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EASTERN STATES DIVISION

BOARD OF EDITORS

Biology

THE CHARITY OF THE UNDERGROUND
William D. Sullivan, S. J.

Unknown to most people there has been an underground movement afoot from time immemorial, which has been the very cause of the maintenance of life for these same people. It is the underground movement of the microscopic plant life, bacteria. Though it is possible to segregate bacteria into what are known as pure cultures, they do not exist as such in their natural habitats. For the most part, they exist in mixed associations with two or three species enjoying the charitable benefits of community life. This mixed state in which bacteria are found is called Bacteria Associations.

One type of such an association is termed symbiosis, or the living together of two different organisms, each one benefitting the other. In the soil there are certain bacteria of the species Rhizobium. These bacteria are found in tiny nodules on the roots of Leguminosae, and are called the nitrogen-fixing bacteria. It was discovered that these nodules, or tumors, as they are sometimes called, are caused by the association of bacteria and the Leguminosae. The bacteria live in the cells of the plant root and because of the different activities of growth and metabolism there is a swelling formed on the root of the plant. The Rhizobium converts the nitrogen in the soil into a form which is available to the legume. The plant, therefore, from the synthetic activities of the bacteria, obtains nitrogen compounds necessary for life. The bacteria, on the other hand, reap the benefits of their labors in the form of nutrients from the plant sap. In this symbiotic relationship of the legume and the Rhizobium there is a perfect communistic atmosphere. Another case of such a mutual friendship exists between the bacteria living in the digestive tract of termites and the termites themselves. The bacteria digest the cellulose, i. e. the cell wall of plants, while the termites supply the necessary nutrients for the bacteria. Since the termite can make no use of the cellulose, as such, the bacteria, as well as those bacteria in the intestines of all herbivorous animals, through the process of hydrolysis, decompose the insoluble substance, a compound carbohydrate, to a form available for this destructive

animal. There is also present in the human intestine a spore-forming bacillus which obligingly decomposes cellulose to form the necessary acetic acid, butyric acid, ethyl alcohol, carbon dioxide and hydrogen. These, too, do not go unrewarded for their charitable services.

A second type of community life among the animate creatures of nature is known as commensalism. This type of association means nothing more than the living together of two organisms, one of which is benefitted by the presence of the other, while the latter is neither benefitted nor harmed by the presence of the former. Such a life do the Bacillus cereus and Pseudomonas fluoressens enjoy. Bacillus cereus, in a medium containing casein, attacks and hydrolyzes the casein with the consequent production of amino acids and other products. Pseudomonas fluorescens, on the other hand, is unable to attack and utilize the casein as a source of nitrogen. It can utilize the amino acids, however. Should both be present in the same medium, the Bacillus cereus attacks and hydrolyzes the casein producing the amino acids, and the Pseudomonas fluorescens absorbs the resulting amino acids. In this case the Bacillus cereus is neither benefitted nor harmed by the Pseudomanas fluorescens; the Pseudomonas flourescens, however, benefits from the unselfish labors of the Bacillus cereus.

The aerobe and the anaerobe bacteria also exemplify this type of bacteria association. Once placed in a sealed medium the aerobe diminishes the supply of oxygen and increases the supply of carbon dioxide. The anaerobe, which does not normally exist in the presence of oxygen, benefits, since it returns to normal growth in the reduced oxygen atmosphere. Here, the aerobe organism is neither benefitted nor harmed, while the anaerobe certainly gains living in common with the former organism.

Not all organism, however, are willing to share this mutual relationship of common life. When two organisms live together in such a way that one harms and eventually brings about the death of the other, we have what has been called antibiosis. In a community consisting of Bacillus coli and Bacillus subtilis or Bacillus mycoides, the inhibited growth and eventual death of the Bacillus coli is the inevitable result. The Bacillus coli is the undesirable member of such a community. Bacillus substilis and Bacillus mycoides secrete certain cytolytic substances fatal to Bacillus coli. Other examples of this unfriendly relationship existing in the underground may be found among cultures of Streptococcus faecalis and Bacillus coli; the Streptococcus faecalis

destroying the Bacillus coli. The Bacillus subtilis and the Bacillus mycoides also destroy the Diplococcus pneumoniae and the Eberthella typhosa. All these victorious organisms have a cytolytic action which is germicidal to the oppressed.

Synergism, the most recent type of common life found among the bacteria, is the living together of two or more organisms which produces a substance neither would be able to produce if compelled to a hermit's life. Should, for example, Staphylococcus aureus be grown on a sucrose medium by itself, there would be no fermentation and hence no gas produced. The same result would follow if Bacillus coli were compelled to live alone in a sucrose medium. But with both of them living together on a sucrose medium, fermentation will take place and the production of gas will follow. The explanation for such a reaction has been given by Sears and Putnam in 1923. They claim that one of the two organisms attack the substance and produce an acid. The other organism, in turn, attacks the acid and from it produces the gas.

Other examples of gas-producing pairs of bacteria are Staphylococcus aureus and certain species of Salmonella on a lactose medium. Staphylococcus aureus and Proteus vulgaris, if grown on a mannitol medium together, will produce gas, but will not do so if grown separately on the same type of medium.

These are the types of Bacteria Association most often found among the bacteria in their natural habitats. And though we study the organisms in our laboratories in pure cultures for the most part, a more accurate, but much more difficult process of interpretation may be had from their natural surroundings.

