids, antipyrin, etc.

For *internal administration* the dose of carbolic acid should not exceed from one to four or five drops, and the daily allowance should not surpass 1 gm. (gr. xv. or ʒ. xv.). A convenient way of giving is first to dissolve in glycerine, in which menstruum carbolic acid dissolves in all proportions, and then dilute the necessary quantity of glycerine solution with water. Each dose of acid should be diluted to at least the volume of a tablespoonful for the taking. Under the title, *Glyceritum Acidi Carbolici*, Glycerite of Carbolic Acid, the United States Pharmacopœia makes official a twenty-per-cent. (by weight) solution of the acid in glycerine.

For *external uses* aqueous solutions are most generally serviceable, as already so frequently seen. There is official in the United States Pharmacopœia a preparation entitled *Unguentum Acidi Carbolici*, Ointment of Carbolic Acid, which consists of official "ointment" charged with five per cent. of carbolic acid.

Edward Curtis.

CARBOLIC ACID, POISONING BY.—Carbolic acid or phenol is one of the most common materials used for suicidal purposes at the present time. This is especially to be wondered at because of its corrosive action and the consequent pain it causes. It is, however, easily obtainable without the need of a prescription, and it does its work with certainty and generally with despatch.

Carbolic acid is a name that was given to the substance obtained from coal tar on account of its corrosive action and because it readily combined with certain basic substances to produce so-called carbolates. In its chemical relations, however, it has been shown to be closely allied to a class of compounds of the fatty-acid series known as tertiary alcohols, or, in the case of the aromatic or cyclic compounds, as phenols. It seems to unite chemically with a few bases, making compounds known as carbolates in which it acts like an acid. It also unites with acids, especially sulphuric acid, and forms salts in which it acts like an organic base.

Phenol is met with in commerce in a number of forms. First, as crude carbolic acid used as a disinfectant and germicide. This preparation is reddish or dark brown, and contains not only phenol but one or more higher homologues known as cresols. It has an odor like smoke and a strongly caustic and biting action on the skin. Secondly, as the carbolic acid or phenol of the United States Pharmacopœia, consisting of a mass of interlaced crystals, white or slightly reddish in color. These crystals are deliquescent on exposure to moist air. This phenol melts readily to a clear, oily liquid, and as it cools again becomes once more a crystalline mass. The addition of eight per cent. of water to the melted liquid prevents its solidifying on cooling. It dissolves in about fifteen parts of water, and also dissolves readily in alcohol, ether, chloroform, benzole, carbon bisulphide, glycerin, and fixed and volatile oils. Thirdly, a solution of the crystals more or less strong kept in every pharmacy as a stock material for prescription use. Fourthly, a mixture of phenol with lard and yellow wax known as *Unguentum Acidi Carbolici* (U. S. P.).

All these forms of phenol are intensely corrosive and deadly in their action. On the skin the strong phenol causes a numbness and sense of irritation or burning. The surface of the skin becomes white, the cuticle after a time falling off and leaving a dark stain. At times the sensibility of the skin is nearly destroyed by contact with the acid, a sense of numbness only being noticed.

A number of fatal cases of poisoning have occurred in

which phenol has either been applied to the surface of the unbroken skin or to a mucous membrane, or has been used as an antiseptic material in treating wounds. In these cases of direct absorption the action of the phenol has been very rapid, producing sudden insensibility.

When swallowed there is at once a hot, burning sensation in the mouth, throat, and stomach. The lining membrane of the mouth is whitened by the contact of the phenol, while the lips are usually more or less brown where the liquid has come in contact with them.

The skin is dry and livid, the pulse is feeble, the pupils very much contracted, the breathing noisy, and the breath smells more or less strongly of the poison. Cases are on record, however, in which the odor has been entirely absent from the breath. At times vomiting occurs. There are usually delirium and giddiness, passing soon into a condition of insensibility. The urine, if any, is dark colored and cloudy.

Death usually occurs within a few hours, and in some instances has occurred within a few minutes.

The amount necessary to cause death is unknown. As with many other poisons, recovery has taken place after a large quantity has been swallowed and death has followed the ingestion of a few drops only.

