tank. The temperature of the tank was from 50 to 65 deg. F. It was then found that the bubbles upon the green tube were much more numerous than on the next tube containing the yellow solution. At the sur-

face of the red tube there were seen but two bubbles. On the blue, there were more than upon the red and yellow, but they were distributed over all the surface and were of larger size. Owing to the composition of

the gases dissolved in water, the bubbles were necessarily rich in oxygen. This phenomenon of localization upon the green tubes seems to be due to an elective absorption of heat rays.

INTERRELATIONS OF THE ELEMENTS.*

A SUMMARY OF RECENT RADIOACTIVE INVESTIGATIONS.

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BEFORE the close of the eighteenth century, attempts at transmutation were recognized as futile, and one thing appeared certain, even at that time: the elements were not to be disintegrated or altered by such chemical processes as those which served to decompose their compounds.

During the past eleven years enormous advances have been made along entirely new lines, in the knowledge of the interrelations of the elements and the nature of matter. This new knowledge had its origin in the discovery by Becquerel, in 1896, of the radiations emitted by uranium. It was found by Becquerel that all uranium compounds send out rays capable of affecting a photographic plate through light-proof paper, and also of enormously increasing the electrical conductivity of air, by ionizing it. Schmidt, and independently Mme. Curie, found that all compounds of thorium produce similar rays. Scientists will never forget the intense interest taken in the discovery by the Curies of radium, a substance which possessed the properties of uranium and of thorium augmented more than a million fold. There were also new properties; powerful physiological effects, evolution of light and even of heat, it having been found by Curie and Laborde that the temperature of a tube of radium is always perceptibly above that of its surroundings. Here then was a most marvelous result—the continuous and seemingly undiminished production of energy by a portion of matter, which appeared to suffer no chemical change. It even seemed as if a source of perpetual motion had been found.

It was soon clearly established that the activity of radioactive substances was not due to the excitation of any *known* radiation. Some scientists, however, including Lord Kelvin, Becquerel, and the Curies, imagined as the source of the observed energy an unknown cosmic radiation, which was intercepted and transformed by the radioactive body, the elevation of temperature of radium above its surroundings being, according to Kelvin, analogous to that of a piece of black paper in a bottle exposed to sunlight.

The solution of the mystery of radium is largely due to Rutherford and his colleagues. There were two main problems: (1) The nature of the radiations, and (2) the nature and cause of radioactivity. The radiations were found to be of three sorts, called the α , β , and γ rays. The nature of the β rays was first established. The photo-activity is chiefly due to these rays; they readily penetrate light-proof paper; are easily deflected by a magnetic or an electric field, and in such a direction as to show that they are negatively charged. In this respect, as well as in many others, the β rays closely resemble cathode rays, which latter have been shown to consist of particles of negative electricity, called corpuscles. These corpuscles, which are shot out from the cathode with 1/10 of the velocity of light, have inertia, due to the moving electric charge; and having inertia, they have mass. The mass of a corpuscle is very small—about 1/1000 that of an atom of hydrogen. The β rays seem to differ from the cathode rays only in having greater velocity. The γ rays are apparently very penetrating X-rays; and just as the latter are produced by the cathode rays, the former are produced by the β rays.

The α rays are quite different: they are unable to penetrate a single sheet of writing paper; but they are the chief cause of the ionization of the air and the elevation of temperature. Rutherford has shown that the α rays consist of positively-charged material particles each having a mass 2 (or 4) times that of an atom of hydrogen and moving with 1/3 the velocity of light. It was now readily understood that the kinetic energy of the rays was the proximate cause of the observed evolution of heat by radium.

The counterpart of the phenomena of the rays was found in the change which occurred at the same time in the active substance itself. Crookes had observed that by treating uranium nitrate solution with an excess of ammonium carbonate, a minute insoluble precipitate remained; this precipitate, called uranium X, was found to possess practically the whole of the photo-activity of the uranium from which it had been separated. Rutherford and Soddy precipitated thorium

with ammonia, and obtained from the filtrate a trifling residue called thorium X, which possessed a large share of the original activity. The activity of the thorium X decreased gradually with time; in four days the activity was reduced to 1/2, in eight days to 1/4. The loss of activity occurred according to the exponential law, or, as the physical chemist would say, the change was that of a first-order reaction: in each unit of time a fixed fraction of the remaining activity disappeared. To some scientists it did not appear remarkable that the radioactive principle of uranium or thorium could be separated by a chemical process; in fact, the original activity of these elements was "explained" as due to the presence of these highly active "impurities." Nor did the loss of activity by UX or ThX, considered by itself, seem extraordinary; it might be likened to loss of temperature by a cooling body.