Chemistry

THE MECHANISM OF ADSORPTION INDICATORS IN VOLUMETRIC ANALYSIS

GEORGE L. DRURY, S. J.

Among the newer methods of volumetric analysis, the use of adsorption indicators in precipitation analyses has become increasingly prominent. This paper proposes to discuss briefly the principle on which this method is based, and to set forth a simple demonstration by means of which this principle is clearly exemplified.

The use of precipitation reactions in volumetric analysis generally involves three methods: the Mohr method, the Volhard method, and the adsorption indicator method. In all of these it is assumed that in the course of the titration a difficultly soluble compound will be formed. The indicators used in these methods, under the influence of the titrating solution, undergo a distinct color change at the equivalence point. However, the nature of this color change is different in each of the methods cited. In the Mohr method the color change results from the formation of a slightly soluble compound whose solubility product has been exceeded. The color change in the Volhard method is brought about by the formation of a highly colored soluble compound with a slight excess of precipitating ion in solution. In contrast to these methods the color change with the use of an adsorption indicator occurs on the surface of the slightly soluble compound formed in the titration; in other words, at the equivalence point a change in the color of the indicator results from its passing out of solution onto the surface of the precipitate formed, or with the reverse effect, a less frequently occurring phenomenon known as desorption. The adsorption indicator method is similar to the Mohr method inasmuch as the indicator is removed from the solution; it differs in that there is no slightly soluble compound formed between the indicator and the titrating solution whose solubility product has been exceeded.

To explain the mechanism of an adsorption indicator we must have recourse to one of the properties of colloidal systems. We know that a colloidal suspension of silver chloride, in the presence of an excess of chloride ions, will become negatively charged, due to the formation of the complex ion: $(AgCl)Cl^-$; similarly, if an excess of silver ion is present, this will be adsorbed at the surface of the silver chloride particle, forming the positively charged silver body: $(AgCl)Ag^+$. This is in keeping with the recognized tendency of particles in the colloidal state to adsorb common ions from solution more strongly

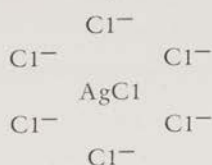than other ions. For our purposes, we may picture the structural formation of the particles like this:

$$
\begin{array}{ccc}
 & Cl^- & \\
Cl^- & & Cl^- \\
 & AgCl & \\
Cl^- & & Cl^- \\
 & Cl^- &
\end{array}
\qquad\qquad
\begin{array}{ccc}
 & Ag^+ & \\
Ag^+ & & Ag^+ \\
 & AgCl & \\
Ag^+ & & Ag^+ \\
 & Ag^+ &
\end{array}
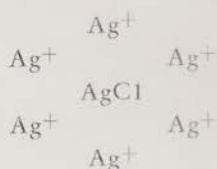$$

$$\textit{Fig. A} \qquad\qquad\qquad \textit{Fig. B}$$

It is evident, therefore, that the particle of silver chloride will possess an electric charge, the nature of this charge depending upon which common ion is present in excess.

Because of this electric charge, these particles are capable of holding, by secondary adsorption forces, ions of sign opposite to that on the particle. We should expect this to occur if the electroneutrality of the solution is to be maintained. Positively charged ions present in the solution will be attracted to the particle bearing a negative charge, and similarly, negatively charged ions will be attracted and held by the positively charged particles.

Suppose now that we had two solutions; solution "a" contains silver ions, chloride ions in excess, and potassium ions, while solution "b" contains silver ions in excess, chloride and nitrate ions. The structure of the particles in these solutions may be pictured thus:
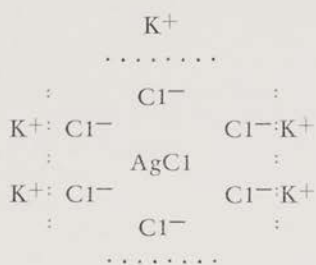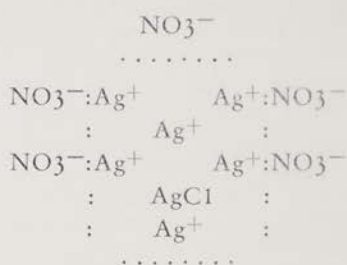
$$
\begin{array}{ccccc}
 & & K^+ & & \\
 & & \cdots\cdots\cdots & & \\
 & : & Cl^- & : & \\
K^+: & Cl^- & & Cl^-: & K^+ \\
 & : & AgCl & : & \\
K^+: & Cl^- & & Cl^-: & K^+ \\
 & : & Cl^- & : & \\
 & & \cdots\cdots\cdots & & \\
 & & K^+ & &
\end{array}
\qquad
\begin{array}{ccccc}
 & & NO_3^- & & \\
 & & \cdots\cdots\cdots & & \\
NO_3^-: & Ag^+ & & Ag^+: & NO_3^- \\
 & : & Ag^+ & : & \\
NO_3^-: & Ag^+ & & Ag^+: & NO_3^- \\
 & : & AgCl & : & \\
 & : & Ag^+ & : & \\
 & & \cdots\cdots\cdots & & \\
 & & NO_3^- & &
\end{array}
$$

$$\textit{Fig. C} \qquad\qquad\qquad \textit{Fig. D}$$

Those ions which are held by secondary adsorption forces (i. e. K^+ and NO_3^-) are not too strongly attached to the silver chloride particle, and if there are present in the solution other ions which are more strongly adsorbed, the potassium and nitrate ions will be readily displaced.