The *Treatment* consists in the use of the stomach pump, the administration of saccharate of lime and of soluble sulphates, and, recently, very excellent results have been obtained by the use of strong alcohol after the stomach pump has taken out the most of the poison. Alcohol has proved useful also to check the action of the poison when applied to the skin. Stimulants are to be used to combat symptoms of collapse.

In fatal cases the lips where the phenol has come in contact with them are stained brown, the mucous membrane of the mouth is dirty white or brown; the stomach is contracted, and its mucous membrane in folds and white in some places, and in some spots greatly inflamed. The odor of phenol is generally noticeable on opening the stomach. The brain, lungs, liver, and kidneys usually show marks of congestion. The left ventricle of the heart is usually contracted, while the right is flaccid. The blood throughout the body is dark-colored and fluid. When phenol is absorbed by the skin there are no characteristic internal post-mortem changes.

The odor of phenol gives the best indication of its presence, but chemical tests in addition should be made to make the identification certain. To this end the material for examination is made acid with sulphuric acid and distilled. The distillate may or may not give the odor of phenol.

In a portion of the distillate place a splinter of pine wood, and on removal from the distillate moisten the splinter with hydrochloric acid. If phenol is present the splinter will turn blue or green. This test should be corroborated by a known solution of phenol.

To a small portion of the distillate add about one-fourth its volume of ammonium hydrate and then a small quantity of a solution of calcium hypochlorite. A blue color appears at once or on standing for a time in the presence of phenol.

To a portion of the distillate add bromine. If phenol be present a white precipitate of bromo-phenol is formed. This may be further tested, after it has been thoroughly washed, by treating it with sodium amalgam (prepared by dissolving sodium in mercury), and then making the solution acid. If phenol be present the characteristic odor of phenol will be developed. Herbert M. Hill.

CARBON DISULPHIDE.—CS₂. This body, commonly called by the older chemical title *bisulphide of carbon*, is official in the United States Pharmacopœia as *Carboni Disulphidum*, Carbon Disulphide. It is thus described: "A clear, colorless, highly refractive liquid, very diffusive, having a strong, characteristic, but not fetid, odor, and a sharp, aromatic taste. Soluble in 535 parts of water at 15° C. (59° F.); very soluble in alcohol, ether, chloroform, fixed and volatile oils. Specific gravity, 1.268 to 1.269, at 15° C. (59° F.). Carbon disulphide va-

porizes rapidly at the ordinary temperature, is highly inflammable, boils at 46°–47° C. (114.8°–116.6° F.), and, when ignited, burns with a blue flame, producing carbon and sulphur dioxide. It should not affect the color of blue litmus paper moistened with water" (U. S. P.). Carbon disulphide should be kept in tightly closed vessels and away from lights or fire. The "strong characteristic, but not fetid, odor" of the above description, though "not fetid" in a perfectly pure sample, is, in the article as commonly met with in the shops, of a rotten-egg quality, so disagreeable and so strong as to constitute a practical bar to a common medicinal use of the compound. The high volatility and extreme inflammability are also points of inconvenience, and the latter quality one of danger also.

Carbon disulphide is a powerful agent, of the general type of the volatile alcohols and ethers. It is locally irritant while yet specifically anaesthetic, and, absorbed into the blood, profoundly deranges the nervous functions in the same general manner as chloroform does. Habitually absorbed, as may occur by breathing the fumes in india-rubber factories, where the agent is largely used, carbon disulphide produces a peculiar form of chronic poisoning, elaborately described by Delpech as observed in Paris workshops. The poisoning commonly begins by severe headache, sometimes accompanied by an exhilarant intoxication. Later follow depression, mental apathy and dulness, loss of memory, impairment of sight, hearing, and sexual desire, and a very pronounced loss of muscular power. Cramps and various dysæsthesiæ are also common. The poisoning is seldom fatal, but, on the other hand, after full development, entire recovery of health and strength is unusual. Treatment is upon general principles, the only special agent recommended being phosphorus, by the use of which in small doses Delpech thinks he has abated the failure of muscular and virile power.

