CHAPTER IV

SOME USEFUL INORGANIC CHEMICAL PRODUCTS AND PROCESSES

GLASS.

The chief constituent of glass is silica or sand, in fact both transparent and opaque glass may be made from pure silica merely by melting and allowing to cool. Such glass has certain remarkable properties. Thus it may be heated to red-heat and then immediately plunged into cold water without the risk of fracture. This is due to its exceedingly small coefficient of expansion. Another point is that transparent silica, or quartz glass as it is sometimes called, permits ultra-violet light to pass through it almost completely. Less than 10% of the incident radiations fail to pass through, which as Fig. 6 shows is considerably less than that rejected by the special ultra-violet glasses. The great difficulty in the preparation of silica glass is the very high temperature necessary to render it molten, and this fact makes the glass extremely troublesome to manipulate. To obtain the requisite high temperatures electric furnaces are used, which, however, are only able to melt relatively small amounts.

As a rule glass contains 70% to 80% of silica, a fair proportion of some basic oxide, e.g., potash, soda, lime, lead oxide, and occasionally small quantities of other ingredients which are added to impart to the glass some particular quality. As shown on page 32, the function of the basic oxide is to convert the silica into a metallic silicate which incidentally lowers considerably the temperature at which the glass fuses. This is a most important factor in the manufacture of glass, though the use of too great an amount of soda tends to make the glass soluble in water and would thereby render the glass unsuitable for use in windows. The following tables, which were compiled by Prof. W. E. S. Turner of the Department of Glass Technology of the University of Sheffield, and are taken from "The Listener," 1929 (January 16) show, at a glance, the various substances used in a glass manufacture and also typical mixtures used for glass-making.

Before mixing, each ingredient is finely ground. Melting is carried out in a suitable furnace at about 1400–1500° C. It takes from 10 to 12 hours. Much frothing occurs due to the evolution of gases, such as carbon dioxide from the sodium carbonate, and a scum forms on the surface of the molten glass. This scum is carefully removed.

Numerous schemes have been used for the production of sheet glass, though they are being rapidly superseded by mechanical methods. Plate glass is made by flowing the molten glass into moulds, in which, after cooling somewhat, the upper surface is subjected to a preliminary smoothing by a single rolling. When it has solidified, it is annealed by passing through a lehr in which the temperature is slowly lowered. Afterwards its surfaces are polished by machinery. Ordinary window glass is not made by this process. The older methods consisted of dipping an iron tube into molten glass, so as to attach an amount, about the size of a man's head, and then

SOME MATERIALS USED IN GLASS MAKING

Fundamental Materials	Materials to make Glass Colourless	Materials for Producing Colours	
		Material	Colour
Sand, pure white	Sodium nitrate	Copper oxide	Blues, green and reds
Sand, brown	Potassium nitrate		
Boric acid	Arsenious oxide	Iron oxide	Greenish yellow to blue green
Arsenious oxide	Manganese dioxide		
Phosphoric acid	Nickel oxide	Cobalt oxide	Blue
Alumina	Cobalt oxide	Nickel oxide	Purple to brown
Soda	Neodymium oxide	Manganese dioxide	Purple to brown
Potash	Selenium	Neodymium oxide	Rose pink to lilac
Sodium nitrate		Chromium oxide	Yellowish-green
Potassium nitrate		Uranium oxide	Yellow to fluorescent green
Sodium sulphate			
Borax		Titanium oxide	Yellow to brown
Limestone or		Cryolite	Opal
Burnt lime, or		Tin oxide	Opal
Slaked lime		Calcium phosphate	Opal (white)
Red lead		Cadmium sulphide	Yellow
Barium carbonate		Gold	Ruby
Magnesium carb.		Silver Salts	Yellow
Zinc carbonate		Sulphur	Yellow to amber
Felspar		Carbon	Yellow to brown
Fluorspar		Selenium	Pink to deep red