The indicators most commonly used in this method are the organic dyes eosin, fluorescein and dichlorofluorescein. Present in solution,

these dyes exist in an ionic state, though their degree of ionization is not high. It is characteristic of these indicator ions in solution that they are preferentially adsorbed by the charged particles in the solution, displacing those ions such as the potassium and nitrate ions which would ordinarily be bound to the particle by the secondary adsorptive forces. It is also characteristic of these dyes, as may be expected from their use as indicators, that in this transition from the solution onto the surface of the particle there is an accompanying change of color.

For the indicators to be of value in volumetric titrations it is necessary that this transition of the indicator ion from the solution onto the surface of the particle and the consequent color change take place at, or sufficiently near, the exact equivalence point to allow for their use in precise analytical work. That this not only is but must be the case at least theoretically, can be shown from the following example. Suppose that we are titrating the chloride ion with silver nitrate, using for our indicator dichlorofluorescein. If our solutions are sufficiently concentrated we may notice immediately, as we begin, the formation of the colloidal AgCl precipitate. Until we reach the equivalence point, these AgCl particles are present in an excess of chloride ions, and the structure of the particles will be similar to that shown in Figure A. At the equivalence point, when all the chloride ion has been converted to AgCl, the first drop in excess of our titrating agent AgNO3 produces a marked change in the nature of our solution. No longer is our colloidal precipitate present in an excess of chloride ions; now it is the silver ion that is in excess. As a result, the structure of our silver chloride particles will now be represented by Figure D. Immediately as this point is reached in the titration, our indicator ion steps in and performs its task. Since we are using dichlorofluorescein our indicator ion is negatively charged. There now arises a competition between this ion and the nitrate ion, as to which will be secondarily adsorbed. As was mentioned previously, the indicator ion exhibits the stronger capacity for being adsorbed, and it is this ion which passes out of solution onto the surface of the AgCl particle with an accompanying change in color to indicate the equivalence point has been reached.

For the successful application of this method, certain factors must be considered in the course of the analysis. Whereas in most analytical procedures colloidal formations are quite undesirable and to be avoided, here on the contrary conditions favoring the colloidal formation should be employed. It is due to the tremendous surface development of a colloidal precipitate that these adsorptive forces are so strong; with crystalline or coagulated precipitates, on the other hand, the adsorptive forces are too slight to attract their own common ions from the solution in sufficient strength to create a secondary adsorptive force that would have its effect on the indicator ion. As a means of sustaining the colloidal condition and preventing coagulation of the precipitate before the equivalence point is reached, it is suggested that a protective colloid such as dextrin or gum arabic be added to the solution.

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The indicator ions used in this method must have a charge opposite to that of the titrating agent; moreover, it must be known that the indicator ion will be preferentially adsorbed and to such an extent as to produce an immediate coloration of the precipitate at the equivalence point. However, the indicator ion must not have so high a degree of adsorbability as to compete with the common ion in solution for primary adsorption, for, should this happen, a color change would occur far in advance of the equivalence point. For this reason, eosin cannot be used as the indicator when we are making a chloride determination.

Depending upon the indicator used, care must be had that the pH of the solution remain within a restricted range, lest the indicator ion be so repressed that it will be ineffective in producing a marked color change when the equivalence point is reached. Fluorescein is a very weak acid with an ionization constant of the order of 10^{-8}; titrations with this indicator must be carried out in a neutral or slightly alkaline medium (a pH between 7-10). Since dichlorofluorescein is a stronger acid, good results with this indicator can be obtained in solutions having a pH value as low as 4.0. Eosin is a stronger acid than either of the preceding dyes, and using this, titrations can be made in solutions with a pH of 2 or less.

The principle of the adsorption indicator method as thus outlined may be very well shown by a simple demonstration, as suggested by Oesper in his book: "Newer Methods of Volumetric Analysis." Two liter beakers, each containing .5 cc. of a .5% alcoholic solution of eosin, are placed side by side. At this dilution the indicator is extensively inonized; the yellow-red transmitted color and the greenish fluorescence are due to the free eosinate ions. We shall work with only one of the liter solutions, using the other for purposes of comparison. To one of the beakers we add 10 drops of a solution of silver nitrate, approximately 1 N. On observation we notice that no change has taken place in the solution from the addition of the silver and the nitrate ions. The color of the solution remains constant. Now we add one drop of a solution of potassium bromide, approximately 1 normal, and observe the result. Immediately on stirring we notice a deepening of the color of our solution to red and also a loss of fluorescence. What has happened? On adding potassium bromide silver bromide was precipitated; this precipitate, however, is evidently in the colloidal state since our solution remains perfectly clear. Since it is in the colloidal state it has necessarily a large surface development, and consequently a strong adsorptive force exists between the colloidal particles and the other ions present in the solution. Because the silver ion is present in excess, the complex ion $(AgBr)Ag^+$ is formed. As this produces a positive charge on the particle, secondary forces come into play that will attract negative ions. Here we see the reason for the deepening of the color in the solution; the eosin ion has been secondarily adsorbed on the surface of the silver bromide silver body, and, in passing from the free ionic state,

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has changed color. We continue now with our addition of the potassium bromide, about two drops more. Again we notice a deepening of the color due to the fact that more of the $(AgBr)Ag^+$ is being formed which, in turn, is causing more of the indicator ion to pass out of solution onto its surface. As two to three more drops of the potassium bromide are added, we notice the color beginning to grow lighter again. At this point we are encountering the phenomenon of desorption. As the concentration of the bromide ion is increased, the concentration of the silver ions grows less which diminishes the positive charge on the particles. Therefore, less of the wosin ions are in the adsorbed state. When the total addition of the potassium bromide reaches the equivalent amount of ten drops we observe that the color of the solution has reverted to the light yellow color of the other beaker. This is to be expected and can be explained as happening due to the excess bromide ion now present. The silver bromide particles are now negatively charged, the eosin ions are displaced from the surface of the particles and return into solution. Now by adding alternately silver nitrate and potassium bromide, the color play can be repeated at will; by producing the positive silver body the dye can be brought onto the surface, or it can be removed if the negative bromide body is formed.