Medicinally the only properly allowable use of carbon disulphide is as a local application for the relief of surface pains. In this employment the action is like that of chloroform—conjointly anaesthetic and sharply irritant. An application of carbon disulphide causes for a few minutes severe pain, and may or may not be followed by subsidence of a neuralgia. The remedy may be used in vapor by saturating with carbon disulphide a sponge at the bottom of a wide-mouthed flask, and then pressing the mouth of the flask to the skin. Carbon disulphide has been given internally in doses of a few drops, but in the absence of any unique therapeutic powers such administration is certainly not to be recommended.

Edward Curtis.

CARBON, HYDRIDES AND OXIDES OF.—There are two well-known oxides of carbon, viz., carbon monoxide and carbon dioxide, or carbonic anhydride. They are both invisible gases at ordinary temperatures and pressures; and are of interest to the physician from the fact that they are both irrespirable gases with which persons are frequently brought in contact, and which frequently produce poisonous and even fatal results. Carbon dioxide plays an important rôle in the physiology of the human organism. The names used to designate these compounds are somewhat variable and confusing, and, to avoid this uncertainty, we place all the names commonly met with at the head of the proper sections.

CARBON DIOXIDE.—Also called *carbonic-acid gas* and *carbonic anhydride*. (Fixed air, choke damp.) Chemical formula, CO₂. Specific gravity (air = 1), 1.52; density (hydrogen = 1), 22.

Sources.—When carbon is burned in oxygen, or with a free supply of air, this gas is formed; hence it is a product of the combustion of all combustible bodies containing carbon. It is prepared in large quantities, by many manufacturing processes, from the combustion of coal. The burning of lime kilns sends large volumes of this gas into the air, partly from the fire and partly from decomposition of the limestone (CaCO₃) into lime and CO₂. Respiration is another source of the gas, and the expired

air may accumulate in a tight room to such an extent as to become poisonous,—indeed, in some cases, to such an extent as to cause death. An adult man exhales about .7 cubic foot (20 litres) of CO₂ per hour, or 18 cubic feet (499 litres) per day. Another source of carbon dioxide is the alcoholic fermentation of saccharine fluids. This source is usually limited to certain kinds of industries, such as beer, wine, alcohol, and whiskey manufactories. In badly ventilated fermenting rooms, deaths have often occurred from the accumulation of this gas. The subterranean heat of volcanic regions causes the decomposition of limestone as above mentioned, giving off CO₂, which either escapes through crevices, or accumulates in underground caverns, under pressure, and finally becomes absorbed by the water, and comes to the surface in the form of effervescing spring-water, as at the well-known Saratoga Springs. The gradual oxidation of vegetable matters, either upon the surface of the soil or buried in it, generates a considerable quantity of carbon dioxide. The gas from these various sources may filter through the soil, crevices in the rock, or coal bed, and accumulate in mines, wells, cellars, etc., in such quantities that the miners are unable to work in it. It is called by them *choke damp*, to distinguish it from *fire damp*. It is produced in mines by an explosion of marsh gas (fire damp), so that if the explosion does not kill persons unfortunate enough to be in the mine at the time, they may die from breathing the CO₂ developed by the explosion. The atmosphere, as will be seen, is continually receiving this gas in abundance from the above sources; hence, outdoor air always contains about .4 part per 1,000. The air of rooms and closed places frequently contains a much larger proportion than this. A well-ventilated room should contain not more than .6 part per 1,000; but owing to poor ventilation it frequently rises as high as 4 parts per 1,000 or more. Even in the open air, the amount depends somewhat upon the state of the weather, season of the year, etc. In still, foggy weather in large cities, the amount present in outdoor air may rise as high as .8 part per 1,000, or enough to give the air a peculiarly suffocating effect upon those who breathe it.