SOME TYPICAL MIXTURES FOR GLASS MAKING

1. English Crystal Glass (Cut Glass)		2. Cylinder-Drawn Window Glass		3. Optical Crown Glass		4. Colourless Bottles		5. Glass for Light-Blown Chemical Ware	
Purest sand	1000	Sand	1000	Purest sand	1000	Sand (pure)	1000 lb.	Sand	1000
Red lead	660	Soda	260	Potash (pure)	420	Soda	325-380 lb.	Alumina	74
Potash	330	Saltcake (i.e., crude sodium sulphate)	60	Limespar	265	Limestone	180-230 lb.	Limestone	112
Potassium nitrate	50	Limestone	370	Arsenious oxide	5	Saltcake	10 lb.	Dolomite	88
Borax	10-20	Scrap glass (variable)				Arsenious oxide	$1\frac{1}{2}$-$2\frac{1}{2}$ lb.	Potash	57
Arsenious oxide	1-$1\frac{1}{4}$					Selenium	2/5-4/5 oz.	Potassium nitrate	81
Manganese dioxide	1-$1\frac{1}{4}$					Cobalt oxide	1/16-1/12 oz.	Soda	404
Scrap glass (variable)						Scrap glass	300-600 lb.	Borax	20
								Scrap glass	400-500

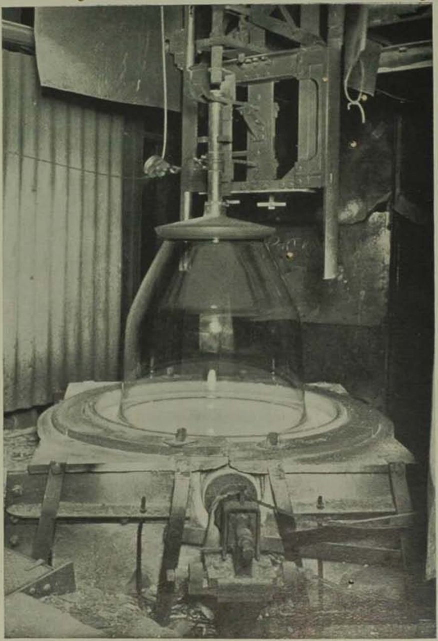

FIG. 2.—Drawing a Cylinder of Window Glass by Compressed Air.

(*Courtesy, Messrs. Pilkington Brothers, St. Helens.*)

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blowing it into a bubble. The sheet glass was ultimately formed from the walls of the bubble. Crown sheet glass was made by attaching the thin glass film opposite to the mouth of the blower, to a rod, re-

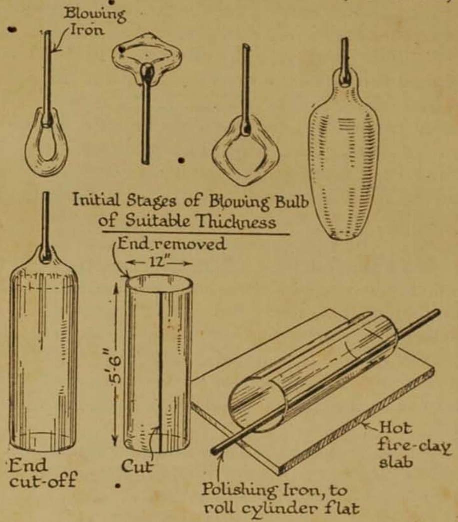

FIG. 3.—The Manufacture of Window Glass by Mouth Blowing.

moving the blowing iron by cutting out the area of surrounding glass and after warming the glass attached to the rod, rapidly revolving it so as to make the glass fly out into one plane. The resulting sheet glass had a thick blob of glass in the centre, which may be sometimes seen in the window glass of old houses. They should not be confused with the "antique" window glass found in some modern houses. This process gave place to a method illustrated in Fig. 3, in which a cylindrical bulb is blown and after cutting off the two ends, the glass is cut parallel to the axis and then rolled out into a flat sheet. This method demanded not only excellent physique but excellent craftsmanship on the part of the glass-blower. The method is still adopted, but is usually carried out by machines and the blowing is done by compressed air. The glass cylinders thus obtained are often 40 feet high and instead of commencing from a bubble, the cylinder is begun from a crucible of molten glass as shown in the picture (Fig. 2). The split cylinders are placed in the flattening kilns where the heat softens the glass, thus enabling the flattener to unroll them on a perfectly flat bed on which they are smoothed down with a wooden "polissoir." Annealing is then necessary. This centuries-old method has the disadvantage that perfect flatness is usually not entirely secured. This gives rise to the distortion effects of common window-glass.

