easily be shown that the total volume of all space is a finite quantity. The sum of the three angles of a triangle extending from star to star would then be greater than the sum of two right angles. Equally legitimate is the hypothesis that it would be less than three right angles; but in this case the total volume of space would still be infinite. Now, this is an hypothesis to be tested by experience. Unfortunately, we cannot triangulate from star to star; our limits are the two extremes of the earth's orbit. All we can say is that, within those narrow limits, the measures of stellar parallax give no indication that the sum of the angles of a triangle in stellar space differs from two right angles. If our space is elliptical, then, for every point in it—the position of our sun for example—there would be, in every direction, an opposite or polar point whose locus is a surface at the greatest possible distance from us. A star in this point would seem to have no parallax. Measures of stellar parallax, photometric determinations and other considerations show conclusively that if there is any such surface, it lies far beyond the bounds of our stellar system.

Such are the considerations by which it seems to me that speculations on this subject may legitimately be guided. The wise man is one who admits an infinity of possibilities outside the range of his experience, but who, in considering actualities, is not deceived by the temptation to strain the facts of experience in order to make them accord with glittering possibilities. The experience of the race and all the refinements of modern science may be regarded as showing quite conclusively that, within the limits of our experience, there is no motion of material masses in the direction of a fourth dimension, no physical agency which we can assume to have its origin in regions to which matter cannot move, when it has three degrees of freedom. Claiming this, we must carry the claim only to the limits justified by actual experience. We have no experience of the motion of molecules, therefore we have no right to say that those motions are necessarily confined to three dimensions. Perhaps the phenomena of radiation and electricity may yet be explained by vibration in a fourth dimension. We are justified by experience in saying that the space relations which we gather from observation around us are valid for the greatest distances which separate us from the most distant stars. We have no right to extend the conclusion further than this. We must leave it to our posterity to determine whether, in either way, the hypothesis of hyper-space can be used as an explanation of observed phenomena.

ON THE LIQUEFACTION OF AIR AND THE
DETECTION OF IMPURITIES (SEPARA-
TION OF HELIUM FROM THE GAS OF
THE KING'S WELL, BATH).

By Prof. JAMES DEWAR, M.A., LL.D., F.R.S.

In a paper on "The relative behavior of chemically prepared and of atmospheric nitrogen," read before the society in the year 1894, it was stated that all samples of nitrogen and oxygen properly purified are, when liquefied, clear transparent liquids, so that the solid matter which always separates when air or nitrogen or oxygen is liquefied on the large scale consists of impurities. Ordinary air containing 4 parts of carbonic acid per 10,000 parts gave a turbid liquid from the solidification of the carbonic acid; and oxygen containing traces of chlorine behaved in a similar manner. With the object of ascertaining the proportion of any gas in air that is not condensable at about -210° C. under atmospheric pressure, or is not soluble in liquid air under the same conditions, the following apparatus has been devised. A cylindrical bulb of a capacity of 101 c. c., marked B in figure, had a capillary tube sealed into it terminating in a three-way stopcock, as shown at E. The parts marked C and D consist of soda lime and sulphuric acid tubes for removing carbonic acid and water. The stand marked G holds the large vacuum test tube into which B is inserted which holds the liquid air maintained under continuous exhaustion. As this low temperature had to be kept steady for from one to two hours, while at the same time the bulb, B, had to be completely covered with liquid air, it was necessary to arrange some means of keeping up the liquid air supply without disturbing the apparatus. The plan adopted is shown at H, which is a valve arrangement which can be so regulated as to suck liquid air from the large vacuum vessel, A, and discharge it continuously along a pipe into the vacuum test tube, G, the latter being kept under good exhaustion. In working the apparatus, the tube, I, is connected to a gasometer containing 10 cubic feet of air, so that the volume of air condensed in each experiment may be observed. This was generally from $2\frac{1}{2}$ to 3 cubic feet. If there is a very small proportion of some substance not liquefiable or soluble in liquid air, then we should expect the vessel, B, would not fill up completely into the capillary tube. This is, however, exactly what does take place. After 40 minutes' cooling the vessel, B, and the cool part of the tube were filled with liquid. In this experiment some 80 liters of air were condensed, and any accumulated uncondensed matter must have been concentrated in the upper part of the capillary tube, which had a volume of 0.5 c. c. Under the conditions, therefore, the material looked for must be less than 1 part by volume in 180,000 of air.