In the ordinary titrations where this method is used, the concentrations of the solutions are generally much greater than those used in this demonstration. There, as the silver halide is formed, the solution generally becomes turbid. The color change, nevertheless, can still be observed in the presence of the larger amount of suspended solid, even in the presence of a flocculated silver halide, although this latter condition is not desirable as was previously noted. In all cases, the essence of the phenomena is the same.

SOME APPLICATIONS OF ELECTRICITY IN THE CHEMISTRY LABORATORY

Rev. Bernard A. Fiekers, S. J.

The prominence of electronic equipment in the acquisitions that colleges have made fun from surplus property has served to place a great deal of emphasis on electrical applications to chemistry in general. Hence this discussion will not be limited to electronics exclusively.

A "halogenation lamp", first seen by the author at Boston College, consists of a five-gallon, sheet-steel, paint bucket with a 250 watt, short-neck, Mazda lamp installed inside at the centre of its base; with vent holes drilled into its side; and with numerous holes drilled into the lid, so as to accommodate just as many "lipped" six-inch test tubes that hang inside the lamp from the lid. The rough edges of the holes are smoothed off for safety in handling. A porcelain insulator conducts

the electric cord through the metal wall so that it cannot be cut by the metal. The inside is done in aluminum paint for good reflection of the light. The top of the lid is done in flat white, so that test tubes can be identified by pencil notation that can be erased with ease. The experiment is, of course, the bromination of hydrocarbons, pure and impure, in elementary organic chemistry, such as experiment number nine in Adams and Johnson's laboratory manual. Indeed there are ultraviolet lamps on the market that could go by the same name. One of these is designed for organic synthesis. It can be immersed into a reaction mixture and spares the demand on quartzware which is relatively expensive.

Variable transformers from surplus were put to good use in chemistry at Holy Cross. A sufficiently large number were acquired so as to permit the luxury of some permanent installation. Universal motors for stirring in our Braun electrolytic cabinets are controlled by "variacs" which have a capacity of one ampere. Five of the same capacity were attached to motors from discarded vacuum cleaners. These had been overhauled and mounted on rings in order to provide general utility stirrers for organic research. When the shaft was prevented from rotating by hand, it was found that one ampere was drawn when the "variac" dial read from 40 - 45 volts. In order to protect the "variac" then, its scale was stopped down at this voltage so that the one ampere value could not be exceeded. These stirrers have given excellent service. We are mindful, however, that they are not explosion proof. This limited voltage application allowed us in some cases to use transformers in which the winding had been damaged at one end. They were repaired adequately for this specific purpose.

In the physical chemistry laboratory some thermochemical experiments involve electrical measurements in terms of volts and amperes. Authors generally recommend low voltage and direct current.

Think of the Fisher-Engel Heat of Vaporization apparatus (FSco 15-345). Liquid is vaporized by a small, hot resistance wire immersed in it; the wattage is measured electrically; heat losses are replaced by boiling another sample of the same liquid under reflux in an outer jacket; condensed vapors are weighed; calorie conversions made; and for water 540 cal. per gram results.

There are thermochemical experiments in which the whole system is heated electrically, from final to initial temperatures in endothermic reactions; from initial to final in exothermic ones. Water equivalents, radiation and stirring effects are sometimes cancelled out by this method. J. Chem. Educ., 18, 510 - 3 (1941).

But alternating current can be used in both of these applications as readily as direct. Meters of sufficient accuracy are frequently available in surplus property; readily and economically available in supply. There is the advantage of independence of D. C. sources and the economy of the A. C. Meters are chosen so that nearly the full scale will

have to be read. This makes for precision. A 115 volt A. C. line is wired to a one-ampere variable transformer and this in turn to a filament transformer with secondary at 6.3 volts and 7 ampere capacity. Very fine control is thus assured. An ammeter with 0 - 5 scale is then put in series with the load, and a voltmeter with similar scale is wired across it. Everything is mounted permanently on 3/16 inch, hard "Masonite". This is built onto a base board at an angle. The overall length is shelf size and this makes for convenient storage. It does not seem that fusing is necessary when variable adjustment is possible. For the same reason constancy of performance in the fixed transformer is not absolutely necessary and added expense is thus avoided.

Direct current for transference numbers in physical chemistry is easily supplied from alternating by a small selenium rectifier which can be purchased cheaply in the radio supply shop. About one hundred volts might be called for, and current in milliamperes. Voltage control, if necessary, can be had to a certain degree.

Selenium or copper oxide rectifiers which are designed for heavier loads are replacing the motor generator in chemical applications. Variable control from an autotransformer on the A. C. side is again possible within limits. Plating jobs, brass analysis and the Hofmann apparatus for the electrolysis of water come to mind.