Seventy years ago an Englishman pointed out the possibility of drawing glass in sheet form direct from the molten glass furnace, but it was not until 1918 that practical methods were devised. In that year, Colburn in America, after 18 years work coupled with bankruptcy, and Fourcault, in Belgium, introduced different processes by which sheet glass could be manufactured. A process which is threatening to revolutionise the manufacture of window glass is one due to Libbey and Owens. It is illustrated on page 39. This machine can draw flat sheet glass straight from a trough of molten glass fed by a melting furnace at the rate of more than one mile a day in a continuous band five or more feet in width along to the cutting tables.

In these modern days strong glass bottles are being increasingly adopted for the hygienic delivery of milk and the storage of foods. Thus in America in 1927, 3,000,000,000 bottles were used for the daily milk supply. Their production has been made

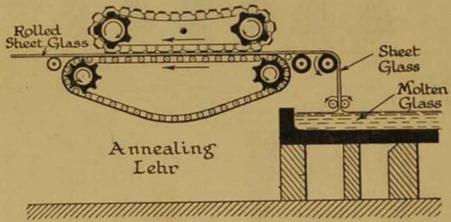

FIG. 4.—The Libbey-Owens Automatic Sheet Glass Machine.

possible by the introduction of automatic machinery. The first machine was invented about 1886 by Ashley, in Yorkshire, but the machine probably the most used at the present time is one invented by Owens. Each of the bottle-making units of which there may be from six to fifteen in a single machine, rotate round a vertical shaft and pass through the several stages shown on page 40.

Although considerable progress has been made in mechanical technique, important advances have recently been made in the manufacture of special glasses. Ordinary window-glass absorbs all the ultra-violet rays in sunlight with the exception of about 2% or

3%. An optical glass has been known for some time that would transmit these radiations, but it was unsuitable for use in windows. Lamplough, in England, in 1924–25, first showed that window glass could also

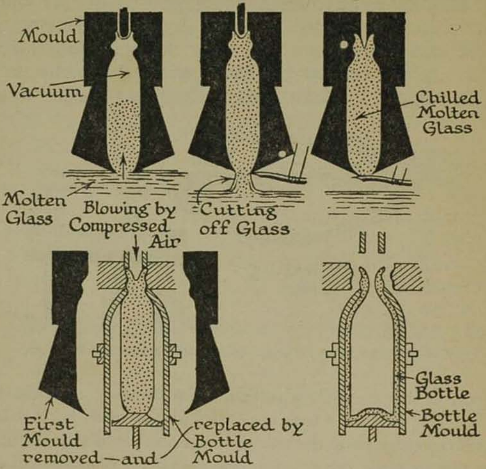

FIG. 5.—Stages in the Blowing of a Glass Bottle by the Owens Automatic Machine.

be prepared that would transmit some of the ultraviolet radiations. Such glass became an article of commerce under the name of Vita-glass, but since that time numerous glasses of a similar nature have been placed on the market. Nearly all of them contain boric acid which seems to assist transmission, though it is not essential for one authority claims that

