3. Comments on the possible commercial application of the results obtained have been made.

SEATTLE, WASHINGTON

[CONTRIBUTION FROM THE KENT CHEMICAL LABORATORY OF THE UNIVERSITY OF CHICAGO]

THE ABSENCE OF HELIUM FROM THE GASES LEFT AFTER THE PASSAGE OF ELECTRICAL DISCHARGES: I, BETWEEN FINE WIRES IN A VACUUM; II, THROUGH HYDROGEN; AND III, THROUGH MERCURY VAPOR

BY S. K. ALLISON AND WILLIAM D. HARKINS

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Introduction

The Whole Number Rule and Nuclear Stability

The "Whole Number Rule"[1] has an important bearing upon the question of atomic stability. This rule states that the atomic weight of any pure atomic species, other than hydrogen, is very close to a whole number on the basis of oxygen as 16. Thus the packing effect in the formation of helium from hydrogen is large and amounts to 0.77%, but the further packing when complex atoms are formed from helium is so small that its effects have not been observed thus far in the atomic weights. According to the special relativity theory of Einstein, a loss of mass of 0.77% indicates an energy output of 6.7×10^{11} calories per mole of helium formed, as was pointed out[2] in 1915. This indicates the great probability that the helium nucleus is exceedingly stable; so stable that it seems entirely improbable that it can be disintegrated into hydrogen by the use of any source of energy now known. While it is easy to obtain sufficient energy to effect such a disintegration, the difficulty comes in obtaining the energy in a sufficiently concentrated form to enable its application to such a minute particle. However, it is possible that later discoveries may reveal alpha particles of a speed so high that the kinetic energy per particle will be as high as the energy of formation of the particle from hydrogen.

The smallness of the packing effect between helium and the heavier atoms gives some evidence in favor of the idea that the alpha particles in a complex nucleus preserve their individuality to a considerable extent.[3]

[1] Harkins and Wilson, THIS JOURNAL, **37**, 1367 (1915).

[2] Harkins and Wilson, *Phil. Mag.*, **30**, 723 (1915). Tolman, THIS JOURNAL, **44**, 1902 (1922).

[3] There is the possibility, however, that the alpha particles lose their individuality to a considerable extent, and that the constancy of the packing effect is due to some characteristic of the positive and negative electrons, or to a compensation due to some unknown factor.

Thus, the whole number rule gives some encouragement to those attempting atomic disintegration. Indeed when highly complex nuclei such as those of the radio elements are investigated, spontaneous disintegration with a *liberation* of energy is observed. Theoretically, at least, the possibility still exists that the nuclei of the more complex atoms might, under certain circumstances, become unstable and liberate helium and possibly hydrogen nuclei.

Temperature and Nuclear Stability.—It was formerly supposed that the composition of the stars as revealed in the spectroscope gives evidence that complex atom nuclei can exist only below a certain range of temperature. This line of evidence has been greatly weakened, if not entirely overthrown, by recent calculations and observations on the phenomenon of thermal excitation,[4] so we should not consider the complex atoms to be absent in the hotter stars merely because the spectroscope fails to reveal lines which characterize these atoms at lower and more familiar temperatures. The work of Russell[5] has explained the anomalous results of several previous researches on the α- and β-ray activity of radium emanation, the active deposit, and radium C, and has shown that at least between room temperature and 1100° the activity of these substances is entirely independent of temperature. There seem to be no good theoretical grounds for supposing that temperature alone will produce the disintegration of atomic nuclei, although it is conceivable that other factors produced by temperatures of several million degrees might affect their stability.

A list of references to articles of recent date dealing with experiments concerning the effects of electrical discharges upon atomic stability is given below.[6]

Experimental Part

Construction and Operation of the Condenser.—In part of the work to be described here a very large condenser charged to about 40,000 volts produced an arc in high vacuum between two very fine metallic wires. In this manner the impact of high speed electrons was utilized, and the electrodes were completely volatilized by the heat evolved, so that any gases formed could not remain occluded in them. In view of the great tendency of metals to occlude hydrogen, it was considered that evolution of this gas could not be attributed to nuclear disintegration. All analyses were directed toward detecting the presence of any helium that might be

[4] Saha, *Phil. Mag.*, **40**, 72 (1920).