Properties and Preparation.—Carbon dioxide is a colorless, transparent, odorless gas, about one and a half times heavier than air, and may be poured from one vessel into another like water. It has a faintly acid taste. At ordinary temperatures it is soluble in its own volume of water, with which it probably enters into combination to form carbonic acid: CO₂ + H₂O = H₂CO₃. By increasing the pressure, water will absorb a very large amount of the gas, a large portion of which escapes again when the pressure is removed. The so-called *plain soda* is a strong solution of carbonic acid (H₂CO₃) in water, made under pressure. The gas may be expelled by heat, by freezing, or by removing the pressure. Under a pressure of fifty atmospheres at 15° C. (59° F.), it is condensed to a transparent, colorless, mobile liquid, not miscible with water or fixed oils, but readily so with ether, alcohol, naphtha, turpentine, and carbon disulphide. When the pressure is removed from the liquid it evaporates with great rapidity, freezing a portion of the liquid into a snow-like solid, by the heat absorbed in the evaporation. The solid evaporates very slowly, and may be kept longer than the liquid. By moistening this solid with ether, and placing it under the bell-jar of an air pump, a temperature of -110° C. (-166° F.) may be obtained. Carbon dioxide is soluble in about one-third its own volume of alcohol at the ordinary temperature and pressure. Dry carbon dioxide has no effect upon litmus paper; but if the latter be first moistened it is reddened. On drying, the blue color is restored. Lime water is at first rendered turbid by CO₂, owing to the precipitation of calcium carbonate; but on conducting the gas into the turbid liquid for some minutes, the precipitate is redissolved, and the solution becomes clear again, owing to the formation of calcium bicarbonate (H₂Ca(CO₃)₂). This process frequently takes place in natural waters to produce *temporary hardness*, so called, because

the calcium, and at times magnesium carbonate thus held in solution, is precipitated by boiling off the excess of carbon dioxide. Solutions of caustic soda, potash, lime, baryta, etc., rapidly absorb CO_2 with the formation of carbonates of the metals. Such solutions are used to dissolve the gas from mixtures containing it. The gas does not support either respiration or combustion, although this property is not peculiar to carbon dioxide. It is not combustible. Sodium, potassium, phosphorus, boron, carbon, iron, zinc, and magnesium, at high temperatures, decompose it by removing its oxygen and converting it into either carbon monoxide or carbon. It is also decomposed by the chlorophyll of plants under the influence of sunlight and moisture, the carbon combining directly with the water to form formaldehyde, $\text{CO}_2 + \text{H}_2\text{O} = \text{CH}_2\text{O} + \text{O}_2$, while the oxygen escapes in the free condition. The formaldehyde then readily polymerizes to form dextrose and the other soluble carbohydrates: $6 \text{CH}_2\text{O} = \text{C}_6\text{H}_{12}\text{O}_6$. Carbon dioxide is usually prepared in the laboratory by treating a carbonate, usually calcium carbonate or marble, with a dilute mineral acid: $\text{CaCO}_3 + 2\text{HCl} = \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2$.

Uses.—The following are among the most important uses of carbon dioxide: Notably, in the manufacture of carbonates and bicarbonates, carbonated beverages, white lead, the decomposition of sucrate of lime in the preparation of sugar from beets, in setting free the hypochlorites from chloride of lime, in bleaching, and in giving a head to beer, ale, wine, etc.

Physiological Action.—The physiological effects of carbon dioxide vary with the degree of dilution or admixture with air. When inhaled in the pure state it causes almost instant death from spasm of the glottis and *apnoea*. Even when somewhat diluted, there is almost immediate insensibility and loss of muscular power, and the person drops as if felled by a blow, and usually dies without a struggle, unless immediately removed into pure air. Such accidents are most likely to occur from going into deep wells, caves, mines, etc., where the gas, termed *choke damp* by miners and well-diggers, has accumulated; or, from putting the head into a fermenting vat which has been closed for a time; or from venturing too near to the mouth of a lime kiln, burning buildings, or volcanoes.

When more largely diluted, or, as is most likely to occur, when the air is gradually poisoned by it, the first feeling is a sense of closeness; then follow weight or fulness in the head, pressure in the temples, giddiness, singing in the ears, somnolency, sometimes nausea and loss of muscular power. Death is preceded by coma, with stertorous breathing, rarely vomiting and convulsions; the face is usually of a leaden hue, or pale, and the heart's action, at first violent, finally stops. It is not poisonous when taken into the stomach.

