schools the curricula of the students of civil engineering provide one term only for geology. The student is expected to master the principles of geology and to find the applications in that brief time without any previous training in physiography, mineralogy, petrology or paleontology. It is obviously a difficult task to arrange the material so that the groundwork of principles is made clear in the short time allotted for the study, and applications emphasized sufficiently to make the study of much practical value. This difficulty is happily met in this volume by brief and concise statements of principles followed by ample and well-chosen illustrations.

The book is well arranged for the mature and serious-minded beginner who wishes to get the maximum of material in a short time. The more advanced student will find also many applications of geology brought from widely scattered sources and some which are not treated elsewhere. Separate chapters are devoted to rock minerals, rocks, structural geology and metamorphism, rock weathering and soils, rivers, lakes, wave action, underground waters, landslides, glacial deposits, cements, clays, coal, petroleum and gas, road material, and ore deposits. The mechanical features of the work are excellent; particularly noteworthy are the clearly executed photographs and line drawings.

W. H. EMMONS

MINNEAPOLIS

Die Umwelt des Lebens. Eine physikalisch-chemische Untersuchung über die Eignung des Anorganischen für die Bedürfnisse des Organischen. Von LAWRENCE J. HENDERSON; übersetzt von R. BERNSTEIN. Wiesbaden, J. F. Bergmann. 1914.

This volume is the German translation of the author's book, "The Fitness of the Environment," recently reviewed in these columns.[1] There are a few additional features; the table of contents contains a very complete and convenient summary of the whole book, important sentences or paragraphs are italicized, and a brief final chapter has been added; there is also an interesting and apposite quotation from du Bois-Reymond in a footnote on page 161; and the subject-index has been omitted. Otherwise the book remains unchanged.

[1] SCIENCE, N. S., 1913, p. 337.

In his final chapter the author calls attention to the existence of "a hitherto unrecognized order among the properties of the chemical elements,"—referring to the remarkable manner in which certain fundamental properties, which have largely conditioned the course taken by the evolutionary process, are distributed among the elements. These properties, far from being distributed with approximate uniformity—as the periodic system might lead us to expect—attain strongly marked maxima, or are, so to speak, concentrated, in relatively few elements, which at the same time are among the most abundant and widespread, namely: carbon, hydrogen and oxygen. "As a result of this fact there arise certain characteristics of the cosmic process which could not otherwise occur:" the implication is that at the outset of cosmic evolution there were present in advance all of the conditions needed for the development of physico-chemical systems having *vital* peculiarities, *i. e.,* possessing the complexity, activity and stability in a changing environment which are essential to living organisms. The properties of these three elements—and of no others—show a most detailed "fitness" for the production of just such systems. If, therefore, the main outcome of evolution be regarded as the development of living organisms, "the biologist may rightly regard the universe in its very essence as biocentric."

The volume is attractively printed and is dedicated to Karl Spiro.

R. S. L.

THE OXIDATION OF NITROGEN AND HOW CHEAP NITRATES WOULD REVOLUTIONIZE OUR ECONOMIC LIFE

How is Atmospheric Nitrogen Oxidized?

IT is not many years ago (1898) that Sir William Crookes sounded the note of alarm concerning the possibility of a future famine in the world's supply of nitrates and other nitrogen compounds. At that time the supply of these salts was largely confined to certain beds of guano and Chile saltpeter. During the past few years most important advances have been made in our knowledge of the fixation of atmospheric nitrogen, and some of the processes have been placed upon a purely commercial basis.

In addition to drawing on the air directly for nitrogen it has been found that large amounts of ammonia and other nitrogen compounds may be obtained as by-products from coal and peat in connection with the manufacture of coke, illuminating gas and the metallurgy of iron. The treatment of various shales, peats, silts and organic refuse often yields nitrogen compounds. The nitrogen in these substances has probably been derived from the atmosphere by one or more of the processes which will now be described.

The amount of nitrogen that enters into the plant and animal growth ("nomadic" nitrogen) has been estimated to be about 20 gm. per square yard of land. Part of this is being constantly changed into nitrogen gas by the action of nitrifying and dentrifying bacteria. In nature an equilibrium is maintained between the action of these bacteria and the oxidization of nitrogen in the air by means of electrical discharges and the action of plants, such as clover. The natural processes of fixing nitrogen are therefore electrical and by the action of bacteria in the legume crops of clover and similar plants. In former geological times certain nitride and other chemical compounds may have been formed directly with the air nitrogen, but it is doubtful if any such direct chemical reactions take place at present.