[5] Russell, *Proc. Roy. Soc. London*, **86**, 240 (1911).

[6] Collie and Patterson, *Nature*, **90**, 653 (1913). Thomson, *ibid.*, **90**, 645 (1913). Collie and Patterson, *Proc. Roy. Soc. London*, **91**, 30 (1914). Strutt, *ibid.*, **89**, 499 (1914). Winchester, *Phys. Rev.*, **3**, 287 (1914). Rutherford, *ibid.*, **37**, 571 (1919). Wendt and Irion, THIS JOURNAL, **44**, 1887 (1922). Rutherford, *Nature*, **109**, 418 (1922). Thomson, *Proc. Roy. Soc. London*, **101**, 290 (1921).

formed. The apparatus was so constructed that after one set of wire electrodes had been volatilized it was possible to replace them and repeat the operation. The gases from a number of such arcs were collected and analyzed for helium by refined spectroscopic methods.

For the details of construction of the condenser the investigators are very much indebted to Dr. Ralph A. Sawyer, of the University of Michigan. His design was adopted with only minor changes. The condenser was built of 440 panes of *double-strength* window glass, 35.6 × 45.7 cm., of average thickness 0.318 cm., specially selected for thickness and absence of defects. The plates of the condenser were constructed of thin "tin" roofing. The rigidity of this sheet iron gives an advantage over tin foil, as the latter is apt to tear where the terminals are attached. Units of 15 panes and 14 plates were immersed in transformer oil of high specific resistance held in galvanized iron tanks.

Using the equation $C = AK/4\pi d$ and assuming that $K = 7$, it is found that $C = 0.44$ microfarad.[7] The energy stored in such a condenser is $\int_0^Q \overline{P.D.}\, dq = \frac{1}{2}\overline{P.D.}^2 \times C$. If $P.D.$ = 40,000 volts, E = 85 calories.

The condenser was charged from a commercially built transformer and rectifier. Measurements with a reliable sphere-gap gave the voltage used in charging the condenser as 42,000. Later the condenser was split in half and reconnected in series; thus the charging potential could be raised to 84,000. Obviously, no change in the energy content of the condenser occurred in this process.

After considerable difficulty in finding a suitable means of closing the discharge circuit, a suggestion by Dr. Sawyer was adopted, and a spring switch under oil was used. When using the 84,000 volt circuit, insulation difficulties prevented the use of this type of switch, and an external sphere-gap was adopted. In this case the discharge occurred while the transformer was supplying current to the condenser. All electrical connections were made with No. 6 B. and S. gage hard-drawn copper wire, having a resistance of 1.2×10^{-5} ohms per centimeter. Bends were avoided in the discharge circuit as much as possible, in order to cut down the inductance. When discharged through a sphere-gap, an intense light was emitted and a loud report occurred. When a long series of arcs was run with an external sphere-gap, the operator was forced to fill his ears with cotton to prevent extreme discomfort.

The Spectroscopic Detection of Helium in Gaseous Mixtures.—Due to the relatively high ionization potential of helium, a large amount of this gas may be present in a gaseous mixture without the appearance of its characteristic lines in the spectrum of the discharge. Collie and Ram-

[7] The amount of energy stored by this condenser is much higher than for some condensers stated to have a higher capacity.

say[8] found that at a pressure of 2.61 mm., a mixture of one part of helium to two parts of hydrogen by volume shows no helium lines at all. The helium lines appeared, however, on reducing the pressure. They concluded that 10% of helium could be detected in hydrogen under the most favorable conditions. By contrast, they state that one part of hydrogen can easily be detected in 10^5 parts of helium.

Soddy,[9] in his work on the formation of helium from the radio elements, devised a spectroscopic method of testing for helium which has been adopted in a modified form. The necessary purification of the helium was accomplished by absorbing all the chemically valent gases with hot calcium. Calcium vapor reacts vigorously with all gases except those of the argon group with the formation of solid compounds. The absorption of hydrogen begins at about 400°, and if the calcium is allowed to sublime to a cooler portion of the container, the pressure of hydrogen in the apparatus rapidly becomes so low that a powerful induction coil cannot force a discharge through the gas.

