

and courses of all storms, was not less mild than now. The trees whose wood is found in the interglacial Toronto beds now have their most northern limits in the same region.

9. IROQUOIS STAGE. Full expansion of the glacial Lake Iroquois in the basin of the present Lake Ontario and northward, then outflowing at Rome, N. Y., to the Mohawk and Hudson rivers. Gradual reëlevation of the Rome outlet from the Champlain subsidence had lifted the surface of Lake Iroquois in its western part from near the level of the present lake at Toronto to a height there of about 200 feet, finally holding this height during many years, with the formation of the well developed Iroquois beach.

Between the times of Lakes Warren and Iroquois, the glacial Lake Lundy, named by Spencer from its beach ridge of Lundy's Lane, probably had an outlet east to the Hudson by overflow across the slope of the highlands south of the Mohawk; but its relationship to the glacial Lake Newberry, named by Fairchild as outflowing to the Susquehanna by the pass south of Seneca Lake, needs to be more definitely ascertained.

10. ST. LAWRENCE STAGE. The final stage in the departure of the ice sheet which we are able to determine from the history of the Laurentian lakes and St. Lawrence valley was when the glacial Lake St. Lawrence, outflowing through the Champlain basin to the Hudson, stretched from a strait originally 150 feet deep over the Thousand Islands, at the mouth of Lake Ontario, and from the vicinity of Pembroke, on the Ottawa river, easterly to Quebec or beyond. As soon as the ice barrier was melted through, the sea entered these depressed St. Lawrence, Champlain and Ottawa valleys; and subsequent epeirogenic uplifting has raised them to their present slight altitude above the sea level.

Later stages of the glacial recession are doubtless recognizable by moraines and other evidences, the North American ice sheet becoming at last, as it probably also had been in its beginnings, divided into three parts, one upon Labrador, another northwest of Hudson Bay, as shown by Tyrrell's observations, and a third upon the northern part of British Columbia. From my studies of the glacial Lake Agassiz, whose duration was probably only about 1,000 years, the whole Champlain epoch of land depression, the departure of the ice sheet because of the warm climate so restored, and most of the reëlevation of the unburdened lands, appear to have required only a few (perhaps four or five) thousand years, ending about five thousand years ago. These late divisions of the Glacial period were far shorter than its Kansan, Aftonian and Iowan stages; and the ratio of the Glacial and Champlain epochs may have been approximately as ten to one. The term Champlain conveniently designates the short final part of the Ice age, when the land depression caused rapid though wavering retreat of the ice border, with more vigorous glacial currents on account of the marginal melting and increased steepness of the ice front, favoring the accumulation of many retreatal moraines of very knolly and bouldery drift.

WARREN UPHAM.

CLEVELAND, OHIO.

---

#### HELIUM AND ARGON.

BRIEF accounts of the discovery of helium and argon have already appeared in the pages of this journal. More recently, several important observations have been made, which, while not establishing with certainty the nature of these substances and their places in the system of the elements, at least afford a reasonable basis for speculation.

Helium was originally obtained from the

uranium minerals cleveite, bröggerite and Connecticut uraninite. Ramsay has since detected it in small amounts in several other minerals and in the gases occluded or combined in certain meteoric irons. The uranium minerals give the best yield, but it is also found in smaller quantities in samarskite, orangite and monazite, and in traces in yttrantalite, hjelmite, fergusonite, tantalite, polycrase and xenotime. All of these, including the uranium minerals above mentioned, are of comparatively rare occurrence and are found in small quantities only. They are all of complex composition and each contains several so-called 'rare earths.' It is a noteworthy fact that all minerals thus far found to contain helium consist in part of one or more of the elements uranium, thorium and yttrium, and it would seem that it is in some way associated with these, especially with uranium. As to the nature of this association nothing whatever is known, and attempts to cause them to recombine with helium have thus far failed.

