VIII. "Experiments on Carbon at high Temperatures and under great Pressures, and in contact with other Substances." By the Hon. CHARLES A. PARSONS. Communicated by the Right Hon. the EARL OF ROSSE, F.R.S. Received June 13, 1888.

The primary object of these experiments was to obtain a dense form of carbon which should be more durable than the ordinary carbon when used in arc lamps, and at the same time to obtain a material better suited for the formation of the burners of incandescent lamps.

There were a considerable number of experiments made in which the conditions were somewhat alike, and many were almost repetitions with slightly varying pressures and temperatures. They may, however be divided into two distinct classes: the first in which a carbon rod surrounded by a fluid under great pressure is electrically heated by passing a large current through it, the second in which the liquid is replaced by various substances such as alumina, silica, lime, &c.

The arrangement of the experiment was as follows:—A massive cylindrical steel mould of about 3 inches internal diameter and 6 inches high was placed under a hydraulic press; the bottom of the mould was closed by a spigot and asbestos-rubber packing—similar to the gas-check in guns; the top was closed by a plunger similarly packed; this packing was perfectly tight at all pressures. In the spigot was a centrally bored hole into which the bottom end of the carbon rod to be treated fitted, the top end of the carbon rod was connected electrically to the mould by a copper cap which also helped to support the carbon rod in a central position. The bottom block and spigot were insulated electrically from the mould by asbestos, and the leading wires from the dynamo being connected to the block and mould respectively, the current passed along the carbon rod in the interior of the mould.

The fluid was run in so as to cover the rod completely. The plunger was then free to exert its pressure on the liquid without injuring the carbon. The pressure in the mould was indicated by the gauge on the press.

Experiments. Class I.

Among the liquids tested were benzene, paraffin, treacle, chloride and bisulphide of carbon.

The pressures in the mould during the several experiments were maintained at from 5 to 15 tons per square inch; the initial size of the rod was in all cases $\frac{1}{4}$-inch, and the current from 100 to 300 ampères.

Results.—In some of these experiments a considerable quantity of gas was generated, and the press had to be slightly slacked back during the experiment to accommodate it and maintain the pressure constant.

In all cases there was a soft friable black deposit of considerable thickness on the carbon.

In no case was the specific gravity of the carbon rod increased by this process. There was no change in appearance of the fracture, excepting when chloride of carbon had been the fluid; it was greyer in this case.

The rate of burning of samples placed in arc lamps was not diminished by the process. Various rates of deposition were tried, but with the same result, and the conclusion seems to be that under very high pressures, such as from 5 to 15 tons per square inch, the deposit of carbon by heat from hydrocarbons, chloride of carbon, bisulphide of carbon, treacle, &c., is of a sooty nature, and unlike the hard steel-grey deposit from the same liquids or their vapours at atmospheric or lower pressures.

Experiments. Class II.

In these experiments the asbestos-rubber packing was omitted, the plunger and spigot being an easy fit in the mould. A layer of coke powder under the plunger formed the top electrical connexion with the rod.

No. 1. Silver sand or silica was run around the carbon rod, and pressures of from 5 to 30 tons per square inch applied; the rod was usually about $\frac{1}{4}$-inch diameter, and currents up to 300 ampères passed.

Results.—The silica was melted to the form of a small hen's egg around the rod. When the current was increased to about 250 ampères the rod became altered to graphite, the greater the heat apparently the softer the graphite. There was no action between the silica and the carbon, the surface of the carbon remained black, and there were no hard particles in or on the carbon rod.

Other substances, such as an hydrated alumina and mixtures of alumina and silica, gave the same results.

The density of the carbon was considerably increased, in some cases from normal at 1·6 to 2·2 and 2·4; in these cases the carbon appeared very dense, much harder than the original carbon, and about as hard as the densest gas-retort carbon. No crystalline structure was visible.

The specimens were treated with solvents, and there appeared no indication of the surrounding substance having penetrated the rod; the carbon was undoubtedly consolidated by 30 per cent.