A few preliminary trials showed that it is entirely practicable to heat calcium in heavy-walled Pyrex tubes to a temperature at which absorption begins. These tubes did not collapse as the pressure inside decreased. After considerable experimentation the apparatus illustrated in Fig. 1 was finally devised. This is very efficient if the total amount of gas to be analyzed is small.

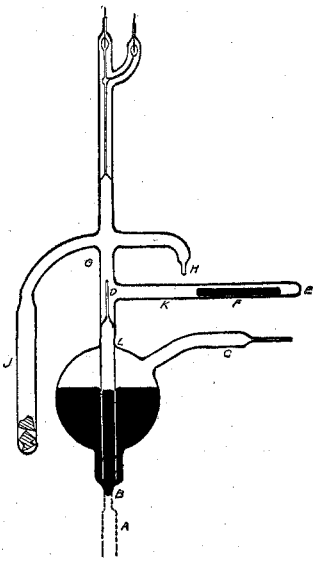

Fig. 1.—Apparatus used for analyzing gaseous mixtures for helium. A, tube through which reservoir and mercury are outgassed. B, constriction for sealing off Tube A. C, tube for admitting air to reservoir. D, capillary shut-off between reservoir and spectrum tube. E, tube to hold slider. F, slider with which capillary is broken. J, slide tube of heavy Pyrex glass containing calcium.

The apparatus is constructed of Pyrex glass. The lower part, which is a mercury reservoir, is at first separate from the upper; they are afterwards joined at G. The mercury reservoir is at first constructed as shown, except that Tube A is attached at B, and the side-tube K is open at E. The slider F, which is a small Pyrex tube filled with mercury and sealed at both ends, is not inserted until later, for fear of prematurely fracturing the capillary D. The mercury reservoir is then inverted, and pure mercury of sufficient volume to flood the entire apparatus is inserted through Tube A in such a manner that none enters the insealed tube and gets into the capillary D. The tube A is then sealed to the high vacuum line and the reservoir evacuated to the lowest possible pressure. During this process the mercury is cautiously heated with a luminous gas

[8] Collie and Ramsay, *Proc. Roy. Soc. London*, **59**, 257 (1896).

[9] Soddy, *Phil. Mag.*, **16**, 513, 532 (1908); *Proc. Roy. Soc. London*, **78**, 429 (1907).

flame. If the inner seal L is correctly constructed, there is no danger of breakage when proper care is taken. In this manner all occluded gases are driven out of the mercury, and from the glass walls of the reservoir. The apparatus is sealed off at B, and inverted to the position shown in Fig. 1. The reservoir is then sealed to the remainder of the apparatus at G; calcium is put into tube J, and the apparatus is sealed at H to the bulb in which generation of gas is to take place. The slider is inserted in tube K which is sealed at E and the evacuation is begun. During evacuation a non-luminous flame is played over the glass walls and the calcium is heated to redness. Apparatus out-gassed in this way was found to hold a non-conducting vacuum indefinitely.

After the gases have been generated in the bulb to which H is sealed, they are forced into the relatively small volume of the upper part of the apparatus of Fig. 1. The spectrum of the gases may then be examined by passing an induction coil discharge through the capillary spectrum bulb at the top. The calcium is then gently heated (a surprisingly small flame is sufficient) until the spectra of all chemically valent gases disappear, or the spectrum tube becomes non-conducting. In case certain gases remain whose spectra are to be examined more critically, the mercury lines may be removed by immersing Bulb J in liquid air.

If the vacuum becomes non-conducting, the apparatus is tipped until the motion of the slider breaks the capillary D. Pressure tubing is slipped over Tube C, and connected to a vacuum pump. The capillary of C is then fractured by compressing the rubber, and air admitted to the reservoir. The mercury then rises and floods the entire apparatus, compressing all remaining gases into the capillary spectrum bulb, whose volume is about 0.04 cc. The spectrum of hydrogen invariably appears again as the volume becomes very small, showing that absorption of this gas by the calcium is not complete. As Soddy points out, this last trace of hydrogen makes the helium test much more delicate, since it serves to conduct the current. He found by trial that in an apparatus similar to this, but in which the mercury was not previously out-gassed, he could detect the presence of 2×10^{-10} grams of helium.

