XXX.—*On the Properties of Liquid Carbonic Acid.*

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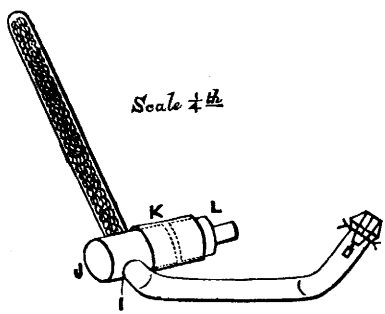
[Abstracted from the Philosophical Transactions, 1861, Part i.]

1. A stout glass tube, of the form shewn in Fig. 1, was filled in its distant limb with small pieces of sesqui-carbonate of ammonia, the last pieces of which were pushed in firmly by means of a rod of gutta-percha; the horizontal part was then filled with strong sulphuric acid. A small cup of glass, containing the substance to be submitted to the action of the carbonic acid, was fixed by heat upon the inner end of the gutta-percha stopper; the stopper wetted with a saturated solution of paraffin in chloroform, then forced strongly (with caution) into the mouth of the tube, and secured firmly by transvere binding wire.

2. For convenience of manipulation, the tube was placed in the hole of a transversely perforated cork; the cork fitted rather loosely in a short piece of brass tube; the tube fixed upon a wooden peg, as shown in figure 1, in which I is the hole, J the Cork, K the brass tube, and L the wooden peg with a prolongation of smaller diameter. The cork could thus be readily turned upon its axis, and the glass tube placed and retained in various positions.

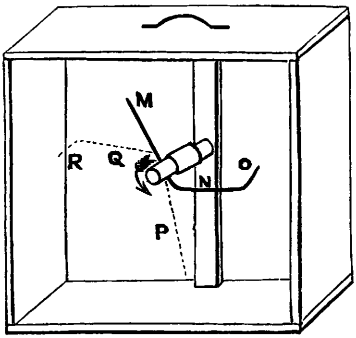
Fig. 1.



3. As a protection from accidents by explosion, and for further convenience of manipulation, a moveable cage or box was con-

structed for each tube; its sides. top, and bottom were made of wood, and its front and back were of fine iron wire-gauze; its dimensions were 12 inches high, 12 inches wide, and 5 inches from front to back; the pieces of gauze were nailed to the wood on one of their vertical edges only, so that they served the purpose of doors. A small vertical strip or piece of wood was fixed at the back part of the box, with a hole at its middle part to receive tightly the small projecting part of the horizontal L, fig. 4. An inspection of fig. 2 will make more clear the whole arrangement.

Fig. 2.



4. The tube, charged with its acid and carbonate, is placed in the frame in the position shown by the lines M, N, O in fig. 2; and the operator having previously protected his hands by thick leather gloves, his eyes by a pair of spectacles, and keeping the wire-gauze door between his face and the tube, occasionally turns the supporting cork upon its axis in the direction of the arrow, so as to cause a little of the acid to flow upon the alkaline carbonate; this must be done with cautious watching and in very small quantities at the commencement, otherwise the bubbles of gas which ascend through the oil of vitriol will carry some of the latter acid into contact with the contents of the little glass cup. The process requires much watching, and if at any time the chemical action is allowed to progress too rapidly, the generating tube is liable to burst in consequence of the heat evolved.

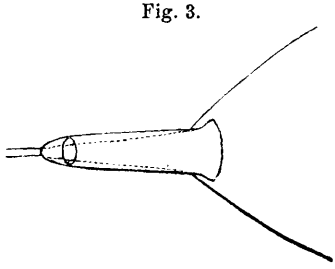
5. The tube is thus occasionally turned until, after the lapse of several hours, it has acquired the permanent position indicated by the dotted lines P, Q, R in fig. 2, when a piece of cotton-wool should be placed upon the stoppered end and saturated with ether, so as to distil off the liberated carbonic acid, and the application of ether be repeated at intervals until nearly the whole of the carbonate is decomposed and the stoppered end of the tube is full of liquid carbonic acid. If the experiment has succeeded well, a length of the tube, equal to 1 or 1¼ inch, will, in cold weather, be filled with the liquid acid. By occasionally (once a day or less) applying the ether to the stoppered end of the tube, that part may

be kept full, or partly full, of liquid acid for a long time; I have kept it in this manner during many months.

6. The most frequent cause of failure is the clogging of the tube with sulphate of ammonia; it is rarely that a leakage occurs at the stopper; and the most frequent causes of explosion are, too rapid generation of the gas, and increased temperature of the atmosphere. It is highly advisable never to examine a charged tube without the wire-gauze intervening to intercept fragments of glass, and to use a large moveable screen of glass to protect the eyes from projected oil of vitriol. Nearly all the explosions which occur take place during the process of generating carbonic acid, or within a few days afterwards. The proportion of tubes fractured or burst at different stages of the process is about one-third.

7. In some experiments, where electric sparks were passed through the liquid acid, two longitudinal cuts $\frac{1}{16}$th of an inch deep, were made by a knife on opposite sides of the gutta-percha plug, extending from its smaller nearly to its larger end, before inserting it in the tube; and two fine platinum wires inserted into the cuts and secured very carefully by means of a heated penknife; the inner end of the plug was then coated with melted paraffin, the plug wetted with paraffin solution, and inserted in the usual manner. The wires extended nearly $\frac{1}{2}$ an inch within the tube, and were imbedded for about $\frac{1}{4}$ of an inch, next to the plug in paraffin, the remaining part served for the electrodes. (See fig. 3.) After inserting the plug and securing it by the binding wires, the whole of the outer end of the plug was freely coated with melted paraffin, to insulate more perfectly the electrodes from each other.