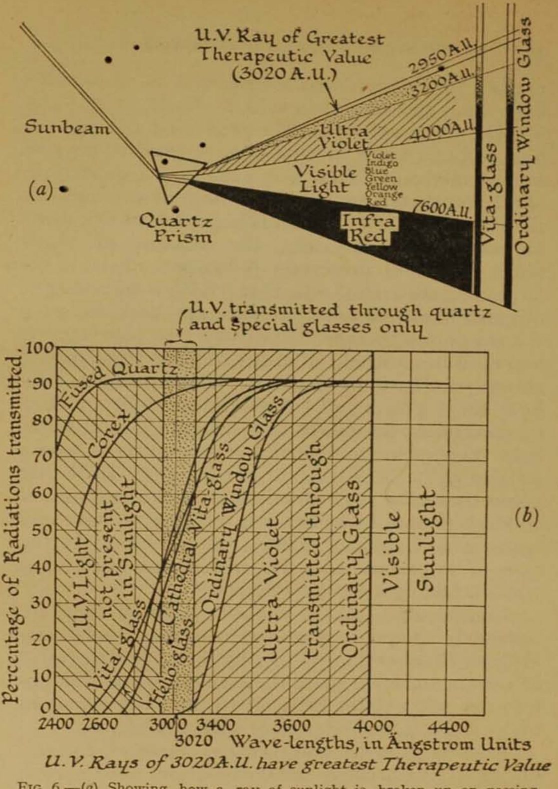

FIG. 6.—(*a*) Showing how a ray of sunlight is broken up on passing through a Quartz prism, and how the constituent light radiations are transmitted through ordinary glass and Vita-glass. The black portions represent complete transmission; the dotted portions, partial transmissions; and the clear portions, no transmission. (*b*) Showing the extent by which ultra-violet rays are transmitted through various types of window glass when new. Based on the observations of W. W. Coblentz and R. Stair. (*U.S.A. Bureau of Standards Journal of Research*, 1929, page 629.)

a glass which was most transparent to ultra-violet light had the composition 1·0 Na_2O, 1·4 CaO, 6 SiO_2. The chief point in producing this type of glass appears to be the use of pure components and refined methods. Thus iron oxide has a deleterious effect and should not constitute more than 0·03% of the glass, ordinary glass containing at least five times as much. Unfortunately, the amount of ultra-violet radiations present in ordinary sunlight is relatively small, and of this, that having a wave-length of 3,020 Ångstrom units (see page 147) and possessing the maximum therapeutic activity (see page 150) is absorbed to an extent of about 60% by these special glasses (cf. Fig. 6, on page 41). On exposure to sunlight these glasses suffer "solarisation," in which a diminution of the power of transmitting ultra-violet light takes place and finally settles down to about 40% to 45%. The amount of ultra-violet light that passes through a pane of such glass is extremely small and it is doubtful whether it is sufficient to have any appreciable beneficial effects, unless perhaps in the case of a person who sits within one yard of a window having a southern aspect.

Contrariwise, glasses can be prepared that are absolutely opaque to ultra-violet light. The late Sir William Crookes showed that by incorporating traces of cerium oxide in glass the resulting glass did not transmit ultra-violet rays. It is therefore useful in making spectacles for persons with weak eyes.

Another glass deserves mention, namely "Pyrex." Owing to its extremely small co-efficient of expansion —each inch expands 0·0000032 inch for 1° C.— thick-walled vessels can be made that are extremely resistant to changes in temperature. Moreover, the glass does not soften until a temperature of 800° C. is reached. It is very hard and is not easily scratched. It contains about 80% of silica, 12% of boric oxide, about 2% of alumina and 4% to 5% of alkali-metal oxides.

CERAMICS AND BRICKS.

The essential constituent of pottery, porcelain, earthenware, bricks, etc., is clay. It is interesting that clay should be employed seeing that it, itself, is a decomposition-product of glass-like minerals such as the felspars and other minerals containing aluminium and silicon. Potash felspar is K_2O, Al_2O_3, $6SiO_2$. The solid matter contained in the various types of clay is made up of 48% to 59% of silica, 13% to 35% of alumina and 1% to 5% of basic oxides. China clay, as mined in Cornwall and Devonshire, approximates to Al_2O_3, $2SiO_2$, $2H_2O$.

The manufacture of articles from mixtures of clay and other substances consists of heating to such a temperature that causes the particles to become cemented together. Unlike glass, the whole charge does not become molten, but only those portions of silica and alumina that are able to fuse, through interaction with basic oxides, as soda or potash. By flowing through the charge the particles become stuck together to form a porous body. For this purpose, temperatures in the region of 1000° C. are necessary. Alkali may be added in the form of sodium salts or of felspar. Fireclays require higher temperatures and are comparatively free from alkalis. In regard to bricks, much of the soluble alkali is removed prior to kilning, otherwise bricks would result that would not be sufficiently resistant to rain. As the various products, pottery, earthenware, etc., are porous, they are subjected to a glazing treatment in which they receive vitreous superficial coating. In effect, these are coverings of glass. They are applied in the form of pastes and subsequently fired. In the case of earthenware drain-pipes, the glazing is formed by the interaction of the pipe surfaces with fused common salt—the glass being formed at the expense of some of the silica of which the pipes are made.