Experimental Work on Platinum and Tungsten.—The apparatus used to produce metallic arcs in a vacuum is shown in Fig. 2.

The fine wires were held in steel holders constructed as shown in the detailed sketch. The steel tip was divided by a fine slit, into which the wire was thrust. The sliding collar S was then pushed on so as to clamp the wire firmly. The steel holders with their wires were inserted through the side arms of the explosion bulb and pushed through the steel collars C until the required gap between the ends was obtained. The ground stoppers were inserted into the side arms and the large valve V opened to the vacuum pumps. The system was evacuated by means of a double-stage mercury condensation pump, backed by a "Cenco Hyvac" oil pump. These pumps working on a tight system rapidly exhausted it until a McLeod gage capable of reading 10^{-6}mm. pressure showed no reading and the rising mercury struck the top of the capillary tube with a distinct click.

As the evacuation proceeded, mercury rose in arms A. These tubes dipped into reservoirs of mercury open to the air so placed that when the apparatus was entirely

exhausted the mercury columns made contact with the steel rods M, which were threaded into the collars C. The terminals of the discharge circuit were dipped into the reservoirs at the bottom of the arms A, and in this manner an electrical circuit was established in which no electrodes were sealed through glass. The small tube D led to a mercury reservoir which could be evacuated. This was placed much higher than the reservoirs of the tubes A. The evacuation was continued for about 2 hours after the McLeod gage had shown that the pressure was at a minimum. Then the valve V was closed, and the oil spring switch in the discharge circuit opened. The condenser was charged at 42,000 volts and then the trip on the opening switch was pulled and the discharge circuit closed. The two wire points disappeared in a brilliant flash.[10] Air was then admitted to the mercury trap at the base of the tube D, and the mercury allowed

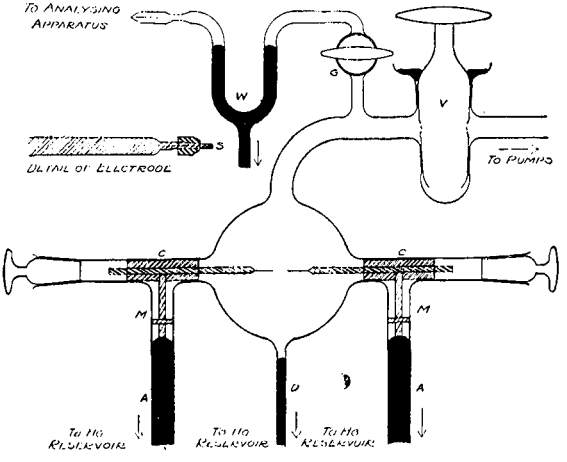

Fig. 2.—Discharge chamber for experiments on wires. A-A, barometric height tubes containing mercury which conducts the discharge. C-C, steel collars for supporting electrodes. D, small tube to reservoir for flooding discharge chamber with mercury. G, large stopcock to analyzing apparatus. M-M, rods for making contact with mercury in A-A. S, detail of electrode tip, slotted to receive wire. V, large valve to pumps, shut before each discharge. W, mercury shut-off, in line to analyzing apparatus.

to flood the bulb. This compressed all gases toward Stopcock G. This was opened and the gases allowed to pass. By pulling the mercury out of Shut-off W the gases diffused into the analyzing apparatus. The mercury was then withdrawn from the bulb. air admitted (with G closed) and the wire electrodes were replaced. In this manner the gases from a large number of explosions could be collected in the analyzing apparatus.

Special grease prepared for high vacuum work was used on the stoppers and stopcocks. By careful selection of the stopcocks and stoppers, an assemblage was obtained which did not permit enough seepage to invalidate the results of the work. This was certain because before each discharge Valve V was closed for 5 minutes and the rise of

[10] High-speed electrons are produced only at the beginning of the discharge. After the arc has struck, the speeds are reduced to values corresponding with only a few volts.

pressure inside the bulb measured. In this time the pressure usually reached 10^{-5} mm., probably due to slow evolution of gas from the steel surfaces and glass walls. The time consumed in discharging and compressing the generated gas was about one minute.