Post-Mortem Appearances.—The body of a person killed by carbon dioxide usually presents a livid, or very pale, external appearance. The face has sometimes been found swollen and distorted, but usually it is placid and there is no evidence of a struggle. The body is found in an easy, natural position, as though in a sleep at the time of death. The superficial veins are usually prominent, and are filled with dark liquid blood. There is nearly always congestion of the brain and its membranes, with engorgement of the sinuses, and congestion of the lungs. The blood is usually liquid and dark-colored. When the source of the poisonous gas is from burning coals, the carbon dioxide is mixed with carbon monoxide, and the blood in this case is bright red instead of dark, and coagulates with difficulty. Putrefaction of the body after carbon-dioxide poisoning takes place slowly, and bodily heat and rigidity are retained an unusually long time. All the internal viscera are usually found congested.

Injurious (Non-Fatal) Effects of the Presence of Carbon Dioxide in the Air of Rooms.—Thus far we have discussed the action of carbon dioxide upon the economy when present in the air in sufficient quantity to cause death. When the air is not so largely charged with this gas, the symptoms and effects are less marked,

but may still be sufficient to occasion some distress. When the air of a given room or locality contains more than 6 or 7 parts per 10,000, it is to be considered contaminated or impure. An adult man exhales about .7 cubic foot (19 litres) of carbon dioxide each hour. This quantity will raise the contents of 3,500 cubic feet of air from .4 to .6 part per 1,000 each hour. It is evident, therefore, that this amount of air must be supplied to each adult man each hour, in order to keep the air he breathes from having more than .6 part per 1,000, or so as not to add more than .2 part per 1,000. It has also been found that the air of a room cannot be changed more than three or four times per hour without causing draughts. Hence $(3,500 \div 4 = 875)$ an adult man should have about 900 cubic feet of space for comfort, when proper care is had to ventilation. When air moves more than 19 inches per second a draught is perceived. If there were no ventilation through walls, which is rarely the case, an open window, having an opening of 6 square feet, would allow 3,420 cubic feet of air to pass, when the draught is barely perceptible; or enough for a healthy adult man. Parkes, in his "Hygiene," p. 161 (Wood's Library), gives the following figures as representing the average amounts of CO_2 given off per hour by persons of different ages when in a state of repose. For adult males (say 160 pounds), .7 cubic foot; for adult females (say 120 pounds), .6 cubic foot; for children (80 pounds), .4 cubic foot; for a mixed community, .6 cubic foot. Under these conditions the amount of fresh air to be supplied in health, during repose, ought to be: For adult males, 3,500 cubic feet; for adult females, 3,000 cubic feet; for children, 2,000; for a mixed community, 3,000 cubic feet, per head, per hour. As more CO_2 is evolved from the body on exertion, these figures are too low for workshops, factories, mines, etc. In mines it has been found that 6,000 cubic feet of air per hour is necessary to keep up the greatest energies of the men. With light work a man weighing 160 pounds throws off .95 cubic foot of CO_2 in one hour, while in heavy work the same man would throw off 1.96 cubic feet per hour. This would require for light work the delivery of 4,750 cubic feet of fresh air per hour, and for heavy work, 9,800 cubic feet. The amount of air necessary for cattle, horses, and other large animals, is estimated by Marcker ("Proceedings of Civil Engineers," vol. xii., pp. 298 and 308) as 1 to 1.5 cubic feet per hour for every pound of weight, or 1,000 to 1,500 cubic feet for every 1,000 pounds of weight. For small animals (sheep, dogs, cats, etc.), 150 to 180 cubic feet of air per hour should be supplied for each 100 pounds weight. Birds require even more. The following table, from Parkes' "Hygiene," shows the amount of contamination produced by one man in different-sized spaces for one hour and each succeeding hour:

TABLE TO SHOW THE DEGREE OF CONTAMINATION OF THE AIR BY RESPIRATION (IN TERMS OF CO_2), AND AMOUNT OF AIR NECESSARY TO DILUTE TO A GIVEN STANDARD OF .2 PER 1,000 VOLUMES, EXCLUSIVE OF THE AMOUNT ORIGINALLY PRESENT IN THE AIR.