But a most extraordinary thing was discovered by Rutherford and Soddy, in the further study of this same thorium experiment. The thorium from which ThX had been removed had, at first, only about 1/3 of its original activity; but in just that measure in which the separated ThX lost its activity, that of the thorium itself returned; until, after a period of several weeks, the thorium had entirely regained its original activity, while the ThX had become inactive. A repetition of the treatment with ammonia now yielded a new portion of ThX equal in amount to that first extracted. The behavior of UX was similar. Rutherford and Soddy then announced their now celebrated Disintegration Hypothesis: the radioactive atom is a complex system, made up of corpuscles and α particles, in rapid orbital motion; of such systems some, in the course of time, become unstable and disintegrate; the corpuscles and α particles resulting from such atomic disintegrations constitute the rays, the kinetic energy of which existed previously in the atom. The residual portion of the atom after the escape of a corpuscle or an α particle constituted an atom of a new substance (e. g. ThX), which atom might have even less stability than the original.

In all, over 20 distinct radioactive substances are now known. These constitute three series, in each of which each member produces, by its radioactive disintegration, the following member. The evidence in the case of each change is just as clear as in that of thorium and thorium X. One case in particular, that of the formation of radium from uranium, is of especial interest. It has been shown in two different ways that radium and uranium are always associated in minerals, and, moreover, in a perfectly fixed proportion, as demanded by the hypothesis that the one is the product of the other. Further, uranium minerals freed from radium by chemical processes slowly but surely reproduce the latter substance.

The chemical and physical properties of radium and its salts clearly show it to be a member of the alkaline earth family; its atomic weight is, according to the latest determination of Mme. Curie, 226.5, assuming the elements to be bivalent. The formation of radium by uranium was then a clear case of the transmutation of one element into another, whatever might be thought of such changes as that involving the production of ThX.

The properties of the α particle led Rutherford and Soddy to suggest, in 1902, that it might be an atom of helium. In 1903 Ramsay and Soddy were able to show that radium emanation actually does produce helium in the course of its spontaneous disintegration; this observation has since then frequently been confirmed. The formation of helium seemed to be another real transmutation, since the element radium undoubtedly produced the emanation which yielded in turn another element, helium.

If now uranium gives ultimately radium, what is the final product of the disintegration of the latter? Boltwood believes it to be lead; since he finds that all uranium-radium ores contain notable amounts of lead. In the disintegration of an atom of radium five distinct α rays changes occur. If each produces one α particle, with atomic weight of 4, the final product of radium should have an atomic weight of 226.5 — 20 = 206.5, whereas the atomic weight of lead is 206.9.

There is now no shadow of doubt that the rate of

radioactive change is entirely independent of the form of chemical combination of a radioactive substance; temperature is also without influence; a given transformation occurs at precisely the same rate at the temperature of liquid hydrogen and at a white heat. It thus appears that radioactive change is a natural process which is entirely beyond man's control, and important as is the establishment of this fact, the discovery falls far short of being a complete solution of the problem of the transmutation of the elements.