As might be expected, small amounts of gas appeared in this apparatus after each discharge. Pressure measurements showed that the average volume of the liberated gases from one trial at atmospheric pressure is about 0.04 cc. These gases may have come from various sources:[11] (1) from gas adsorbed in the wires; (2) from gas adsorbed on the glass and steel surfaces; (3) possibly from gas formed at the surface of the glass by the bombardment with electrons. The tungsten and platinum wires used were 0.00254 cm. (0.001 inch) in diameter. The gap between them was varied from 1 mm. to 2 cm. in various runs. The average length of each wire was 1.25 cm., though this also was varied widely. Thus the average weight of tungsten volatilized was 2.4×10^{-4} g.; of platinum, 3.5×10^{-4} g. In some cases the behavior of the discharge was erratic, and only one wire was volatilized, showing that the discharge path is very narrow through the vacuum. This behavior seemed especially common when the wires were of tungsten.

The gases from 168 such arcs were analyzed. In the earlier work the gases were collected in a spectrum bulb with a charcoal tube attached. When coconut charcoal is cooled to liquid-air temperatures, all gases except those of the argon group and hydrogen are readily absorbed, but this method is not so delicate as the calcium method, since charcoal occludes appreciable quantities of helium.

The spectra were examined with a direct vision spectroscope which was capable of resolving the sodium D lines easily. Since the helium D_3 line is in the yellow region to which the eye is most sensitive and the light entering a direct vision spectroscope is very well conserved, the visibility of the D_3 line is an *extremely* sensitive test for the presence of small amounts of pure helium.

The gas evolved from these arcs proved to be hydrogen with faint traces of nitrogen. The spectrum of mercury vapor was always present. The secondary spectrum of hydrogen made the region between the H_2 line and the mercury yellow lines luminous, and to the inexperienced observer it might appear that the D_3 line of helium was present. When the charcoal bulb was immersed in liquid air, however, *all* lines grew fainter until no spark pass.

The results of 48 discharges each between points of platinum and tungs-

[11] While the glass parts of the apparatus were heated during outgassing, the electrodes used in these particular tests were not heated, since they give out hydrogen in only extremely small amounts, and this hydrogen increases the sensitiveness of the test for helium. If helium had been found it would have been necessary to heat the electrodes to drive out any absorbed helium, but in case of negative tests for this element this should not be done.

ten were analyzed by the charcoal method with negative results. In each of the final trials, the total gas resulting from 20 such discharges was collected in the calcium analyzing apparatus. No trace of helium was found in six of these trials, three on platinum and three on tungsten, making 120 discharges in all.

In a few sets of 20 discharges single wires were used which were pushed into the apparatus clamped in one electrode and touched to the other. This corresponds to the conditions in the experiments of Wendt and Irion,[6] but no helium was detected by us.

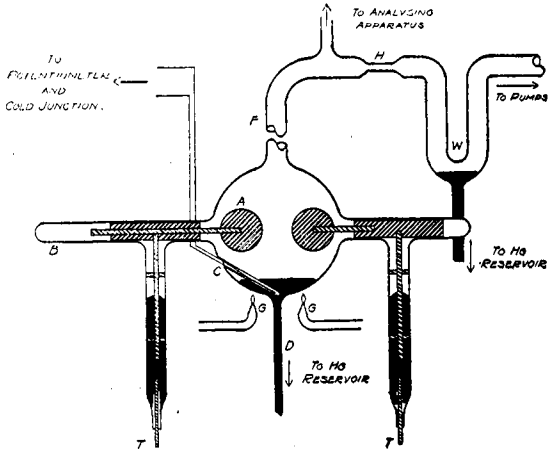

Fig. 3.—Discharge chamber for experiments on mercury vapor and hydrogen. A, steel sphere electrode 3.2 cm. in diameter. C, thermocouple for reading temperature of mercury. D, tube leading to mercury reservoir for flooding discharge chamber. G-G, gas flames for heating mercury to obtain vapor. H, constriction for sealing off bulb after required number of discharges have passed. T-T, tungsten rods for carrying current; 2 mm. in diameter. W, mercury shut off; closed while discharges are being passed.