Helium has also been found in the gases escaping from certain mineral springs. Kayser, of Bonn, has detected it in the gas from the Wildbad spring in the Black Forest. After sparking with oxygen to remove nitrogen, which is the chief constituent, 340 c. c. of the gas left a residue of 9 c. c., which gave a brilliant helium spectrum. Bouchard has found it associated with nitrogen and sometimes also with argon, in the gas obtained from several sulphur springs in the Pyrenees. As it is thus constantly escaping, we might well expect to detect it in traces in the atmosphere, and Kayser claims to have observed faint helium lines in the spectrum of the purest argon obtained from the atmosphere of Bonn. In fact, it seems to be a very widely distributed substance.

Cleve and Langlet have obtained helium with a density as low as 2.02, or about

double that of hydrogen; it is, therefore, next to hydrogen, the lightest gas known. This figure corresponds to a molecular weight of 4.04, and since the molecules of the gas appear to consist of single atoms, like those of argon, 4.04 represents the approximate atomic weight also. The importance of this observation lies in the fact that, although our present classification of the elements would lead us to infer the existence of several elements with atomic weights between those of hydrogen (at. wt. 1) and lithium (at. wt. 7), none of these are known. Helium may, therefore, well be one of these missing substances.

Careful spectroscopic studies by Crookes, Lockyer, Runge and Paschen, and others, have shown, however, that what we now call *helium* is not a single substance, but a mixture of two or more hitherto unknown gases. The composition of the mixture varies both qualitatively and quantitatively according to the source from which it is obtained. Crookes has published a very elaborate study of the spectra of samples of helium from different varieties of uraninite, from which it appears that even these are not absolutely identical. Sixteen bright lines are mentioned as common to all these samples of helium, including the famous  $D_3$  line, first seen by Lockyer and Frankland in the solar spectrum. The gas from Connecticut uraninite seems to be the most complex and shows fourteen strong lines which are absent from the spectra of other varieties and presumably belong to another element. Twenty-seven lines are mentioned which seem to coincide with lines of the solar spectrum.

Runge and Paschen, who have studied the spectrum of the gas from cleveite, including the invisible ultra-red portion, have reached the conclusion that even this gas consists of two substances, one of which, the true helium, giving the  $D_3$  line, is denser than the other (unnamed) constitu-

ent, which also shows a characteristic spectrum. The difference of density was detected by the slower rate of diffusion of the true helium, implying higher density. From spectroscopic considerations they are able to separate the composite spectrum into its two constituents, and to conclude that the true helium may have an atomic weight of about 5, and the other of not far from 3. Both of these substances, according to Kayser, are present in the gas from the Wildbad spring, while according to Bouchard helium from the Pyrenean springs also contains a second ingredient. The lines of both constituents of helium have also been noted in the spectra of several stars.

It was formerly asserted that helium and atmospheric argon have a constituent in common, this belief being based on the existence of a certain set of spectral lines common to both. Recent observations by Lockyer, with an instrument of high dispersive power, indicate that this coincidence is not exact, and hence that the theory of a common constituent is without foundation.

The only evidence favoring the view that atmospheric argon, as thus far obtained, is pure is found in the apparently constant boiling point of liquid argon, as observed by Olszewski. It may be questioned whether an experiment with only 1–10 c. c. of liquid is sufficient to prove the total absence of other substances of unknown boiling points. All samples of atmospheric argon naturally have the same composition, being derived from the same source, and argon from other sources has not yet been studied with sufficient accuracy to throw any light on the matter. It is therefore quite likely that the atomic weight of 40 will have to be changed to the extent of one or more units.

From these results it is obvious that the present figures for the atomic weights of

helium and argon, which are based on density determinations with impure material, must be regarded as provisional, but it is evident that one at least of the constituents of crude helium must have an atomic weight lower than the mean and hence must precede lithium. As it is possible that both crude helium and crude argon contain even more than two gases, the problem of their complete separation will doubtless be one of considerable difficulty, especially as all seem to possess a high degree of inertness.

The few experiments thus far made for the purpose of ascertaining if argon is a constituent of living beings have failed to detect it.

At present there is no evidence that any of these gases are decomposable into simpler constituents, and until such evidence is forthcoming we may continue to regard them as elementary.

