VII.—*On the Combustion of Iron in Compressed Oxygen.*

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WHILST oxygen was being compressed into a Natterer's apparatus, recently supplied to the Royal Institution from Vienna, an accident occurred, which deserves to be placed on record, owing to the interesting relations of iron to highly compressed oxygen revealed by it. The accident occurred in the following manner:—Oxygen was liberated from pure chlorate of potash, heated in a Florence flask, and was collected in a floating bell-gasholder, whence it was drawn through a flexible tube, and pumped in a strong wrought-iron receiver, of .62 litre capacity, and weighing 2.775 killogrammes. When about 25 atmospheres of oxygen had thus been introduced into the receiver, a sharp explosion occurred, followed by a shower of brilliant sparks, which lasted for several seconds. On examining the apparatus, it was found that the union-joint connecting the pump with the receiver, had given way, allowing the compressed gas to escape from the latter. The pump-head, containing the valve, was slightly scorched internally. The steel tube connecting this head with the receiver, was very hot, and had obviously been in a state of active combustion, as it was coated internally with a layer of fused oxide of iron, whilst its bore had increased to at least three times its original size, and in two places the tube was even perforated. The receiver was also heated, although not to such an extent as to be unbearable to the hand. On examining its interior, it was found that the combustion had been propagated to the steel cap, the narrow passage in which was hollowed out into a capacious chamber, whilst the steel screw-valve had been completely consumed. The combustion had not, however, stopped here, but, extending into the receiver itself, had seized upon the internal walls of the latter, and covered them with fused globules of magnetic oxide of iron, and there can scarcely be a doubt, that, had the union-joint not given way, and thus furnished an outlet for the compressed oxygen, the latter would, in a few seconds more, have converted the receiver into a most formidable shell, the almost inevitable explosion of which would have scattered fragments of intensely ignited iron in all directions.

Regarding the primary cause of this explosion, there can

scarcely be two opinions. The piston and valves were lubricated with olive oil, and the latter, becoming ignited by the heat of the compressed gas, had communicated its combustion to the steel and iron of the apparatus. Although the pump and receiver were not artificially cooled, yet this circumstance did not in all probability contribute materially to the ignition, because the oxygen was very slowly pumped into the receiver, the operation having to be frequently interrupted, to wait for the necessary quantity of gas which was being contemporaneously generated. Moreover, I had ascertained, immediately before the explosion, that the receiver was quite cold, and the head of the pump only just perceptibly warm. A few days previously, 60 atmospheres of oxygen had been with impunity *rapidly* pumped into the same receiver, and equally without any external refrigeration. How, then, is this difference of result to be accounted for? The answer to this question is not difficult, when an apparently trivial alteration of the condition of the apparatus, in the two operations, is known. In the directions for the use of Natterer's apparatus, contained in the article "Kohlensäure" (*Handwörterbuch der Chemie*, Band. iv,) the writer states, that before the pumping commences, the space between the piston and the valve should be filled up with oil, so as to prevent the retention of any gas between the piston and valve, when the former, in compressing, is pushed to the extreme limit of its stroke. Any gas so remaining in such space (*schädlicher Raum.*), expands again on the return of the piston, and thus causes, if not an actual loss of power, at least a considerable retardation in the-compressing process. In the operation above described, in which 60 atmospheres were compressed with impunity into the receiver, I omitted to follow this part of the directions of the *Handwörterbuch*, whilst in the subsequent experiment in which ignition occurred, a layer of olive oil, about 0.1 inch thick, was poured upon the piston, so as exactly to fill the space above mentioned.

Now, a careful examination of the burnt parts of the apparatus, leaves no doubt that the combustion commenced in the space between the piston and valve, and that it was this layer of oil which first became ignited. The compression of oxygen to $\frac{1}{25}$ th of its volume should, according to thermo-mechanical laws, raise the temperature of the oxygen to upwards of 2,000° C., but after making due allowance for the loss of heat to surrounding surfaces, there still remains a temperature sufficiently high for the ignition of oil

under favourable circumstances. If the oil be spread as a thin film upon the surface of a mass of metal, the rapid absorption of heat by the latter prevents the temperature of the oil from rising to its igniting point; but, in the form of a layer, 0.1 inch in thickness, no such rapid refrigeration can occur, and the surface of the oil, in contact with the gas, may become ignited by the rapid communication to it of the high temperature of the compressed oxygen. It is also not improbable, that traces of chlorate of potash, which are always carried over with oxygen when the latter is rapidly evolved, may have found their way into the pump, and contributed, to some extent, to the ready inflammability of the oil. However this may be, the result ought to be regarded as a caution against the use of combustible lubricants in the compression of oxygen or nitrous oxide. If ignition of the oil occur at high pressures, it will assuredly be communicated to the iron of the receiver, which evidently burns in oxygen compressed 25 times, with at least the same facility as tissue-paper in atmospheric air, the condition of the various parts of the apparatus, after the explosion, leading to the conclusion, that the combustion from the beginning to end, occupied only a very short time, probably not more than 3 or 4 seconds. The risk attending the compression of oxygen and nitrous oxide, may be avoided by the employment of a non-combustible lubricant. For this purpose, a strong solution of soft-soap in distilled water, appears to answer very well.

The facility with which a mass of iron thus becomes ignited, and the rapidity with which it burns in oxygen, at high pressures, suggests the possibility of employing shells of wrought or cast-iron charged with compressed oxygen, for warlike purposes. The interior of such a shell would scarcely be more difficult to ignite than gunpowder, and, once ignited, the pressure of the enclosed oxygen would, notwithstanding its absorption, be for some time augmented by the intense heat, whilst the walls of the shell would become thinner, until they finally burst into fragments of burning and semi-molten iron. The condition necessary to secure such a result, may be determined from the known absolute thermal effect of iron in oxygen. Andrews found that the union of one litre of oxygen with iron, produces sufficient heat to raise the temperature of 5,940 grammes of water through 1° C. It hence follows, that 780 cubic inches of oxygen, by combination with iron, would evolve sufficient heat to raise 1 lb. of cast-iron to its melting point. This

amount of oxygen introduced into the receiver above described, would exert a pressure of 20·5 atmospheres, consequently it would require the union of a quantity of oxygen exerting a pressure of 125 atmospheres, to raise the whole of the receiver to the melting point of cast-iron. These conditions are not encouraging; for, although a less amount of oxygen than that required for the complete fusion of the shell would suffice for the purpose required, yet, it would doubtless be necessary to augment the thickness of such a vessel when used as a projectile, and this would necessitate a corresponding increase in the bursting charge of oxygen. Thus, little could probably be effected with less than 100 atmospheres of oxygen forced into the shell,—a pressure, which, I fear, would prove not only dangerous, but unmanageable.