In view of the fact that many experimenters have reported that helium is occluded in appreciable quantities in metal electrodes, it may seem remarkable that no helium at all was discovered in this work. This may be due to the very small quantities of tungsten and platinum volatilized.

As a matter of record, the spectrum of the unpurified gases from a number of discharges was photographed by the use of a Rowland concave grating, and compared with known helium, hydrogen, and mercury spectra. All the lines of the unknown spectrum were shown to be those due to hydrogen and mercury.

Experimental Work on Mercury.—In passing the condenser discharge through mercury vapor, the apparatus was constructed without stoppers,

since it was unnecessary to replace electrodes after each discharge. The apparatus used for this purpose is shown in Fig. 3.

The electrodes are two large steel ball-bearings, 3.2 cm. in diameter and very accurately round. They served as a sphere gap and concentrated the discharge into a narrow space between them. The gap between these spheres was adjusted by moving the electrode A. A gap of 2 cm. was finally decided upon, and side-tube B sealed. Two pieces of tungsten rod, T, which were 2.5 mm. in diameter were used to conduct the discharge into the bulb and they did this without cracking at the seal. The connection between the tungsten inseals and the supporting framework of the steel spheres was made with mercury as shown. All mercury used in these experiments was treated with a mixture of nitric acid and mercurous nitrate, dried, and distilled in a vacuum before use.

Sufficient vapor to conduct the discharge was obtained by heating mercury which had been allowed to rise into the discharge chamber through Tube D, which led to a large mercury reservoir, the pressure in which could be controlled. The mercury was heated with the small gas flames G. A thermocouple junction was inserted through the glass in seal C, and thus the temperature of the liquid mercury could be determined. The lead to the vacuum line, F, was made long enough to act as a reflux. As before, the entire apparatus was constructed of Pyrex glass. It is doubtful whether a soft glass apparatus of this type could be built which would not crack under the thermal differences imposed on it.

It was found that this apparatus could be very completely evacuated. When preliminary tests had shown that the apparatus was free from leaks, the mercury in the discharge chamber was heated to 90° and evacuation continued for several days. During this time high-voltage currents from the transformer secondary were run through the bulb, and the glass walls were heated at intervals with the Bunsen flame. After this treatment the mercury in the shut-off W was raised and the apparatus allowed to stand, in one case for seven days. At the end of this time the pressure inside was too low to permit an induction coil to force a discharge through the small spectrum bulb of the analyzing apparatus.

In the discharges in mercury vapor, the condenser was divided and the halves connected in series, thus allowing a potential of 84,000 volts to be used in charging. With this arrangement an external sphere-gap was used in place of the spring switch. The relative amount of energy expended in the outside and inside gaps depends on the resistance offered to the discharge while it is passing; hence, much more energy is expended in the gap in a vacuum than in the gap at atmospheric pressure, on account of the relatively large number of ions formed in the air gap.

Three trials of 100 discharges each were made. When the required number had passed, the constricted portion of the line at H was heated until its walls collapsed, thus separating the discharge bulb from the vacuum line. The bulb was flooded with mercury from the reservoir below D and all gas compressed into the analyzing apparatus which was then sealed off.

Very small amounts of hydrogen were liberated in these discharges.

After some 30 discharges enough was obtained to produce a faint bluish discharge in the capillary of the spectrum tube. This gas was then absorbed from the entire apparatus by heating the calcium, and the discharges continued. During the discharges the temperature of the mercury as shown by the thermocouple was kept between 80° and 90° at which the vapor pressure is about 0.1 mm. Completely negative results as to the presence of helium were obtained.