Cement.

Cement is closely associated with pottery for it contains silica and alumina, but instead of alkali oxides it contains lime. The manufacture involves the reaction between the lime and the other two oxides to form more or less indefinite aluminates and silicates of calcium. This is effected by heating finely divided mixtures of mineral matter containing these oxides and volatile substances to a temperature of 1400° to 1600° C. This causes a partial fusion and the mass rolls up into little balls, which, before use, require to be thoroughly ground. Cement furnaces are usually made in tubular form and are inclined slightly to the horizontal. Heating is carried out by blowing flames of pulverised coal through the charge. Portland Cement contains 20% to 24% of silica, 5% to 9% of alumina, and 60% to 64·5% of lime. The materials used are lime and clay, though certain rocks, blast furnace slag and gypsum are also used. The ratio of the percentage amount of lime to the sum of percentage amounts of silica and alumina should be 1·9 to 2·1, whilst the ratio of silica to alumina should be 2·5 to 4·0. Should the cement contain too little calcium oxide it will set too quickly. Much alumina gives a quick-setting cement and by using a large amount of silica there will result a slow-setting cement. The setting of cement is caused by the water tending to decompose the insoluble aluminate and silicate of calcium and setting free some calcium hydroxide within the cement. As the latter becomes converted into calcium carbonate by absorbing carbon dioxide from the air, yet another insoluble substance is deposited within the matrix, with the consequence that solidification gradually takes place.

"Permutit" Process of Water-Softening.

As we have seen (page 30), "hard" water is caused by the presence of calcium salts which, by reacting with soap, form an insoluble calcium soap that has no detergent properties and accumulates on the surface of the water as a scum. Sodium salts, however, in the water do not interfere with the washing power of soap. A recent method, involving the use of "permutit," eliminates calcium and magnesium from the solution and replaces them by sodium. "Permutit" is very similar to glass in its composition but contains a relatively higher amount of soda. One method of preparation is to fuse china clay with quartz and sodium carbonate and then to remove the soluble portion by washing with water. The remaining portion, "permutit," contains sodium oxide, alumina and silica. One variety of permutit is "doucil." It is stated to agree closely with the formula : Na_2O, Al_2O_3, $5SiO_2$, xH_2O. The removal of hardness may be represented thus : (1)

$Ca(HCO_3)_2$ (temporary hardness) + Na Permutit (insoluble) $\longrightarrow$ Ca Permutit (insoluble) + $NaHCO_3$,

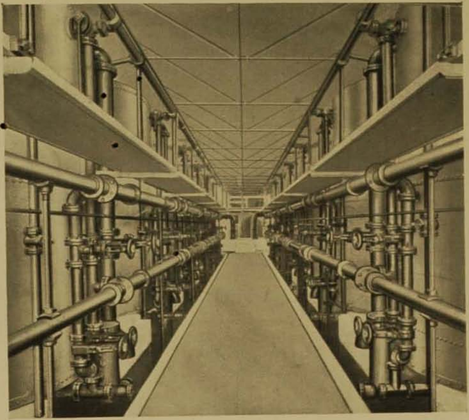

FIG. 8.—" Permutit " Base-Exchange Water-Softening Plant installed by the West Cheshire Water Board, at their Hooton Purifying Station in 1913, to Soften Public Drinking Water Supply. Capacity, 750,000 gallons per day.

(Courtesy, Messrs. United Water Softeners, Ltd., London.)

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and (2) $CaSO_4$ (permanent hardness) $+ 2$Na Permutit (insoluble) $\longrightarrow$ 2Ca Permutit (insoluble) $+ Na_2SO_4$.

When the "permutit" has been exhausted, i.e., converted into calcium permutit, it can be regenerated by simply passing through a concentrated solution of sodium chloride. The reaction is as follows:

$$\text{Ca Permutit} + 2NaCl \longrightarrow \text{Na Permutit} + CaCl_2$$

The calcium chloride must be removed by subsequent treatment with water.