There is a trend toward what might be called "candid instrumentation". Paul Bender, Demonstration Potentiometer, J. Chem. Educ., 24, 195 - 6 (1947). The idea was anticipated at Holy Cross when we wired our student potentiometers and conductivity bridges to "Lucite" panels on a "shelf" so that the student could study the wiring diagram through the Lucite. Indeed, we used varicolored "Vinylite" coated wire in order to help the student out. From the same

motive we threatened to include wiring diagrams in his examinations. We compromised with the old physics tradition, that the student wire his own apparatus, in an effort to get more physical chemistry done.

In effect we finished with an instrument similar to the L & N, type K potentiometers, with scale adjusting resistors incorporated, as well as all switches, protective resistors, keys, binding posts for unknowns, batteries, standard cell, galvanometer and other items which are too expensive for permanent installation. Again, radio parts made the job compact and economical.

The whole internal circuit of the potentiometer itself was not "candidized". Any change in the length of the leads thus introduced might change the characteristics of the instrument and serve to exclude it from manufacturer's service. Further, flexibility was retained by allowing for the use of the slide wire part of the instrument in conductivity bridges and so forth. Another feature is that provision was made for easy coupling of a manually operated polarograph which is

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similar to the Fisher "Elecdropode". See figure 1 in J. J. Lingane and I. M. Kolthoff, J. Am. Chem. Soc., *61*, 828 (1939).

For those who are interested in the scale adjusting resistors, the following notes are included. Onto the Lucite panel are wired two parallel variable resistors (0-200 ohms for coarse adjustment and 0-5000 ohms for fine adjustment). A fixed resistor of 400 ohms was wired in series with the 5000 ohm variable. This assured fine adjustment with that variable even at the lower end of its scale. By making this substitution, expensive decade boxes do not have to be tied up with the potentiometer. The inclusion of a double pole, double throw switch makes provision for using a decade box as a voltage multiplier, when necessary. The box is connected externally through binding posts.

Other applications of electricity to chemistry come to mind. The author has been interested in an electrical funnel heater. Chemist Analyst, *35*, 93-4 (1946). An electrically heated Thiele tube for taking melting points in organic research comes to mind. Lamp board control with multifilament bulbs seems to answer the purpose. The use of Neon lamps in conductivity demonstrations is well known. A manufacturer of chemical fume hoods recommends that lights be wired to the fan switch so that pilot lighting can be eliminated. Time switches on certain furnaces seem desireable; hour meters as well.

The author has a bibliography of specifications for oscillators in conductivity work. Specifications for amplifiers and other electronic devices are readily available.

In upshot, it seems obvious that chemistry calls for much more permanent installation than the other sciences; that a good background in electricity is demanded of the major in chemistry; and that co-operation between chemistry, physics, purchasing and maintenance departments is desireable. For such co-operation, the author is grateful.

Geology

TRIASSIC REMNANTS OF THE EASTERN SEABOARD

James Skehan, S. J.

Following the great period of Appalachian Mountain building that characterized the close of the Paleozoic era in North America, the eastern half of the continent was fully emergent for two full geologic periods, the Triassic and Jurassic. The first half of the Triassic period left no record except that due to erosion. Then the axis of the Appalachian chain began to be split by several great normal faults which produced a narrow chain of block mountains bordered by downfaulted troughs or grabens. Such faulting is thought to have occurred as a result of the relaxation of the compressive forces that folded the Appalachian Mountains.
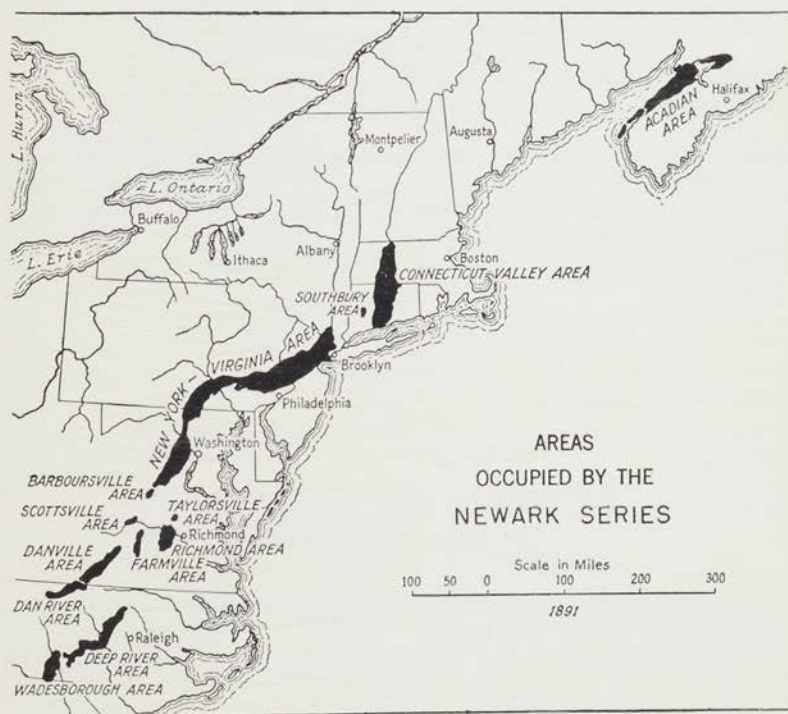

Fig. 1.   AREAS OCCUPIED BY THE NEWARK SERIES.
After I. C. Russell, U. S. Geol. Survey.