Attempts to produce compounds of argon have given some indications of succeeding, but as yet no substances of definite and constant composition have been obtained. Besides the compound with benzene vapor described by Berthelot, this chemist has obtained a solid by submitting a mixture of argon and carbon disulphide vapor, confined over mercury, to the action of the electric discharge. This substance is said to evolve argon on heating. Ramsay found that, by forming an electric arc between carbon rods in an atmosphere of argon, the spectrum of argon nearly vanished after several hours' action, its place being taken by a brilliant 'channeled' spectrum. According to Crookes this shows many analogies with the spectra of carbon compounds, and may well proceed from a compound of carbon with argon. If Ramsay's observation that an *increase* of one fifth volume occurs should be confirmed, it would seem to do away with the view that argon molecules are monatomic, for a monatomic gas cannot increase in volume on entering into combination.

It was early observed that the metallic electrodes in the Plücker tubes used for obtaining spectra were very effective in removing traces of nitrogen. Even helium seemed to be slowly absorbed, its spectrum gradually becoming fainter and ultimately vanishing. Troost and Ouvrard have found that a powerful silent discharge through tubes of argon or helium containing magnesium or even platinum causes absorption of the gases. The absorption is exceedingly slow, but is ultimately complete. Nothing is known as to the nature of the products.

The elementary nature of helium has been very generally conceded. Several hypotheses assuming argon to be a compound of known or unknown elements have been suggested, most of which are without the least experimental basis, and need not be noticed here. A view which earlier met with considerable approval is that the argon molecule consists of three nitrogen atoms,  $N_3$ . This allotropic form of nitrogen has never been obtained, and we have no means of predicting whether it would be more stable than the common form,  $N_2$ . If more stable, and if formed in small amounts in the course of ages, it would tend to accumulate in the atmosphere. This view was supported by a not very close coincidence of densities, argon having a density of about 20, while the density of  $N_3$  would be 21. Not the slightest evidence has been found, however, that argon and nitrogen are convertible into each other, even in traces, while such transformations are quite readily effected in all known cases of allotropism. Neither is argon formed when nitrogen is liberated from combination. If it is a more stable form of nitrogen it should be one, if not the main product under these circumstances, just as ordinary oxygen, not ozone, is the chief product when this element is set free. Until it can be shown that the evidence of the specific heat ratio, which is based on the kinetic theory of gases, is inconclusive, or

until argon is actually decomposed into simpler or familiar substances, we must regard it as a new element.

The elementary nature of the new gases being conceded, the first question which arises is whether they represent an entirely new order of substances, or whether they can be harmonized with the classification which has been found to apply to all known chemical elements whose properties have been established with any degree of exactness, and if so whether this system will admit of their adoption without any essential change, or whether it must be more or less modified and extended.

Our present classification is known as the Periodic or Natural System, and is based on a consideration of the broad chemical properties of the elements, rather than on special similarities or differences such as are considered in a classification for analytical or other practical purposes. If the elements be arranged in the order of increasing atomic weights there is a gradual modification of chemical properties as we ascend in the series, but this does not proceed uninterruptedly in the same sense through the entire list. At certain points there is a break, and the following element has properties resembling one several places back. This abrupt change is perhaps most obvious in respect to the metallic and base forming, and the non-metallic and acid forming properties, and is well illustrated in the following small table, which gives the first part of the series.

Li	Be	B	C	N	O	F
7.02	9	11	12	14.03	16	19
Na	Mg	Al	Si	P	S	Cl
23.05	24.3	27	28.4	31	32.06	35.45
K						
39.11	etc., etc.					

Lithium (7.02), the element of the lowest known atomic weight excepting hydrogen, is a pronounced metal, electropositive,

and forming a strongly basic 'alkali.' Beryllium (9) is still metallic, but with boron (11) the metallic, base forming properties have vanished, and it is a weak acid former, while in fluorine (19) we have an element which is gaseous, highly negative, an acid former, and as different from lithium as could well be imagined. The next element, sodium (23.05), does not possess in a still stronger degree the properties shown by fluorine, as we might expect; on the contrary, it closely resembles lithium. A similar gradual modification again occurs as we proceed, the metallic, basic properties fading out and being gradually replaced by non-metallic, acidic properties. Silicon (28.4) is no longer a metal and chlorine (35.45) is a gas, chemically and physically much resembling fluorine. Beginning with the next element, the alkali metal potassium (39.11), a similar series of gradual transitions is gone through, followed by a sudden interruption and reversion, and this is several times repeated through the whole list, with certain modifications which it is not essential to our purpose to consider. Each set of elements beginning with a metal and ending with a non-metallic acid former is called a *period*. Those elements which fall into the same vertical column constitute a *group* or *natural family* and have a marked resemblance, lithium being followed by sodium, potassium, rubidium and cesium, the *alkali metals*, and fluorine by chlorine, bromine and iodine, the *halogens*, all of which give rise to strong acids.