The natural oxidation of nitrogen by electrical discharges takes place during electrical storms, the aurora discharges at high levels and possibly in a slight degree in the bombardment of the higher strata of air by cathode and similar rays, ultraviolet light, and possibly by other radiations. The disintegration of radium and thorium products yields a small amount of oxides of nitrogen. It has been estimated that in this way about 100,000,000 tons of fixed nitrogen is carried to the earth every year by rain water.

The other natural method of fixing atmospheric nitrogen is that of the action of bacteria in the root nodules of the clovers, peas, vetches and other legumes. The chemical processes are very complicated and are at present unknown. This process is, however, of tremendous importance to the farmer and is probably the cheapest method now known of obtaining nitrogen as a fertilizer. This method is, however, quite expensive in that clover seed is expensive and the raising of a crop of clover requires attention, time and the exclusion of other crops. On the poor soils where humus is the most needed it is found very difficult to get clover to grow. Restoration of fertility to run down soils by this method is therefore slow and expensive.

The commercial methods of manufacturing nitrogen salts includes the cyanamide process, the direct synthesis of ammonia, the various nitride processes of making ammonia and the electrical methods of oxidizing nitrogen.

A process that is being used commercially is that of treating calcium carbide with nitrogen gas, thus yielding cyanamide which itself makes a good fertilizer. Although the reactions are known to be complex, they may be represented as regards the end products as follows:

$$CaO + 3\ C \rightleftharpoons CaC_2 + CO,$$
$$CaC_2 + N_2 \rightarrow CaCN_2 + C.$$

The latter reaction begins at 1000° C. or at even lower temperatures. The N_2 may be prepared by the Linde process or by passing air over hot copper. According to Caro the energy consumption for fixing one ton of nitrogen (including making the CaC_2, azotising, machine driving, grinding, charging, air liquefaction) is less than 3 H.P. years.

The direct combination of nitrogen and hydrogen into ammonia is very successful when done on a small scale with pure gases but, so far as is generally known, this process is not being worked on a large scale. A German company, however, is planning to make large quantities of ammonia by this process.

The nitride (including the Serpek) processes have not as yet proven to be successful from the commercial point of view. It is quite possible that these methods may be used in connection with the manufacture of aluminium and other metals with which these chemical methods are intimately connected.

The Electrical Methods for Fixing Nitrogen

Several electrical methods are used for oxidizing the nitrogen of the air into nitric acid and various salts of nitrogen. These methods all produce chemical reactions between gaseous oxygen and nitrogen in intense electric fields. Potential differences of thousands of volts are used and in the arc methods large currents and high temperatures accompany the use of intense electric fields. In all these methods the aim is to have the electrical discharge take place in the gaseous oxygen and nitrogen and to eliminate as much as possible the effect of the metallic electrodes. Large arcs are therefore necessary when the electric current is large. In the Birkeland-Eyde method the arc is drawn out by a magnet; in the Schönherr process by a helical current of gas and in the Pauling process by horn electrodes and currents of gas. In the author's method a corona current is used and this seems to give the most perfect type of a purely gaseous discharge.

The various electrical processes give about the same order of efficiency when this is measured by the number of grams of nitric acid produced per kilowatt hour of consumption of electrical energy. About 60 to 80 gm. of nitric acid are formed per hour per kilowatt of electrical energy.

The Complexity of Chemical Reactions

Although single atoms, ions and possibly molecules have been isolated, the condition under which the isolation takes place is entirely unique, the particles traveling with a very great velocity. In general chemical reactions will not take place under these conditions in any way that they can be studied individually. Our knowledge of chemical reactions is therefore entirely statistical and our laws apply to a very large number of reactions. There are numerous instances where experimental evidence indicates that the chemical reactions are frequently complex. The speaker's work on the absorption spectra of uranyl and uranous salts indicated the possible existence of various intermediate compounds in chemical reactions in solutions.