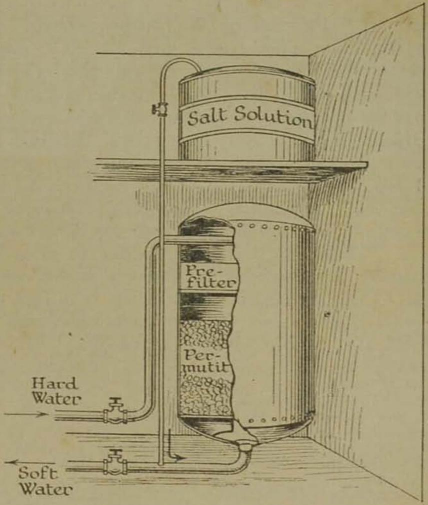

FIG. 7.—Diagram illustrating "Permutit" Process of Water-Softening.

PROTECTION FROM FIRE.

Fabrics may be made fireproof by immersing in solutions of various chemical compounds. Fire-proofing " flannelette " is sometimes effected by using sodium tungstate, though immersing a fabric in a solution of aluminium sulphate to which ammonium phosphate is afterwards added renders it fireproof on account of the enveloping of the fibres with a gelatinous precipitate of aluminium phosphate. On drying, however, the fabric is harsh to the touch. The clothes which certain firms are producing for use by firemen during fire-fighting is made of asbestos. The picture illustrates an outfit made of tightly-woven strong asbestos cloth, together with a leather smoke helmet, covered with asbestos cloth. For working in a dangerous atmosphere sufficient air may be carried to enable a man to breathe comfortably for 5 to 10 minutes, according to the amount of energy he is expending.

Asbestos is a fibrous material, of volcanic origin, that is composed chiefly of magnesia, silica and a little water, though it may sometimes contain alumina and iron oxide. Depending on its physical structure, it is used to manufacture fireproof textiles, board, roofings and cement.

Several forms of fire extinguishers are being used. Syringes filled with carbon tetrachloride, CCl_4, is a familiar type carried on motor cars. Carbon dioxide is sometimes dissolved in the liquid and oil of myrbane is often added to impart di-electric properties, so that it can be used in fires caused by electricity such as those originating through the exposure of a glowing live wire. Another type is that which derives its fire-extinguishing property from

FIG. 9.
Asbestos Flame-Resisting Clothing. (Merryweathers' "Mefisto.")
(Courtesy, Messrs. Merryweather & Sons, Ltd., London.)

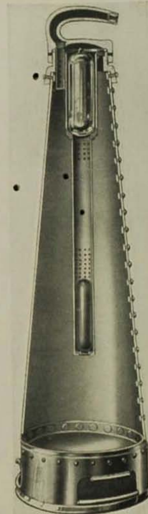

FIG. 10.
Fire-Extinguisher
("Konus-Kemik)."
(Courtesy, Messrs. Merryweather & Sons, Ltd., London.)

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the evolution of vast quantities of carbon dioxide. Merryweathers' "Konus Kemik" is of this design. A solution of sodium bicarbonate fills the outer vessel, while the interior cylinder contains a loose-fitting lead weight. At the top lies a hermetically sealed glass receptacle filled with strong sulphuric acid. On inverting the vessel the lead weight smashes the glass cylinder and releases the acid, and gas-charged water is forced through the nozzle to a considerable distance. The water being projected on to the fire releases the carbon dioxide, which being heavier than air, lies like a blanket over the burning material and prevents the continuance of combustion.

The use of so-called "fire-foam" has come greatly into prominence in late years on account of its suitability for dealing with oil fires. One disadvantage of using carbon dioxide gas alone is its tendency to escape when placed on a vigorous fire, such as one of oil, and may, therefore, prove useless. By using a foam this gas is contained inside tough bubbles, which can form a heap or blanket and so smother the fire. Foam may be ejected through a nozzle of an apparatus similar to that shown in Fig. 10. The acid solution consists of aluminium sulphate and the gas is liberated from a sodium carbonate solution in which is also dissolved some froth-producing organic matter, usually extract of liquorice root or saponin. These in conjunction with the gelatinous aluminium hydroxide liberated during the reaction provide an excellent foam which is inflated with carbon dioxide.

SOME USEFUL GASES.