To test the working with an uncondensable gas added to air, a volume of 10 cubic feet was taken in the gasholder and to that 500 c. c. of hydrogen were added. This is in the proportion of less than 1 in 500. Even after two hours' cooling, the tube, B, could only be filled four-fifths. In order to prove that the gas accumulated in the upper part of B was hydrogen, the threeway stopcock at E was turned, and the temperature allowed to rise so that the gas was expelled from the evaporation of the liquid air and collected over mercury as shown at F. The gas thus collected was easily combustible and consisted chiefly of hydrogen. The amount of hydrogen was then reduced to 1 part in 1,000 of air, and it was found that after one and a quarter hours' cooling the bulb, B, had filled to within a half c. c. of the capillary tube. A new sample of air containing 1 part of hydrogen in 10,000 of air filled the bulb, B, completely as if it were ordinary air.

It appears from these experiments that 1 part of hydrogen in 1,000 of air is just detectable by this plan of working. As the 80 liters of air condensed contained

some 80 c. c. of hydrogen, it appears that 100 c. c. of liquid air at from -200° to -210° C. had dissolved nearly all this gas; in fact, that 20 c. c. of hydrogen at the low temperature is dissolved in 100 c. c. of liquid air. In the paper on "The liquefaction of air and research at low temperatures" (Proc., 1885, 11, 221), it was shown that if hydrogen containing a small percentage of oxygen were employed for the purpose of getting a hydrogen jet, the liquid collected from it was oxygen, containing, however, so much hydrogen dissolved in it that the gas coming off for a time was explosive.

In order to press this inquiry a little further, some natural gas known to contain a different constituent like helium, suggested itself as being worthy of trial. Lord Rayleigh's results of the examination of the gas from the King's Well at Bath showed that it contained 1·2 part of helium per 1,000 volumes, so that it seemed admirably adapted for such experiments. The author has to express his thanks to the corporation of Bath for giving permission to collect samples of the gas.

The sample of gas from the Bath Spring was treated exactly in the same way as the hydrogen mixtures described above. During the liquefaction there was a marked difference in the appearance of the liquefied gas, for while the hydrogen and air mixtures gave a clear, transparent liquid, the product from the Bath gas was turbid, and the precipitate by transmitted light looked yellow-brown. This solid turns out to be of organic origin, probably of the petroleum order of compounds. It has a very marked aromatic smell resembling such bodies. The trace of material left gave, after treatment with concentrated nitric acid, the smell of nitrobenzene; and as its detection cannot be explained by the presence of any material of the kind in the vessels used in collecting, it must be assumed to be a normal constituent of the Bath gas. A further quantity of the Bath gas must be collected in order to confirm the presence of such bodies and to definitely make out their nature. Another peculiarity of the liquid is that, on examining it with the spectroscope, even through a thickness of two inches, no trace of the characteristic oxygen absorption spectrum could be detected. In all attempts to make nitrogen for liquefaction on the large scale, oxygen could always be detected in the liquid with the greatest ease by means of its absorption spectrum. After the cooling had continued for one hour the gas ceased to flow into the con-

feet of air or Bath gas, but from hundreds of cubic feet of such products. This investigation will be continued with new samples, in order to see if the composition of the gases changes and to isolate the hydrocarbons.

The author has to thank Mr. Lennox and Mr. Heath for able assistance in carrying out the experiments.

MODERN ALCHEMY.

By W. E. ORD, B.A.

A LOVE of science for its own sake has been the noblest incentive of the world's greatest discoverers, but in the pursuit of chemical science there has ever been an inducement of a more practical kind. We find the alchemists of old continually urged forward in their arduous labors by the dreams of wealth which their science, if it could be so called, appeared to render capable of realization; or perhaps by the infinite possibilities which seemed to exist in the changing substances around them. In mediæval times, when the European world was throbbing with the excitement occasioned by the discovery of untold wealth in the New World, when adventurers were giving their lives in the vain endeavor to become rich at a stroke, the alchemists in their laboratories were scarcely less eager in their investigations, impelled by that dream of wealth which never fails to rouse the dormant energies of mankind. Strange as the hope of the alchemists may seem to us, the idea of transmuting the baser metals into gold appeared, with the knowledge of chemistry then possessed, to have a plausible foundation of fact. In the view of the alchemists, the baser metals could have none of that stability of character with which the pure elements are now associated. Examined in an impure state, they were changeable in their properties, and often unrecognizable, for a minute trace of impurity alters their character. A trace of lead or arsenic, for example, renders gold exceedingly brittle and alters its color; while, as is well known, a small quantity of carbon in iron causes it to become elastic, and if more be present, it becomes hard and brittle.