In gases chemical reactions are undoubtedly much less complex than they are in solutions, although here the reactions may not be as simple as they are sometimes represented. The spectroscope is beginning to show indications that the light centers are more numerous than the possible number of atom, ion and molecule types. In the case of nitrogen we have various types of line spectra and quite recently Grotrian and Runge[1] have made convincing claims that the so-called cyanogen spectrum is due to nitrogen. (These experimenters worked with large Schönherr arcs about a meter in length.)

Chemical Reaction Centers

Under conditions such as exist in the arc, spark or whenever the temperature is high, many kinds of "centers" may exist. These "centers" may be the sources of light and heat emission or absorption, the ions that show deflections by electric and magnetic fields, and the particles that take part in chemical reactions. It must not necessarily be assumed that the "centers" of the various physical phenomena are the same. They may be widely different.

Among the centers which may exist in arcs and sparks and which have been shown to exist in vacuum tubes are

$$\overset{-}{O}_2,\ \overset{-}{O},\ \overset{+}{O},\ \overset{+}{O}_3,\ \overset{+}{O}_6,\ \overset{++}{O},\ O,\ O_2,$$

$$\overset{++}{N},\ \overset{+}{N},\ \overset{+}{N}_2,\ \overset{+}{N}_3,\ \overset{+++}{N},\ N,\ N_2.$$

Negative electrons also exist in comparatively large numbers.

The formation of nitric oxide in the electric discharge may take place in a large number of

[1] *Phys. Zeit.*, June 1, 1914.

ways. Some of these possible chemical reactions are as follows:

$$
O\begin{cases}
+ N + e + e + e = NO & (1)\\
+ N = NO & (2)\\
+ \overset{++}{N}_2 = NO + N & (3)\\
+ \overset{+}{N} + e + e = NO & (4)\\
+ \overset{+}{N} + e = NO & (5)\\
+ \overset{+}{N}_2 + e = NO + N & (6)\\
+ \overset{+++}{N}_3 + e = NO + N_2 & (7)
\end{cases}
$$

$$\overset{+}{N}_2 + \bar{O}_2 = 2NO.$$

In the place of O we might place O_2, $\bar{O}_2$, $\bar{O}$, O, O_3, $\overset{+}{O}_6$ and $\overset{++}{O}$. We thus have 56 possible chemical reactions to represent the fixation of nitrogen. No doubt only a few of these reactions actually take place though all are possible, provided all these kinds of ions exist where the oxides of nitrogen are being formed.

The comparative probability of some of these reactions is very small, especially when more than two products take part in the reaction. Since the oxides of nitrogen are apparently not removed from the gases by the electric field, it is probable that the oxide of nitrogen centers are not charged. Hence it follows that reactions which involve the presence of an electron are improbable. The apparent fact that the reaction is "electrical" would indicate that the reactions $N_2 + O_2$ and $N + O$ are not probable. The latter is in accord with the view that active nitrogen consists of N and that N does not take any active part in the formation of oxides of nitrogen.

It seems quite probable therefore that the main reaction that results in the formation of oxides of nitrogen is

$$\overset{+}{N}_2 + \bar{O}_2 + 43000 \text{ calories} = 2NO$$

This type of ionization is produced by cathode rays or rapidly moving electrons according to Thomson and others and accordingly this equation would indicate that the oxidization of nitrogen is indirectly due to cathode rays. It may be for this reason that thermionic electron radiations may play an important rôle in the formation of oxides of nitrogen in the various arc processes. In contrast to the above reaction is the reaction resulting in the formation of ozone. Ozone must necessarily be formed under conditions where some O_2 is dissociated.

The above reaction may be only one of several reactions, and under different conditions of pressure and temperature these reactions may be of relatively quite different degrees of importance.

Efficiency of the Nitrogen-fixing Process

We can get some idea of the inefficiency of the present methods of oxidizing nitrogen when we consider that when gram molecular weights of the gases are used one has:

$$N_2 + O_2 + 43{,}000 \text{ calories} = 2NO$$

approximately. The amount of energy used in this reaction is therefore about $1.7(10)^{12}$ ergs for about 126 gm. of nitric acid. Assuming 80 gm. of nitric acid to be made per kilowatt hour, we should have an energy consumption of about $5(10)^{13}$ ergs or an efficiency of about 4 per cent.