Amount of cubic space (= breathing space) for one man in cubic feet.	Ratio per 1,000 of CO_2 from respiration at the end of one hour, if there has been no change of air.	Amount of air necessary to dilute to standard of .2 during the first hour.	Amount necessary to the given standard every hour after the first.
100	6.00	2,960	3,000
200	3.00	2,800	3,000
300	2.00	2,700	3,000
400	1.50	2,600	3,000
500	1.20	2,500	3,000
600	1.00	2,400	3,000
700	.86	2,300	3,000
800	.75	2,200	3,000
900	.67	2,100	3,000
1,000	.60	2,000	3,000

In hospital wards, where sick persons are confined, ventilation should supply more air than is required by the healthy. This is due not alone to the CO_2 which

they give off, but to organic emanations which permeate the air and give it an unpleasant odor and closeness. In hospital wards, Parkes lays down the rule that the quantity of air supplied should be from 4,000 to 4,500 cubic feet per person each hour. The following table from Witthaus' "Chemistry" gives the amount of air which ought to be supplied to each person under the conditions annexed:

Situation.	Cubic metres.	Cubic feet.
Barracks (day-time).....	35	1,236
Barracks (night-time).....	70	2,472
Workshops (mechanical).....	70	2,472
Schoolrooms.....	35	1,236
Hospital wards.....	85	3,004
Hospital wards (surgical).....	170	6,004
Contagious and lying-in wards.....	170	6,004
Mines.....	150	5,297
Mines (coal).....	170	6,004

This table assumes that no artificial light is used; but even in this case, the quantities given are smaller than most physicians would prefer to supply. No hospital ward occupied by a number of persons should supply less than 4,500 or 5,000 cubic feet of air, per person, every hour, and in the case of most septic diseases, outdoor air is to be preferred.

Carbon Dioxide from Gas-Lights.—A burner which burns 3 feet of gas per hour (ordinary size) produces about 2 cubic feet of CO_2 per hour, and removes a corresponding amount of oxygen from the air. It has been calculated that each burner of the usual form (not Argand) should be supplied with from 4,500 to 5,500 cubic feet of air per hour to prevent injurious contamination with CO_2 . Owing, however, to the evolution of heat and watery vapor, and the removal of oxygen, a larger quantity than this should be supplied to keep the air comfortable. A cubic foot of coal gas produces about from .5 to .8 cubic foot of CO_2 , being rather higher for "water gas" than for "coal gas." A burner consuming 3 feet of gas per hour would produce from 1.5 to 2.5 cubic feet of CO_2 , being a little more than three adult men, or four average persons, would produce. Pettenkofer has determined that a burner consuming 5 feet of gas per hour, giving 12 candle power, gives off as much heat as 8 men, more CO_2 than 3 men, and as much watery vapor as 5 men. Adopting this as a basis of calculation, a 3-foot burner should be supplied with as much air as 3 persons, or about 9,000 feet per hour, to keep the air in a comfortable condition. In reality, this amount of ventilation is seldom obtained in a room of ordinary size. The basis of calculation that has usually been adopted is to furnish 1,800 cubic feet of air for each foot of gas burned. For the same illuminating power, oil does not give a greater degree of contamination than gas. An ordinary lamp gives about the same contamination to the air of a room as one adult man.

Tests for Carbon Dioxide.—The physician may be called upon to test the air of rooms, or enclosed spaces, for CO_2 , either for diagnostic or for medico-legal purposes. The following simple tests may be employed: A moistened, blue litmus paper suspended in the air of the room is at first reddened and then bleached by carbon dioxide. If the amount of CO_2 exceed ten or twelve per cent., and if it have been added to the air, without the removal of any oxygen, a candle will usually be extinguished. If the CO_2 has been produced by combustion or respiration, the candle will be extinguished by five per cent. An atmosphere in which a candle will burn may be fatal to animals or man. Lime water or barium hydroxide (baryta water) is rapidly rendered turbid on pouring it from one vessel into another in an atmosphere rich in CO_2 . A piece of filter paper dipped in lime water colored red with phenolphthalein is bleached white by CO_2 , the rapidity of the bleaching depending upon the amount contained in the air. Or the same colored solution may be poured into a bottle filled with the air of the space as follows: Fill a quart bottle with water, and pour it out slowly in the room whose air is to be tested, or, better, siphon it out, using a piece of rubber tubing as a siphon. One cubic centimetre of thoroughly saturated lime water, colored pink with phenolphthalein, should be decolorized

by 1.6 litre (1.6 quart) of outdoor air, or one quart (roughly) of ordinary indoor air. The air of a room should not decolorize more than 1 c.c. for each quart. The 1 c.c. (1/16 xv.) of colored lime water may be diluted to 15 c.c. (3/8 ss), with distilled water and poured into a quart bottle of the air, and shaken up. If the color be discharged, add .5 c.c., and so on until a permanent color remains after ten minutes' shaking. Where proper appliances are at hand, it will be much more accurate to use the following method:—