In addition to this instability of character, the transmutation had every appearance of possibility under the view then generally accepted—and first taught by Geber, an Arabian chemist—that all the metals were alloys of sulphur and mercury in varying proportions,

Apparatus for the examination of the least condensible portion of Air.

densing vessel, and some 20 c. c. at the upper part of the glass cylinder, B, was filled with a gas that had not undergone liquefaction or solution. About 70 liters of the Bath gas were condensed, certainly the largest quantity of this gas ever subjected to chemical examination. This was boiled off just as the hydrogen was treated in the experiments described above, and as, by accident, too much nitrogen had volatilized along with the gas, oxygen was added and the mixture sparked over alkali to get rid of the excess of nitrogen. During the sparking, the helium lines were well marked (along with others the origin of which must be settled later), and a vacuum tube filled with the product of the sparking gave a splendid spectrum of the gas. The sample of gas directly connected from the liquid nitrogen contained about 50 per cent. of helium. It is therefore possible to separate helium from a gas when it is only present to the extent of one-thousandth part by liquefaction in the manner described. From this it would appear that helium is less soluble in liquid nitrogen than hydrogen is in liquid air, and is of greater volatility than either of the constituents of air, as Prof. Olszewski found (Bull. Ac. Crac., 1896, 287) by direct experiment on a pure sample of the gas sent to Cracow by Prof. Ramsay with the object of liquefaction. In the author's lecture (Proc. Roy. Inst., 1896), entitled "New researches on liquid air," the following observation occurs: "The exceptionally small refractive value observed by Lord Rayleigh in the case of helium shows that the critical pressure of this body is proportionately high. It would therefore be more difficult to liquefy than a substance having about the same critical temperature but possessing a lower critical pressure than hydrogen." Now that it has been shown by Prof. Moissan and the author that two substances like fluorine and argon, differing by 2 units in molecular weight, boil at nearly the same temperature, it seems reasonable to extend the analogy to the case of hydrogen and helium, where the same difference occurs, and to suggest that they also probably have about the same volatility: If the sample of uncondensed gas resulting from the first liquefaction of the Bath gas were again treated in the same way, a much more concentrated specimen of helium could be obtained. Provided helium were wanted on a large scale, then a liquid air apparatus similar to that in use at the Royal Institution transported to Bath and worked with the gas from the King's Well could be made to yield a good supply. With a modified form of apparatus, it will be possible to collect any residuary gas from the use, not of 3 cubic

their various properties being produced by the existence of a great or less quantity of either of these elements. The noble metals were held to be particularly rich in mercury and poor in sulphur, and the transmutation of the baser metals was thought to consist in the withdrawal of sulphur from them and the addition of mercury. The difficulties and confusion which the alchemists had to contend with were still further increased by the spirit of mysticism pervading their writings, and the consequent impossibility of following up the discoveries of previous investigators. In view of such difficulties, it is not surprising that, though a belief in alchemy lingered on into the last century, the alchemists should have been a long way from finding the true path to a process of transmutation which is still regarded by many as undiscoverable.

Within the past year a claim has been made to the discovery of a solution of the problem of the alchemists which is both startling and interesting. Dr. Emmens, an eminent chemist of New York City, and inventor of the high explosive "emmensite," has recently published an account of some researches which would seem to have resulted in the actual transmutation of silver into gold—an achievement as important in its economic aspect as it is revolutionary with regard to chemical theory. In order, however, to properly appreciate the work which appears to have been accomplished, it is well first to consider the subject in the light of modern chemistry. The chemist, in pursuing his analyses of matter as far as his methods will permit, discovers that there are some seventy kinds of substances which refuse to be split up into other substances, and to these ultimate constituents of matter he gives the name of "elements." To the elementary bodies he finds, by reason of certain considerations which cannot now be gone into, that different numbers, representing the ratios of the weights of their respective atoms, may be attached, and thus we obtain a series of elements with atomic weights, ranging from that of hydrogen to those of the heaviest elements known. It is, moreover, found (as was first observed by Newlands in 1864) that if the elements are arranged in the order of their atomic weights, similar elements recur at definite intervals in the series. Thus they arrange themselves in several groups or "natural families," and the properties of the elements are said, mathematically, to be periodic functions of the atomic weights. In view of the problem of the transmutation of the metals (which are elementary bodies) this classification is supremely interesting. As it is found that certain elements are more nearly