A further step in this direction seems to have been taken within the past few months, however, by Sir William Ramsay. The alchemist, in his attempts to alter the elements, could apply only the forces of moderate heat and chemical affinity. The chemist of the nineteenth century could command enormously greater ranges of temperature as well as powerful electrical forces; all these means were likewise without avail. And now Ramsay has tried a new force, that of radioactive radiations—corpuscles and particles of matter, both electrically charged, projected with almost inconceivable velocity. The results of the experiments of Ramsay and Cameron may be stated very briefly: Radium emanation acting on water produces neon; while with a solution of copper nitrate it produces argon; and even the copper itself appeared to be attacked, for when the latter element was removed by means of hydrogen sulphide, the filtrate was found to contain lithium. A blank experiment, in which the radium emanation was omitted, but all other conditions remained precisely the same, yielded no trace of lithium. The formation of lithium from copper has been observed four times by Ramsay, and though, as he writes in a private communication, "he was loth to believe," yet he "had to chronicle the results after four repetitions." The importance of these facts, provided they are not due to some spurious cause, needs no comment. In this connection it occurred to me that radium emanation or in general radioactive radiations might act on copper in the solid state; if so, uranium-radium minerals which contain copper should contain lithium also. For another purpose I had, more than a year earlier, separated a sample of pitchblende into its principal constituents. There was a considerable quantity of copper; there was also a solution which could contain only alkali and ammonium salts. It was but the work of an hour to examine this solution for lithium: in the spectrum the characteristic red line of lithium was next in brilliancy to that of sodium. Later, from one to two grammes of four other uranium minerals, including samples of pitchblende, carnotite, and gumite, from widely separated localities, were examined for copper and lithium; all contained lithium, and all but one contained copper. The presence of lithium in a mineral free from copper may be explained upon the supposition that the transmutation of the latter metal had been completed.

The view that the atom is a complex system made up of negatively-charged corpuscles and positively-charged α particles has been made the subject of extensive mathematical studies by J. J. Thomson. Thomson's hypothetical atom is a system composed of rings or shells of corpuscles in a uniform sphere of positive electrification. The electro-positive or negative nature of atoms, their chemical affinity as well as their dual valence toward hydrogen and oxygen, are all most beautifully and at the same time simply explained by the behavior of such imaginary systems, the properties of which vary periodically with increasing number of corpuscles and so fulfill another indispensable requirement of any hypothetical atom. Numerous other properties of matter also receive a satisfactory explanation in terms of the new hypothesis: among such are the conductivity of metals for heat and electricity, bright line spectra, and the Zeeman effect. That the corpuscular theory is the last word on the nature of matter, none will contend. Thomson himself writes: "The theory is not an ultimate one; its object is physical rather than metaphysical. From the point of view of the physicist, a theory of matter is a policy rather than a creed; its object is to connect and co-ordinate apparently diverse phenomena, and above all to suggest, stimulate, and direct experiment."

* Read at Chicago meeting of the American Chemical Society. Reprinted (abridged) from Jour. Amer. Chem. Soc., March, 1908.

The view just given of the nature of the atom accounts also for its radioactivity. A system of revolving corpuscles of negative electricity would slowly radiate energy, at an almost infinitesimal rate, it is true; but the final result would be to produce in the system a condition of instability which would cause its partial disintegration and rearrangement. Is, then, all matter undergoing evolution? That is the question which cannot be positively answered at present. And yet there is much evidence that many elements are faintly radioactive. Such activity may be either intrinsic or due to minute amounts of known highly active substances.

Radioactive matter is easily extracted from the air by means of a negatively-charged wire exposed out of doors, as first shown in 1901 by Elster and Geitel. The rate of change of this active matter indicates that it is chiefly the excited activity, Ra A, B, and C, resulting from the disintegration of radium emanation. A simple experiment which I

recently tried shows the correctness of this view. Air was liquefied, and about a liter of the liquid was allowed to evaporate, and the last portion was examined for radioactive emanations. A considerable activity was found, the rate of change of which plainly indicated the presence of radium emanation together with small amounts of other active matter. The excited activity, which is deposited everywhere by the radium emanation contained in the air, is certainly the cause of a portion of the observed activity of common things. Nevertheless, at least one common element, potassium, seems from the studies of Campbell to possess slight intrinsic activity.

On the other hand it is found that α particles having less than a certain minimum velocity are unable to produce ionization of the air. It is therefore quite possible that some atomic transformations may occur which do not show radioactive phenomena, the initial velocity of the α rays being, in such cases, below the minimum. Such change might occur at rates far

greater than that of uranium and still be impossible of detection in the course of a life time by gravimetric or even probably by spectroscopic methods; since in the case of uranium the rate of change is so slow that no more 0.001 per cent disintegrates in 10,000 years; and yet the ionization method of recognizing α radiations is so surpassingly delicate that one may detect with certainty the activity due to a single milligramme of uranium in any form of combination.