The only records of Triassic time in eastern North America are the structural troughs filled as they sank with Triassic sediments. The northernmost basin of this Newark Series, as it is called, lies in Nova Scotia, and others stretch southward as far as North Carolina. The relative areal extent and distribution of the Triassic basins is illustrated in Fig. 1.

Near the middle of this chain of basins is the Triassic trough of central Connecticut and Massachusetts which very well illustrates the geology of these basins as a whole.

The Connecticut Valley Lowland occupies an area about 95 miles long and 20 miles wide, and consists of moderately level or rolling topography sloping gently from a height of 400 feet at the north end down to sea level.

The valley has been structurally depressed, and downfaulted on its eastern side as illustrated in Fig. 2. Locally it has been downfaulted on the west. The Triassic sediments of the trough are several miles thick and the volcanic sheets add 500 to 600 feet to this total thickness. All the rocks dip east at angles of 15 to 20 degrees, the base of the series being on the west side where the old crystalline surface passes under the sediments at a similar angle. The entire belt is 20 miles wide and is divided into blocks by roughly parallel faults trending north-south, each block being upthrown on its west side and downthrown on the east.
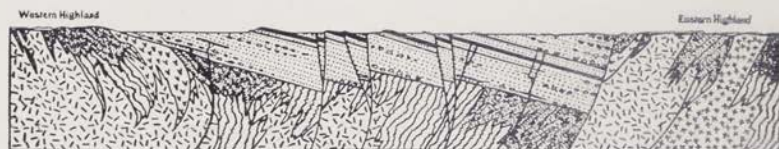

Fig. 2. PRESENT GEOLOGIC TIME.
After Mather, Roy and Theismeyer.

The structure of the Triassic rocks in the Piedmont of New Jersey with their included volcanics is like the mirror image of the Connecticut Valley structure, as illustrated in Fig. 3, the dips being toward the west.
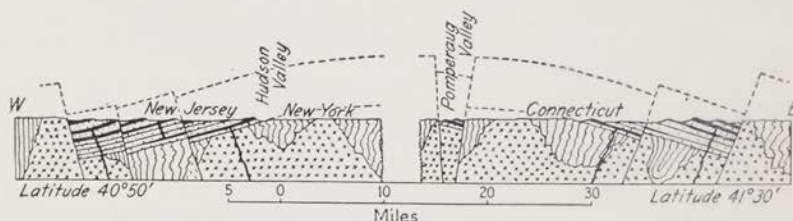

Fig. 3. SECTION ACROSS NEW JERSEY AND CONNECTICUT.
After C. R. Longwell.

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The rocks of the area are part of a synchronous facies, and vary in their character depending on the nature of the rocks from which they were derived, upon the strength and direction of the currents by which they were carried, and upon the distance from shore and the depths of water in which they were laid down.

Due to the great depth of the western portion of the basin, and the abundance of granite along the western shore, the waters are thought to have begun depositing the Sugarloaf arkose here earlier than the other rocks. This phase of sedimentation is illustrated by Fig. 4. Soon followed deposits derived from the argillites and schists of the eastern border.

Triassic sediments — Paleozoic intrusive granite-gneiss
Late Paleozoic lavas and tuffs. — Paleozoic sediments.
0. Scale in miles, horizontal and vertical. 10. — Pre-Paleozoic complex gneisses.
After Mather, Roy, and Theismeyer

Fig. 4. BEGINNING OF THE TRIASSIC SEDIMENTATION.

The nature of the overlying Longmeadow sandstone indicates that it was deposited in rising waters, since in the central portion of the basin were formed offshore deposits. Later, when the waters spread over the maximum width of the basin, these sediments graded laterally into fine grained sand and mud beds of the Chicopee shale in the middle portion of the basin.

After much of the coarse grained, basal Sugarloaf arkose had accumulated, a bed of lava called the Talcott diabase was poured out on the arkosic beds. The extrusive bed was then covered by further accumulation of sediments. This period of sedimentation was interrupted by an eruption in which the Holyoke diabase poured out through a fissure in the bottom of the basin. This main sheet of lava spread over the bottom of the basin and solidified in a sheet with a maximum thickness of 400 feet.

Later this lava sheet was covered by sand and mud layers, in which are preserved the footprints of the huge reptiles of the Triassic age.

When the sand sediments had accumulated to a great thickness over the Holyoke diabase, a third outflow of trap rock occurred named the Percival or Hampden diabase. This outflow was immediately followed by an explosive eruption of local extent, the evidence for which are blocks and pulverized water-laid deposits of dust of diabase forming the Granby Tuff. The eruption is known to have occurred while the Hampden diabase was still liquid because amygdaloidal blocks a foot across are sunk in the surface of the flow in Mountain Park.

Later the uppermost layers of rusty sands were laid down in which most of the tracks of Triassic life have been preserved. These formations in the middle of the basin were then capped by thin Chicopee shale in which only leaves and small tracks are found.

The sequence of sedimentary deposition is illustrated in Fig. 5.
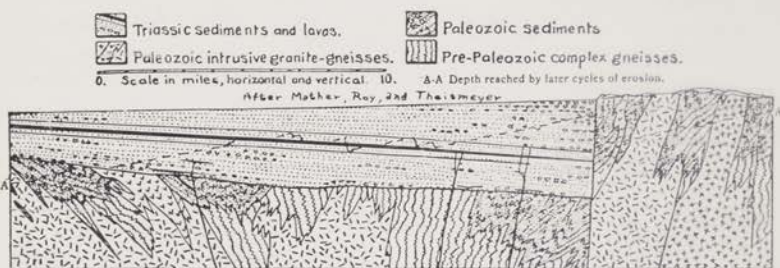

Fig. 5. CLOSE OF THE TRIASSIC SEDIMENTATION.