We have just referred to one use of carbon dioxide. Carbon dioxide is evolved in large amounts during

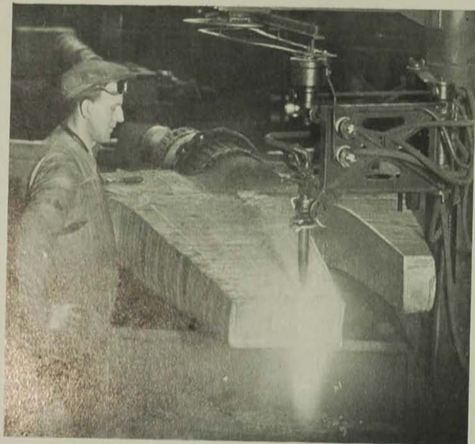

FIG. 11.—Heavy Steel Forging being shaped by the Oxygen-Acetylene Cutting Machine at the Works of Messrs. Walter Somers.

(Courtesy, Messrs. British Oxygen Co., Ltd., London.)

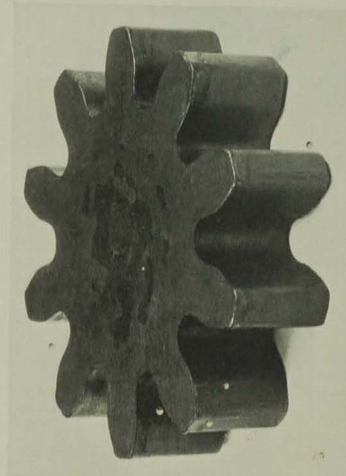

FIG. 12.—Gear Wheel of 7½ inches diameter, cut from 2-inch Steel Plate by Oxygen-Acetylene Machine in 7 minutes.

(Courtesy, Messrs. British Oxygen Co., Ltd., London.)

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fermentation. In some breweries this gas is collected, stored under pressure in cylinders, and sold for aerating beverages. Another use is just beginning to create a new industry, that of Dry Ice. Carbon dioxide is one of the easiest gases to liquefy and even to solidify. It is only necessary to hold a duster over the open mouth of carbon dioxide cylinder to cause the solid gas to be formed in the duster. Solidification occurs owing to the sudden cooling of the gas as the result of sudden expansion. Solid carbon dioxide sublimes at —78·6°C. (i.e., —109·6°F.) and each pound in rising to 40°F. absorbs 273 B.Th.U. It is therefore an excellent refrigerating agent and is already being used in ice-cream making, storage of flowers, vegetables, etc. The gas usually employed in refrigerators is ammonia on account of the ease with which it is liquefied.

Oxygen and hydrogen burn together to give a very hot flame which, if allowed to impinge on a piece of lime, cause it to emit a brilliant white light, the lime remaining unmelted. This property was taken advantage of in the oxy-hydrogen flame which, before the introduction of electricity, was used in magic lanterns. Substituting acetylene for the hydrogen, the flame is even more intense and can reach the appalling temperature of 3000°C. (5400°F.). Such a temperature is more than sufficient to melt any metal at the point of contact with the flame. The oxy-acetylene flame is consequently used for welding metals and cutting hard metals, such as steel. The blowpipe is made of three concentric tubes. Through the second tube oxygen flows and acetylene is passed through the outer tube, the flame being confined to a fine jet at the end. The flame is reducing and in the case of steel-cutting the burning-away of the metal can be assisted by passing yet more oxygen through the middle tube.

Reference is made elsewhere in this book to certain uses of helium. This rare gas is one of the disintegration products of radio-active substances, e.g., radium, uranium and, besides occurring in the air and natural gases, is found locked up in certain minerals. Some scientists have attempted to calculate the age of these minerals from the amounts of helium gas which they contained, and the known rates of disintegration of one of the radio-active elements, uranium, radium and thorium, whichever the minerals happened to contain. Estimates of the age of the earth range from 31 millions to 710 millions of years. Estimates made from the lead contents of radio-active rocks have led to similar conclusions.

Argon, another rare gas of the atmosphere is used in gas-filled electric lamps, whilst neon has become quite an important substance industrially. Glass tubes containing this gas, even at low pressures, when subjected to electric discharge emit a characteristic red glow. This property has been utilised in testing whether sparking-plugs in petrol engines are in working order. Neon is extensively used in electric signs, and to some extent in harbour and landing lights.