In conclusion it may be said that while the work of the 19th century produced abundant and varied evidence that between the elements there exists the most intimate interrelations, the researches of the past few years of this new century have shown the fundamental significance of these relationships and lead us to the conclusion that the elements may no longer be considered immutable; that matter is probably of but a single sort, of which our commonest elements represent the more stable forms, which have resulted from a process of natural evolution.

THE PRODUCTION OF SMOKE.*

WITH SUGGESTIONS AS TO ITS PREVENTION.

BY D. T. RANDALL.

THE term smoke as used in this paper refers to chimney gases that contain small particles of unconsumed carbon, which give the gases a dark color. Smoke may be of any degree of blackness, but what some persons would call smoke is not considered smoke by others.

Smoke is due to a lack of air at the proper temperature at the point where the volatile gases should be burned, the result being that these gases are only partly burned and the carbon is set free. The density of smoke is measured in many ways, but the most satisfactory at present is by means of the Ringelmann charts. These charts are made by drawing black lines at right angles on a white background. The lines are so spaced as to give the effect of different percentages of blackness when placed at a distance of about 50 feet from the observer. The charts are numbered, 1, 2, 3, 4, and 5, and represent, respectively, 20, 40, 60, 80, and 100 per cent of black smoke. As a matter of fact, anything but a clean stack will result in a smoky atmosphere. If a stack continuously emits a small amount of smoke, it may, during the course of the day, have given off as much carbon and have had as bad an effect as another stack which has been clear most of the time, but which for three or four periods of five minutes each has emitted a dense black smoke. In localities where bituminous coal is burned exclusively a plant is considered good if the average blackness is equivalent to 5 per cent or less.

The following information, taken from the report of the committee for testing smoke-preventing appliances, Manchester, England, is of interest:

"Observations were made for an entire day on 179 chimneys. The general averages of these stacks gave the equivalent of black smoke 102 minutes in 10 hours. The averages for the individual stack varied from the equivalent of black smoke for 423 minutes in the worst to 4 minutes in the best. The relative amount of the smoke from different kinds of equipment may be taken as follows:

"Average of 36 hand fires with air admission, 81 minutes in 10 hours; average of 10 hand fires with air admission, good firing, 40 minutes; average of 4 sprinkling stokers, about 103 minutes in 10 hours; average of 21 coking stokers, about 16 minutes in 10 hours; best coking stokers, about 4 minutes in 10 hours.

"Coking stokers show best economy as well as prevention of smoke.

"Sheffield Association suggest that the permissible limit of smoke emission should vary with the number of boilers as follows: For 1 boiler, 2 minutes per hour; for 2 boilers, 3 minutes per hour; for 3 or more boilers, 4 minutes per hour."

The following are reasons why furnaces sometimes smoke:

1. The furnaces and the grates are not properly designed to burn the coal available. There is almost no equipment on the market that will handle equally well all the fuels found in the United States.
2. There is a lack of sufficient draft.
3. The firemen are unskilled.
4. There is not enough combustion space.
5. Wood, paper, and other refuse are burned.
6. The load is changed quickly.
7. Excessive overloads are maintained.

Within the last few years there has been a remark-

able development in the utilization of coal under the steam boiler. To-day many steam power plants in the United States are burning bituminous coal practically without smoke. This has been brought about by improving the design of the furnaces and by careful attention on the part of the fireman.

It is now possible to design and operate boiler plants burning a high-volatile coal which will be practically smokeless under usual operating conditions, giving off no black or dense gray smoke except when a fresh fire is being built. Banking the fire, shutting dampers, etc., causes smoke of a light or gray shade only. This has been demonstrated at the engineering experiment station of the University of Illinois, where a boiler has recently been installed, properly equipped with a furnace for burning Illinois coal. Under ordinary conditions this plant makes no smoke whatever. This equipment is not suitable for burning low-volatile coals such as are largely used in the East. In experimenting with this furnace an effort was made to produce smoke, but it was found impossible to make black smoke, the worst being about 50 per cent black.

A number of large commercial plants having properly designed furnaces are now operating daily without smoke in many of our larger cities.