Nitrogen Fixation and Our Economic Life

The small percentage efficiency of the present methods for oxidization compared with the theoretical efficiency indicate that improvements in the present methods would yield most important results. At the present time sodium nitrate sells for about $45 per ton. If the efficiency of the oxidation method could be increased so that calcium nitrate could be sold for $6 or $8 per ton, it would change our economic life fundamentally. Food products would be greatly decreased in value, real intensive farming could be pursued, suburban homes could easily be made self supporting and "abandoned" farms could be reclaimed. Probably no other one scientific development would so materially add to the material well being of the people as this.

One of the reasons for the high cost of living is the fact that our soil fertility is difficult to maintain. Continued cropping will eventually impoverish the most fertile soils if the crops are not replaced. Cheap nitrogen fertilizers will not only practically restore virgin fertility, but will permit of the continual removal of crops. In this way the percentage of the crops that can be removed from the soil will be very much greater than under present conditions.

The cheapening of nitrogen fertilizers will permit of doubling, trebling or even more greatly increasing farm crops. In addition to these results cheap nitrogen fertilizers will permit a very much greater percentage of crops to be removed from the farms. Cheap nitrogen fertilizers will also permit of the most intensive farming in the immediate vicinity of industrial centers, thus lessening the time and cost of food distribution.

Surely the problem of nitrogen fixation should appeal to every one interested in the conservation of our resources. Our waterfalls represent an equivalent of nitrogen salt continuously going to waste instead of being used. And surely work of this kind is of greater importance than the building of dreadnaughts or the training of armies.

W. W. STRONG

GARBAGE INCINERATOR AT BARMEN, GERMANY

OWING to the great distance garbage had to be hauled for dumping, the city of Barmen, numbering 172,000 inhabitants, formerly experienced considerable difficulty and inconvenience in disposing of its refuse and waste matter, and finally decided to build a garbage incinerating plant where waste material of all sorts is now burned.

The plant was constructed in 1907 and has given excellent satisfaction in every particular. Not only is all city garbage disposed of in a sanitary way, but from the cremation of this waste two important products are gained, an excellent quality of sand, and electricity.

The city's garbage is collected by an average of twenty wagons, which convey the same to the incinerator and there dump it into large bunkers measuring 4×12 meters (floor space) each. There are seven of these bunkers, each having four trapdoors to receive garbage. From the bunkers the garbage is carried on wheelbarrows to huge funnels which feed the furnaces where the refuse is burned. These funnels have a capacity of 1,200 lbs. each and they are also seven in number. After being filled, a large plug in the center of the funnel is raised and the garbage falls through the opening beneath into the furnace, where it remains for an hour. During the first half hour it rests in the rear of each furnace, where it is ignited by the former deposit, and after burning for half an hour it is brought to the mouth of the furnace by large iron scrapers manipulated by the men serving the fires, and there remains the rest of the hour, cooling and igniting the next deposit from the funnel.

The garbage is then in the form of a glowing, molten mass, called slag, which is removed from the furnaces with long iron hooks and is pulled directly from the grate into metal wheelbarrows, to be then wheeled to the sprinkling quarter, where the redhot slag is cooled by means of water sprinkled thereon for fifteen minutes. Later this process will be simplified, the slag being dipped into reservoirs instead of sprinkled.

After sprinkling, the slag resembles large clinkers and these now come to the crusher where they are broken, ground, and finally reduced to various grades of sand which is used with splendid results for building purposes and for the construction of bricks.

While the garbage itself is thus reduced to sand, the burning of the same gives another very valuable product, namely electricity. This is manufactured in the following manner. The gases resulting from the burning of the garbage have a temperature of from 1,200 to 1,500 degrees Celsius. These gases are conducted to two boilers and there utilized in the production of steam, the latter having a pressure of 10–12 atmospheres. Normally steam of this pressure has a temperature 180° Celsius, but in this case the steam is superheated until its temperature is 300° C., in order that it may be perfectly dry and there may be no danger of its injuring the turbine to which it is now conducted. This steam turbine is a 600 h.p. machine of 3,000 revolutions per minute, and its axle is directly united with that of the dynamo. The capacity of the latter is 400