Following the deposition of these beds the area underwent a series of movements resulting in the dislocation or faulting of the beds. During this time, the sediments and volcanic rocks were divided into great blocks trending north-south, and rift valleys were formed as the blocks sank between parallel fissures. The blocks slipped one past another along nearly vertical planes and the strata generally tilted east. During these movements associated perhaps with regional uplift, the area became land and exposed to erosion. The conditions in the Valley at this time are illustrated by Fig. 6.
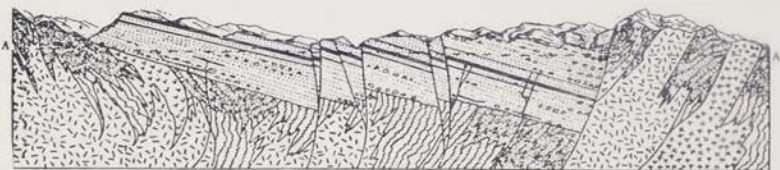

Fig. 6. BLOCK MOUNTAINS OF THE EARLY JURASSIC.
After Mather, Roy and Theismeyer.

In the geologic periods that followed the filling of the basin with sediments and faulting of these beds, erosion reduced the land to base level. Then the land was slightly uplifted and erosion began anew though on a smaller scale. The surface of the land was later modified by glacial activity. Since Pleistocene time the area has been subjected to moderate erosion which has given to the Valley the topographical development that it exhibits today, as shown in Fig. 2.

Physics

CURRENT NUCLEAR PHYSICS. PART I.

WILLIAM G. GUINDON, S.J.

OUTLINE

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INTRODUCTION

The purpose of this series of articles, appearing in this and in future issues of this BULLETIN, is to provide a survey of recent American publications in the field of nuclear physics. For reasons of expediency the discussion will be limited to articles and letters published in the Physical Review since January, 1947. While no claim is laid to a complete and exacting analysis of all the techniques described and of the accuracy of their results, it is hoped that a summary view of the outstanding contributions in the various departments of nuclear science will assist in bringing order out of the huge mass of current literature and will aid to the interpretation of future discoveries as they are made known.

I. NUCLEAR REACTIONS

    1. Nuclear Fission

        a. Materials

The raw materials for the nuclear cleavage, called "fission," are well known to include thorium, protactinium, and uranium, once

thought to have the highest atomic number of any naturally occurring element, and, since the publication of the Smyth Report (1), plutonium. In the Smyth Report it is disclosed that plutonium, a transuranic element formed by neutron absorption in uranium, also undergoes fission, in which the nucleus, or central core of the atom, breaks up into two or more energetic fragments. The various isotopes of uranium undergo fission preferentially under different conditions of excitation. Thus U^{235} undergoes fission upon absorbing a "slow" or "thermal" neutron (energy of about one fortieth of an electron-volt) while U^{238} does not receive enough energy for fission unless the neutron energy is about one million electron-volts. Pu^{239}, a radioactive decay product of the absorption by U^{238} of a neutron too slow to cause fission, is itself a nuclear "fuel" undergoing fission by neutron absorption.

Recently, however, several new isotopes have been announced to be capable of fission. Neutron-induced fission, the process usually signified by the simple term "fission," is possible in U^{233} (2) and in NP^{237} (3) which are two of the links in the long suggested, but only recently published, Neptunium series of radioactive elements (4). This series, made up of isotopes whose mass numbers have the form $(4n+1)$, where n is an integer, fills the gap between the Thorium (4n) series and the Uranium (4n+2) and Actinium (4n+3) series. Both U^{233} and Np^{237} are alpha-emitters, and the latter undergoes fission only for fast neutrons (5).

Some of the transuranic elements (so-called because they are elements of atomic number greater than that of uranium, (92) have been studied for their radioactive emissions and under this aspect find mention here by way of digression. For instance, there is the alpha-particle emission of Np^{237}, the alpha-particle energies of Pu^{238} and $Pu23^9$ (6), and the existence at least of some other isotopes of plutonium, of americium (Am) and curium (Cm), the latter being elements of atomic number 95 and 96, respectively (7).

b. Fission-producing processes.

In addition to the process of neutron capture, resulting in a nucleus unstable against dissociation into at least two heavy fragments, and besides the spontaneous fission known to take place at a very slow rate in uranium, fission has now been produced in uranium by 100 million electron-volt gamma-radiation. Furthermore, fission has been induced in a series of elements from tantalum to bismuth by very fast neutron bombardment and by bombardment with very high energy deuterons and alpha-particles (helium ions). The 100 million volt betatron-produced gamma-radiation was sufficiently energetic to produce cleavage of the nuclei of U and Th, but not of Bi, nor of any of several elements of lower atomic number (8). Neutrons, deuterons, and alphas, of energies up to 100, 200, and 400 million electron-volts, respectively, produced fission in Bi, Pb, Tl, Pt, and Ta (9). In the case

of the fission of Bi by high energy particles the high energy end of the distribution in energy of the fission fragments has been carefully inspected for signs of ternary fission, but with negative results (10).