Coal can be burned smokelessly, the same as gas, gasoline, or kerosene oil, if the equipment is properly designed and adjusted. Each of these fuels will give off smoke if conditions are not favorable. All the authorities on the subject of combustion and smoke prevention agree upon the following conditions as requirements for a smokeless furnace:

1. The coal should be supplied to the furnace in small quantities at frequent intervals. The more nearly the feed approaches a continuous and uniform supply the better the results.
2. The air supply should be slightly in excess of the theoretical amount required and be admitted principally through the fuel bed, with an auxiliary supply admitted at the front or rear of the furnace to burn gases from the coal.
3. The temperature in the furnace should be sufficiently high to ignite the gases given off from the fuel bed.
4. There should be a fire-brick combustion chamber of sufficient dimensions and so designed as to cause the thorough mixture of the gases and air, permitting complete combustion before the mixture reaches the boiler surfaces.

It has been found in this country, as well as in Europe, that when smoke is given off, there is also a loss of carbon monoxide (CO) and other combustible gases. The loss due to the carbon which we see and call smoke is seldom more than 1 per cent, but the loss due to the escape of the combustible gases may amount to an additional 3 to 10 per cent.

Contrary to general opinion, with extremely high temperatures more smoke is produced and more unburned gases are lost up the stack. High temperature is of course due to a supply of air approaching the theoretical amount, and on account of the difficulty of obtaining a complete mixture of the gases and air some gas is allowed to escape unburned.

The combustible gas most frequently found in the flue gases is carbon monoxide (CO). This gas is nearly always present when the stack gives off black smoke, indicating imperfect combustion. Hydrogen and hydrocarbon gases may also be expected in connection with the CO, but on account of the difficulty

of determining the small percentages of these gases they are seldom recorded, though the loss due to their escape is considerable.

Numerous inventions for preventing smoke have been made. Most of them have not been properly designed to meet the severe service to which a boiler furnace is subjected.

The proper design of the furnace and settings, including the breeching and stacks, is a subject of much dispute. All authorities, however, agree that sufficient air must be admitted to allow complete combustion. This means that ample draft must be provided. Stacks less than 125 feet high are usually unsatisfactory, but steam or electrically driven fans are now very commonly used to produce either forced or induced draft in connection with stacks shorter than would otherwise be required.

Provision should be made for the admission of air above the fuel bed. It is also now generally conceded that there should be a fire-brick chamber of sufficient length to allow time for the gases and air to mix and burn. Numerous observations made on power plants show that it takes an average of twelve seconds for the gases to pass from the furnace to the top of a stack 125 feet high. This allows but one second for combustion to take place before the gases leave the combustion chamber. These conditions have been so successfully met in some plants as to permit the use of low-grade coal without the production of objectionable smoke. These plants are few when compared to the total number in operation, but they indicate the possibilities of securing practically perfect combustion.

DIFFICULTY IN SECURING PERFECT COMBUSTION.

With so great a variety of furnaces it seems at first thought that there should be no difficulty in abating smoke. It is, however, difficult to construct a furnace that will be smokeless under any and all conditions of operation. Some furnaces now in operation are practically so, conforming to every requirement outlined for smokeless combustion, but there is no type of grate or stoker on the market to-day which does not give off offensive black smoke in some of the plants in which it is installed. This may or may not be due to faults in the furnace. It may be due to lack of combustion space or to improper handling.

The efficiency of the furnace and the degree of success attained by any equipment in the prevention of smoke depend on the following factors: Skill of the fireman, proper design of the furnace and boiler setting, character of the coal, capacity of the boilers and furnaces, and load carried.

Gallizing.—A process discovered by Ludwig Gall, by means of which, from sour must, by the fermentation with it of glucose or grape sugar and water, a drinkable wine may be obtained. The amount of sugar and acid in the must to be improved should first be determined and then the dilution and the addition of sugar calculated, according to a normal must. For instance, supposing a must to have a volume of acidity of 1.2 per cent and sugar amounting to 15 per cent, from such a must a drinkable wine could never be obtained, but when, by the addition of an equal volume of water, we bring this must to a normal acidity of 0.6 per cent and to each 1,000 parts of the mixture add 125 parts of sugar, we have 2,000 parts of a must, which, with a sugar volume of 20 per cent, corresponds to the vintage of an average year, and after fermentation will yield a drinkable wine.

* Abstract from a Bulletin issued by the United States Geological Survey.