Fig. 3.



8. In a first experiment, the electrodes being $\frac{1}{10}$th of an inch apart, and the liquid acid below 32° Fahr., not the slightest conduction occurred with 40 Smee's batteries; and sparks from a Ruhmkorff's coil which passed through $\frac{3}{8}$ths of an inch of cold air would not pass through the liquid acid. And in a second experiment, with electrodes about $\frac{1}{70}$th of an inch apart, sparks from the coil, which were passing freely through $\frac{9}{32}$nds of an inch of cold air, occasionally passed through the cold liquid acid and exhibited a pale blue colour.

9. These experiments show that liquid carbonic acid is a strong insulator of electricity, and that when prepared with concentrated oil of vitriol, and with the precautions stated, it is free from water, sulphuric acid, and sulphate of ammonia. As further proofs of the freedom of the liquid acid from oil of vitriol and water, it may be mentioned,—1st, that dry extract of litmus exhibited no signs of redness by immersion in the liquid acid; 2ndly, a small fragment of glacial phosphoric acid did not appear at all liquefied, or lose the sharpness of its edges after being immersed several weeks; and 3rdly, anhydrous sulphate of copper did not become at all blue in the liquid acid.

10. The following are the results obtained with various solid substances immersed in the liquid acid; some were immersed during several months, many during several weeks, and a few only during several days. The temperature of the liquid acid was generally a little below that of the external atmosphere. Wood-charcoal remained undissolved and unaltered. Anhydrous boracic acid in powder slightly dissolved. White phosphorus slightly dissolved. Glacial phosphoric acid, green solid biphosphide of hydrogen, and ordinary yellow sulphur, undissolved and unchanged. (Bisulphide of carbon absorbs *gaseous* carbonic acid.) Sulphide of phosphorus, and selenium, undissolved and unaltered. Iodine, biniodide of phosphorus, and iodide of sulphur, all dissolved in small quantities (iodine the most freely), and formed red or reddish solutions. Anhydrous hydrochloric acid (prepared by first half-filling the limb A of the tube with sesquicarbonate of ammonia, and then filling the remaining half with hydrochlorate of ammonia) did not produce two strata in the condensed liquid, but imparted to the liquid a brownish colour in each of two experiments, probably by acting upon the gutta-percha stopper. Pentachloride of phosphorus dissolved slowly and formed a colourless liquid. Metallic potassium and metallic sodium slowly acquired bulky white coatings of alkali. Phosphide of sodium, fused chloride of sodium, phosphide of calcium, anhydrous chloride of calcium, bright metallic aluminium, crystals of silicium, anhydrous silica, silico-fluoride of potassium, and arsenic acid, all remained undissolved and unaltered. Terbromide of arsenic and terbromide of antimony, each dissolved slightly. Hydrated crystals of monosulphate of iron became dehydrated and fell to pieces as a white powder, and did not dissolve. Anhydrous sulphate of copper remained white and undissolved; the hydrated salt became white.

Protochloride of mercury and nitrate of silver remained undissolved and unaltered.

11. Cyanide of mercury, oxalic acid, benzoic accid, succinic acid, pyrogallic acid, gallic acid, tannic acid, tannic acid and potash, paraffin, and cocostearic acid remained undissolved and unaltered in appearance. Pitch softened and partly dissolved. Napthalin dissolved in small quantity. Gutta percha; the liquid acid dissolved out the dark-brown colouring matter, and left the gutta percha undissolved, and much more white. India rubber remained black externally, but became perfectly white through the whole of its thickness; on removing it from the acid, it suddenly swelled to a large size, and gradually shrank in a few hours to its orginal dimensions, and afterwards, (in a few days) slowly regained its original colour. Common yellow resin dissolved slightly. Gum-copal remained undissolved. Camphor dissolved rapidly and formed a clear colourless liquid. (Spirit of turpentine dissolves more than its own volume of *gaseous* carbonic acid.) Spermaceti, indigo, pyroxylin, and solid extract of litmus remained undissolved and unaltered. Gamboge dissolved in minute quantity and formed a slightly yellow liquid.

12. These experiments show that liquid carbonic acid is a chemically inert body, and is also a very feeble solvent of substances in general, and is not deoxidized by any of the ordinary deoxidizing agents except the alkali-metals

13. The way to discharge the tubes of their contents is to support them over a gutta-percha vessel within the safety-cage, or behind a duble screen of glass and wire gauze, and, protected by gloves, cut off the binding-wires with a pair of nippers; then if the stoppers are not blown out, pour boiling water upon them. Sometimes the explosion occursimmediately upon cutting the wires, but in most cases it requires the application of the hot water; this is a most convincing proof of the tightness of the stoppers, as the pressure of liquid carbonic acid, (according to different authorities) varies from 500 to 1,100 pounds per square inch, according to the temperature of the atmosphere. The tubes nearly always break by the violence of the recoil. In many instances a safer plan was adopted; the wires were not cut, but a current of steam was directed upon the stoppers until they were expelled; the discharge was then less sudden, and the tubes were less frequently broken. It would probably be a still further improvement if the lower end of the tube were closed by a stopper in a

similar manner to the upper end; the contents of the tube might then be discharged at that end, and the substances operated upon would then be exposed to less risk of being lost, and of being brought into contact with the acid and saline matters by the discharge.