This system, while presenting some difficulties, just as nearly every system of natural phenomena does, bears abundant evidence of being based on some natural cause, of the nature of which we know as yet absolutely nothing. Quite a number of blanks or 'missing links' occur, but it is generally expected that elements will ultimately be discovered which will fit into these places; an expectation which has in several cases

been realized in the most striking manner. The properties of helium and argon and their atomic weights, as at present roughly determined, do not hold out any promise that these elements will fit into any of the vacancies; on the contrary, it seems quite certain that they will not.

The abrupt jump from the halogen at the end of each period to the alkali metal beginning the next, in contrast with the gradual change elsewhere observed, is one of the most remarkable facts in chemistry. Given the existence of a periodicity of properties, we should rather expect the periods to be connected by a series of elements showing gradations in a reverse order, or at least by transitional elements of intermediate properties. We should expect to find a continuous curve with maxima and minima rather than a series of disconnected lines. While the law which makes the properties of elements a function of their atomic weights is wholly unknown we cannot assert that this must be so, and it is rather our reliance on the principle of continuity which leads us to feel that it should be so. We may assume that the connecting links actually exist though as yet undiscovered. It is on such an hypothesis that the most plausible attempts to classify the new elements have been made.

Rayleigh and Ramsay, at the close of their memorable paper on argon, read before the Royal Society in January, pointed out a possible way of harmonizing their discovery with the Periodic Law. They called attention to the variation of valency in the latter half of the second period :

Element:	Silicon.	Phosphorus.	Sulphur.	Chlorine.
Valency:	4	3 - 5	2 - 6	1 - 7
Atomic wt.	28.4	31	32.06	35.45

The next known element is potassium, beginning the third period with an atomic weight 39.11. Between this and chlorine, however, we may imagine another element,

which would form a continuation of the second period and which, following out the above order, would have an atomic weight between 35.45 and 39.11 and a valency of 0 or 8. A valency of 0 would imply absence of combining power, in other words, great inertness and molecules consisting of single atoms, both of which characterize argon. As pointed out above, the atomic weight of argon may prove to be less than the upper limit of 39.11.

Lecoq de Boisbaudran and Julius Thomsen have advanced hypotheses which consist essentially in the assumption of an eighth group of elements, intermediate between and transitional from the halogens to the alkali metals. Thomsen's table is here given, the hypothetical transitional elements being printed in heavy type. It is otherwise simply an abbreviated form of Lothar Meyer's table of the Periodic System. The dashes represent some of the missing elements above referred to, and the dots places of elements omitted for the sake of clearness.

I. Hydrogen				1	—	—	—	4
II. Lithium-fluorine	7	9	11	12	14	16	19	<b>20</b>
III. Sodium-chlorine	23	24	27	28	31	32	35.5	<b>36</b>
IV. Potassium-bromine	39	40	.....	.....	.....	79	80	<b>84</b>
V. Rubidium-iodine	85	87	.....	.....	.....	125	127	<b>132</b>
VI. Cæsium —	133	137	.....	.....	.....	—	—	<b>212</b>
VII. —	—	—	.....	.....	.....	—	—	<b>292</b>

The atomic weights 4 and 36 would correspond to the chief ingredients of what we now call helium and argon. It must be borne in mind that the figures in the last column may be altered several units without affecting the theory.

It has been shown, however, as above stated, that helium and perhaps argon are more or less contaminated with other new elements. Until the atomic weights of these contaminating substances have been determined, it would be useless to assign them places in Thomsen's system. There are several possibilities. They may be other members of the last column.