In some cases when the material surrounding the rod was alumina

saturated with oil, soft crystals of graphite exuded from specimens that had been kept for some weeks.

No. 2. Pure hydrated alumina, carbonate and oxide of magnesia and lime all rapidly destroyed the carbon rod, by combining with it, the hydrated alumina forming large volumes of gas of which it appeared to be a constituent. On account of the great diminution of bulk, no analysis was made; the gas issued from the mould explosively at from 10 to 12 tons per square inch. The alumina was found in a crystalline crust, like sugar, around where the rod had been. Hardness that of corundum, almost translucent.

No. 3. The following is the most interesting experiment of the series:—

On the botton of the mould was a layer of slaked lime about $\frac{1}{4}$-inch thick, over this silver sand 2 inches, then another layer of lime of the same thickness as the former, finally a layer of coke-dust, and then the plunger. With a pressure of from 5 to 30 tons per square inch in the mould, and the carbon of from $\frac{1}{4}$ to $\frac{5}{16}$ diameter, currents from 200 to 300 ampères were passed.

In from 10 to 30 minutes the current was generally interrupted by the breaking or fusing of the rod, or by the action of the lime in dissolving it at the top or bottom. On opening the mould when it had cooled a little, the silica usually appeared to have melted to an egg-shaped mass, and mixed somewhat at the ends with the lime; the surface of the carbon appeared acted on, and sometimes pitted and crystalline in places; silica adhered to the surface, and beneath, when viewed under the microscope, appeared a globular cauliflower-like formation of a yellowish colour, resembling some specimens of "bort."*

After several days' immersion in concentrated hydrofluoric acid, this formation remained partly adherent to the carbon; on the surface of the carbon was a layer or skin about $\frac{1}{64}$th of an inch thick of great hardness, on the outside grey, the fracture greyer than the carbon, but having a shining coke-like appearance under the microscope.

The powder scraped off the surface of the rod has great hardness, and will cut rock crystal when applied with a piece of metal faster than emery powder. It has, under the microscope, the appearance of bort, the minute particles seem to cling together; they are not transparent as a rule, and though some such particles are found among them, it is not clear that such are hard.

When a piece of the skin has been rubbed against a diamond or other hard body, the projecting or hard portions have a glossy coke-like appearance.

A piece of the skin will continue to scratch rock crystal for some time without losing its edge. It will scratch ruby, and when rubbed

* The bort-like powder is not acted on by hydrofluoric and nitric acids mixed.

for some time against it will wear grooves or facets upon it. When a cut diamond is rubbed on the surface of the skin, it will cut through it into the carbon beneath, making a black line or opening about $\frac{1}{4}$-inch long; the facet on the diamond, originally $\frac{1}{32}$-inch diameter, will have its corners evenly rounded, and its polished surface reduced to about one-half its original area; the appearance of the edges is as if they had been rubbed down by a nearly equally hard substance.

The subject of the last experiment is scarcely sufficiently investigated to warrant any definite conclusions.

The substance in the several ways it has so far been tested seems to possess a hardness of nearly if not quite the first quality. The minuteness of the particles, which appear more or less cemented together, and are less cohesive after the action of acid, make it very difficult to determine their distinctive features.

The mode of formation is not inconsistent with the conditions of pressure, temperature, and the presence of moisture, lime, silica, and other substances as they appear to have existed in the craters or spouts of the Cape Diamond Mines at some epoch.

From the few experiments that have been made it appears that at pressures below 3 tons per square inch, the deposit does not possess the same hardness, though somewhat similar in appearance.

What part the lime and silica play, whether the former only supplies moisture and oxygen which combine with the carbon, or whether the presence of lime is necessary to the action, is not clear.

We may, however, observe that so far it seems as if the lime and moisture combining with the carbon form a gas or liquid at great pressure, which combining with the silica, forms some compound of lime, silica, and carbon, or perhaps pure carbon only, of great hardness.

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