WITHIN TWO DEGREES OF ABSOLUTE ZERO.

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AMONGST the many brilliant discoveries of the present year, the approach within two degrees of the absolute zero of temperature will most likely be awarded the prize. Professor Kammerlingh Onnes of Leyden has penetrated into this unknown region and discovered most remarkable facts. To make these intelligible to the unprofessional reader, we must begin with a few preliminaries.

We know that heat expands bodies, and that cold, which is but a reduction or removal of heat, condenses them. This is so obvious that it is needless to give examples. The amount, or in scientific terms, the coefficient of expansion for one degree of a unit of volume, is very different for different solids and liquids but it is absolutely the same for all gases, no matter what they are, whether they be air or hydrogen or dry steam, or anything else. This coefficient is one two-hundred-and seventy-third of their volume at the temperature of the freezing point of water. This latter we number thirty-two on our ordinary Fahrenheit thermometer, but on the scientific or centigrade scale, we call it zero. Lowering the temperature of a gas say 68 degrees centigrade below this zero, will take 68/273 of its volume away. If now, for the sake of convenience in avoiding negative numbers, we place the zero or starting point of our thermometer 273 degrees below the ordinary zero at which water freezes, we call this new one the absolute zero, and can then with as much truth as elegance say that the volume of a gas varies directly with its absolute temperature. Thus in the above instance in which we supposed the temperature of a gas to be lowered 68 degrees below the freezing point

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of water, we may say that its absolute temperature is 273 less 60 or 205 degrees and that its volume is 205/273 of its volume at the ordinary zero. From this it would logically follow that if we could ever cool a gas down to the absolute zero, its volume would have to be zero too, provided of course that it remained a gas. This is not possible however in fact, because before that low temperature is reached, the gas is changed into a liquid, which has another coefficient of expansion. Another well known effect of cold is to increase the electrical conductivity of bodies. A wire that is made to carry too heavy a current, is heated rapidly and even melted, but if we can by an artifice manage to keep the wire cool, it will readily carry a current that an electrical inspector would not ordinarily approve of.

There are many other properties of bodies which are a function of their absolute temperatures. Thus, chemical action becomes sluggish at low temperatures, and some gases even begin to show magnetic propensities, and the interest in their behavior increases at a feverish rate the nearer we actually come to absolute zero. This has never yet been reached, but science has approached so close to it, that the liveliest speculation has arisen as to what would happen when we really did reach it. Some scientists maintain on theoretical grounds too technical to mention here, that there might be an inversion in the electrical conductivity of metals, and just as water when cooled below 4 degrees centigrade (39 degrees on the common thermometer), expands instead of contracting as usual, so also the conductivity might increase down to a few degrees above the absolute zero, but at the zero itself it might cease altogether and refuse to transmit any current at all. As 4 degrees absolute was reached, however, it was found that the resistance of mercury suddenly dropped to nothing, so much so that a wire of frozen mercury, as Professor Woods says in Harpers Magazine for October, only half as thick as the lead of a lead pencil, would easily carry a current of one thousand amperes, sufficient to light two thousand ordinary incandescent lamps. This current would not heat the slender mercury wire to any noticeable extent, but when forced through a half-inch copper wire at the ordinary summer temperature, at which the copper is fifty times as conductive as mercury, it would instantly fuse it.

Now Professor Onnes has come within one and eight-tenths degrees of the absolute zero, every degree here being as hard-fought as the last entrenchments of a fortress. But before we tell of what happened there, it will be of interest to know how he fought his way so near to the Ultima Thule. Low temperatures are always produced by rapid evaporation of a liquid. When we pour water on our hands, and more so if we use alcohol or ether, they feel cool, because the heat that makes the water or the alcohol evaporate, is taken from them.

Evaporation however is not sufficient to condense a gas into a liquid, we must also use heat pressure. If we subject air to pressure by means of a pump; we know that it becomes warm, because the heat that was spread over say ten cubic feet now is confined within one cubic foot. When this heat is allowed to escape, so that the compressed air may assume the temperature of its environment, and then the pressure is removed, the reverse process of cooling takes place, because the heat of the one cubic foot is now spread over ten. By repetitions of this process in which the expanding air takes its heat from other air under high pressure, we at last succeed in liquifying it. Its boiling point, that is, the temperature at which the liquid air changes into gas, is 100 degrees absolute. The boiling point of hydrogen is only 20 degrees above the absolute zero, and that of helium only 4.4.

At such intensely low temperatures, these liquified gases can only with the greatest difficulty be prevented from evaporating, because the temperature of surrounding bodies being so much higher than their own, the problem would be like keeping ice from melting in a blast furnace. It has been solved in great measure by the Dewar flask, which consists of two glass flasks joined only at the top and separated by as perfect a vacuum as can be produced. This has been found to be an excellent insulator against heat.

The next artifice was to place liquid air in one flask, liquid hydrogen within that, and liquid helium within both, all three being separated by vacuum spaces. Then the helium in the inner flask was allowed to evaporate and abstract the necessary heat from whatever substances were placed in a fourth flask inside that of helium. By this means Onnes reached the temperature only 1.8 degrees above the absolute zero.

What did he discover at this low temperature? How did bodies behave? In order not to lengthen this article too much, I will mention only one item: the resistance of a lead wire disappeared completely. This resistance is always so high that no electrician would ever use a wire of lead to carry a current except when he wanted it to melt at the least excess, as is the case in the fuses that protect our wiring against sudden overloads. No resistance whatever in any conductor would mean that a current once started would run forever, just as water in a circular basin when once set gyrating, would keep up its circular motion forever, were it not for the internal resistance of the particles of the water and the external resistance of the basin. Now Onnes did do this, he started a current in the lead wire when at 1.8 degrees absolute and had the satisfaction to see it continue undiminished without any external supply. It was like an electromagnet in which a current in a spool of wire makes a temporary magnet of its iron core. In fact the wire itself without any core, as even tyro electricans know, is a magnet. So in the case of the lead wire, which itself is not at all susceptible of magnetism, the current once started made and kept it a magnet permanently at the low temperature, so that outside magnets were attracted or repelled according to the ordinary behavior of two magnets of unlike or like polarity. This resistanceless flow of electricity in a lead wire so near the absolute zero of temperature is hailed by scientists as the greatest discovery of the present year.