Experimental Work on Hydrogen.—The effect of the condenser discharge in hydrogen was tried, using the apparatus shown in Fig. 3. Pure hydrogen was prepared, using the zinc amalgam cell of Richards, and introduced into the apparatus in such a way that contamination with air was impossible. Air must be carefully excluded, since the argon from 1 cu. mm. of air vitiates the test for helium, as was found by Soddy. A large absorption tube using calcium was constructed to absorb the greater part of the hydrogen before the gases were compressed into the chamber used for the analyses. The pressure of the hydrogen in the apparatus was 40 mm. One hundred discharges were made, and the excess of hydrogen absorbed in the large calcium tube, after which the bulb was flooded with mercury and the analysis performed. The gas left after 300 discharges in hydrogen was completely analyzed. No helium was detected.

In spite of the large evolution of heat which would attend the synthesis of helium from hydrogen, we believe that the difficulty in making any accurate calorimetric measurements with the necessarily complicated apparatus makes the spectroscopic method, as applied by Soddy, at least as sensitive as the calorimetric.[12] For, assuming that the production of 4 g. of helium would liberate 6.5×10^{11} calories, it is obvious that the formation of 2×10^{-10} g. of helium (the minimum amount spectroscopically detectable) would produce only 33 calories, which is of the order of magnitude of the heat evolved in the condenser discharge alone.

Summary

1. A powerful condenser of approximately 0.5 microfarad capacity, charged to 42,000 volts, was allowed to discharge through very fine points consisting of platinum or tungsten wires 0.0025 cm. in diameter, inclosed in an evacuated bulb.

2. The condenser was divided and reconnected in series so that it could be charged to 84,000 volts. The discharge was then allowed to pass through saturated mercury vapor at 90° (0.1mm. pressure) between accurately round steel balls 3.2 cm. in diameter.

3. The gases evolved in these discharges were tested for helium; 168 discharges were made between points as described in (1), and the discharge was allowed to pass through the mercury vapor 300 times. Hydrogen

[12] Compare Rutherford, Ref. 6.

was liberated in all the trials, but in no case was helium detected, even by the use of the highly sensitive spectroscopic method of Soddy, which will detect 2×10^{-10} g. of helium. It is found that ordinary spectroscopic methods for the detection of helium are, on the other hand, not at all sensitive. In no case was the amount of heat produced noticeably greater than that to be expected from the condenser discharge alone. However, no actual measurements were made of the heat liberated, since it was found that the spectroscopic method of Soddy is fully as sensitive as the calorimetric method, and is more definite in its significance.

4. The theory of atomic disintegration is discussed, and it is pointed out that the failure of the electrical discharge methods to disintegrate the atom is due to the fact that energy is not transmitted to the nucleus in a sufficiently high concentration. Electrons with velocities of several million volts may prove effective, though thus far only high-speed α-particles have induced disintegration, as in the experiments of Rutherford.

5. The condenser, using the 84,000-volt arrangement, was discharged 100 times through a 500cc. bulb containing very pure hydrogen at 40mm. pressure. This was repeated three times. Tests by the method of Soddy revealed no trace of helium.

CHICAGO, ILLINOIS

[CONTRIBUTION FROM THE RESEARCH LABORATORIES OF THE AMERICAN TELEPHONE AND TELEGRAPH COMPANY, AND THE WESTERN ELECTRIC COMPANY, INCORPORATED]

THE RELATION BETWEEN THE HYDROGEN CONTENT OF CERTAIN CHARCOALS AND SOME OTHER PROPERTIES

BY H. H. LOWRY

RECEIVED OCTOBER 17, 1923

Investigations of sorption of gases and vapors by charcoals have yielded such varying results that many theories have been advanced to explain the nature of the sorption. While these various theories are usually consistent with the particular data from which they were derived, they are not sufficiently general to enable one to predict correctly the course of the sorption in any specific case. That this should be so is, however, almost to be expected for two main reasons. First, because the process is complex, involving adsorption on the surface, diffusion into fine capillaries, condensation within these capillaries, and possibly solution, the relative effects of these factors varying in different samples of charcoal with the source of the material and the method of preparation. Second, because all charcoals cannot properly be assumed to be the same chemically and to be amorphous carbon. The present investigation shows that charcoals contain a proportion of hydrogen chemically combined with the carbon and that the amount of this combined hydrogen depends