Pettenkofer's Method for Estimating CO_2 in Air.—A glass globe or bottle holding about 4 litres is carefully measured by filling it with water and then pouring the water out into a suitable graduated measure. The bottle is now filled by an air bellows with the air to be tested. Twenty-five cubic centimetres of barium hydroxide solution of known strength, in comparison with a 1/1000 oxalic acid solution, are added, and the bottle is tightly corked and allowed to stand for a half-hour, with occasional shaking. At the end of this time the stopper is removed, a few drops of phenolphthalein solution added, and the 1/1000 oxalic acid run in from a burette until the pink color is just discharged. The oxalic acid combines with the unused BaO_2H_2 , but does not decompose the barium carbonate formed by the CO_2 of the contained air. If the number of cubic centimetres of acid required to neutralize 25 c.c. of the barium hydroxide solution put into the bottle be known, or determined by a separate titration, the difference between this number and the number of cubic centimetres used in neutralizing the residual BaO_2H_2 , will represent the acid equivalent of the CO_2 in the air contained in the bottle, expressed in cubic centimetres of 1/1000 acid.

If we make the oxalic-acid solution by dissolving .2863 gm. of the pure crystalline acid in a litre of water, each cubic centimetre will represent 1 mgm. of CO_2 . The volume of 1 mgm. of CO_2 at 15° C. (59° F.) at the average air pressure, is .536 c.c. At 17° C. (62.6° F.) the volume is .544 c.c. At 20° C. (68° F.) it is .546 c.c. At 22° C. (71.6° F.) it is .549. By means of these figures the volume of the CO_2 found may easily be calculated by multiplying the number of cubic centimetres of acid corresponding to the loss of saturating power of the BaO_2H_2 solution, by the volume of 1 mgm. of CO_2 at the temperature of the room when the sample was taken. From the volume thus obtained it is easy to calculate the relation of this to the air taken. Suppose, for example, that the bottle contains 4,500 c.c. when full. After adding the 25 c.c. of barium hydroxide it would contain 4,475 c.c. Assume, also, that the temperature of the room at the time of filling the bottle is 22° C., or 71.6° F., and that the titration of the residual BaO_2H_2 in the bottle required 14 c.c. of the oxalic acid. Suppose, further, that 25 c.c. of the BaO_2H_2 solution requires 22 c.c. of the acid. Then $22 - 14 = 8$ c.c., the acid equivalent of the CO_2 in the contained air, and its weight = 8 mgm. At 22° C. the volume of 8 mgm. of CO_2 is $.549 \times 8 = 4.392$ c.c.

Then $4475 : 4.392 : : 1,000 : x = .986$ part of CO_2 in 1,000 parts of air.

CARBONIC ACID (H_2CO_3) exists only in solution. It has not yet been isolated. When an attempt is made to concentrate it, the acid breaks up into water and carbonic anhydride (CO_2), which escapes with effervescence. The salts of the acid, the carbonates and acid carbonates (bicarbonates) are well known. Carbonic acid is a feeble acid, and is expelled from its salts by most strong acids. The carbonates all effervesce when treated with the mineral acids, and this serves as a ready test. Some of the metals are dissolved by this acid, but with great slowness. Copper and lead are corroded by it, and hence these metals may contaminate "soda water," beer, etc., drawn through pipes composed of these metals.

CARBON MONOXIDE.—*Carbonous Oxide, Carbonic Oxide (CO).* This gas was discovered in 1799 by Priestley. It is always formed when carbon, or combustibles containing carbon, are burned with an insufficient supply of air. It does not occur free in nature except as the result of certain manufacturing processes. It is produced by the