Instead of only one transitional element between each period there may be several, and we would have, instead of only one, two or even three new columns on the right of the table. There remain several places open between hydrogen and lithium, and we cannot at present deny the possibility of unknown elements even preceding hydrogen. Although this element heads the list, there is no evidence of a natural reason for its occupying this unique position. On the hypothesis of a common origin of the elements from one primitive substance, the 'protyle' of Crookes, the existence of such substances is by no means improbable. The most exact atomic weight determinations indicate that the true unit of the whole system, the greatest common divisor of all atomic weights, if it exists at all, must be a comparatively small fraction of the atomic weight of hydrogen, a mass which could give rise to several elements still lower in the scale. The discovery of such elements would be scarcely more surprising than that of helium, and that they have not been thus far detected, even by the spectroscope, is no more remarkable than that this instrument overlooked argon.

While Thomsen's view cannot at present be regarded as more than a suggestion, it is certainly the one which best accords with our present knowledge. The Periodic System, imperfect as it still is, bears unquestionable evidence of some fundamental natural law, but it is at present as great a mystery as the natural system of plants and animals before the days of the evolution theory. The problem which the chemist faces to-day has much resemblance to that which confronted the biologist in those times. There appears to be no reason for expecting the recent discoveries to be in any way revolutionary, but they will doubtless contribute to the solution of the great problem of the chemist, not only by the enlarged conceptions which they involve, but

also by stimulating the search for new elements and the efforts to ascertain the true relation of those already known. In this sense the present year may well mark the beginning of a new era in chemical discovery.

H. N. STOKES.

WASHINGTON, October, 1895.

*ECONOMICS OF ENGINEERING PUBLIC WORKS.*

It has become almost proverbial that the inhabitants of new countries are in many respects lavish and extravagant. Our Puritan forefathers were undoubtedly the most rigorous and economical people that ever faced privation and hardship, yet it can hardly be gainsaid that their descendants have lost that characteristic of frugality to such an extent as to make the American people distinguished for extravagance and prodigality; notably so in this nineteenth century. As a people we have not spent our wealth on the fine arts, but on silks and velvets for clothing, on diamonds and jewelry for adornment, on luxuries in food and drink, and in similar indulgences of a low order, and we are now beginning to feel the evil results of this course of action.

This lavish expenditure of money has been made possible by the great accumulation of wealth resulting from the natural resources of the land, the wealth of the soil, of the forests, of the mines, and from the labor and frugality of the pioneers. We, of this generation, not only have felt no need to practice the economies familiar to other countries, but we have been impelled by the consciousness of our national and personal possessions to make use of them in what has often been vain and extravagant display.

Then again, this general success in the battle of life has made individuals self-reliant, or rather has prevented that feeling of the need of coöperation which only lately has shown signs of existence. There

was a time when men rose unaided to the top round of financial success, made their own fortunes, and spent them as their tastes dictated; individuals hired individuals, and laborers worked for this man or for that, as fancy or personal preference led them; but not now. By means of coöperation and combination with others, man is enabled to have advantages which, as an individual, he cannot secure; for we have begun to act on the principle that, while one man's opinions may be ignored, there is power in the expressed wish of numbers. Trusts and brotherhoods are alike in trying to secure some advantage for their individual members to the exclusion of the rest of the world. Man has reached a point where he sees that to benefit himself he must be willing to help a few others as well. One step has been taken away from individualism, but only one, and that a short one. Let us look at some instances of corporations and associations seeking their own advantage at the expense of the public good. This is sometimes done wilfully, in the face of public needs and desires, and sometimes through blindness and ignorance.

There are in the United States thousands of miles of railroad which have been uselessly built. The money for their construction has been practically taken out of the store of the world's wealth and literally buried in the ground. They have been built either by shortsightedness or by knavishness on the part of a few, and can only be maintained by a higher rate on all railroad business, and a correspondingly increased tax on all who use the railroads. No one would hesitate to say that were the New York Central Railroad, for example, to have all the freight business between New York and Buffalo, instead of having to divide with its competing roads, the rate per ton on freight would be greatly lowered and yet a working profit be maintained. Aside, then, from the local business, which