One suggestion which these experimental findings bring forward is the consideration of first place importance in fission is the fact of a high state of nuclear excitation, not so much the actual method employed in achieving this excited state. Thus, for example, in uranium, fission occurs (a) spontaneously, because its natural state is sufficiently energetic to allow for a quantum mechanical transition, similar to the "tunneling" of alpha-particles through nuclear barriers, (b) by the absorption of a neutron, either fast or slow, depending on the isotope, and (c) by the reception of pure energy in the form of a very hard gamma-ray.

c. Properties of the fission process.

For understanding the process of fission itself it is of interest to know exactly the number and masses of the parts into which a given nucleus may split. It is a simple hypothesis, and one readily confirmed by experiment, that most of the fissions result in two fragments, and these of roughly comparable masses, but very rarely of equal masses. Thus the frequency distribution of the various mass numbers of isotopes observed to be fission products has a distinctive two-humped shape with maxima, for U^{235}, in the neighborhood of mass numbers 95 and 140. The symmetry of this "yield curve" is an indication at least that, by and large, the fission process results in but two fragments.

However, long range alpha-particles have been observed to be emitted in coincidence with the fission of U^{235} and Pu^{239} (that is, within 5×10^{-6} second of the fission itself) (11), and evidence has been adduced from photographic tracks for the existence of ternary and quaternary fission processes (12). Ternary fission takes place about ten times as frequently as quaternary fission, but ternary fission itself occurs only about once for 250 U^{235} fissions, once for 500 Pu^{239} fissions. The maximum energy of the alpha-particle is very high, approximately 22 million electron-volts, and further study of the angular correlation between the track of this particle with the tracks of the heavy fragments shows that it is emitted in the process of fission itself, not from one of the fragments, even immediately after fission (13).

It is known that on the occurence of fission some neutrons are emitted promptly. As a consequence of the existence of tripartite fission, shown by the presence of alpha-particles emitted in the fission act, it seems natural to investigate the possibility that some of the prompt neutrons also are emitted in the act of fission itself, and not from the separating fragments. Here a study of the angular distribution of the fission neutrons allows the simple interpretation of isotropic evaporation of the neutrons from the fragments themselves, after the act of cleavage of the nucleus (14).

The lapse of time in neutron-induced fission between the absorption of the neutron by the fissionable isotope and the fission itself has been given an upper limit: for U^{235}, less than 5×10^{-5} of the fissions are delayed by as long an interval as 10^{-8} second (15).

d. Fission products

The most interesting products of the process of fission are not the occasional alpha-particles emitted, or even the promptly emitted neutrons, but the great spread of heavy fragments, highly radioactive and productive of a large variety of radiations: gamma-rays, electrons, positrons, and neutrons. The range of these fragments has been the object of investigation (16), and the distribution in energy of these heavy products studied (17). A distribution curve of the energies is of course directly related to the yield curve, since, in the assumption of binary fission, the laws of conservation of momentum and energy allow one to be derived directly from the other. In the latter study, on the energy of the products, it is found that the energy distribution curve for U^{235} is practically the same for fission by slow and fast neutrons, while comparison with a similar curve for Th^{232} seems to indicate that the asymmetry of fission decreases as the atomic number of the original nucleus increases. This is also to be compared with and distinguished from the yield curves from the fission of bismuth, etc., by fast charged particles and neutrons of energies of the order of 100 million electron-volts and higher: here the asymmetric cleavage is not so pronounced as in slow neutrons U^{235} fission, but there are other differences, such as the production of the lighter isotopes of some product elements, and even, probably, of stable isotopes (18).

As for the radiations emitted by the fission products, two in particular have been the object of scrutiny because of their obvious connections with the design and operation of nuclear energy piles. The gamma radiation associated with the products of fission of U^{235} was analyzed roughly by means of the gamma-induced disintegration of the deuteron (19). Accurate knowledge of this type of penetrating radiation, as well as of the neutrons emitted subsequent to fission, is valuable in its own right, and essential for solving the problem of adequate shielding for the safe operation of a nuclear plant.

Much research has been devoted to the question of the half-periods of the so-called "delayed" neutrons: those neutrons emitted by the fission products, but after a measurable lapse of time subsequent to the fission itself. The rate at which these neutrons are emitted by the parent products, and hence the half-periods of the parent-product activities, have an essential role in the control of a nuclear pile, contributing a sort of inertial effect to the flux of neutrons through the active material of the pile (uranium or plutonium). The half-period, or half-life of a radioactive material is the time required for half the nuclei in a given batch to decay by some radioactive process. Thus, for example, a lump containing today one gram of pure radium will, at the end of 1590 years, the "half-life" of radium, contain only half

a gram of radium. In a series of publications by several independent groups the precision of the measurements of the half-lives of delayed neutron activities in the fission products has been gradually advanced with the result that now it is possible to assign them to six different groups, of half-life 55.6, 22.0, 4.51, 1.52, 0.43, and 0.05 seconds (20). These are the delayed neutron periods for the products of fission induced in U^{235} by slow neutrons, but it has also been shown that the plutonium fission products have the same neutron-emitting products (21). In all likelihood the 50 millisecond period will be resolved into two or more periods as the present discriminating devices gain improved precision. These half-lives show that at least six different isotopes, formed in fission, emit delayed neutrons. Although the total number of delayed neutrons per fission is only about $3/4$ of one per cent of the total number of all neutrons, prompt and delayed, per fission, still there are enough delayed ones present to assist in the control of nuclear reactors, smoothing out by their inertial effect sudden changes in the activity of the pile itself.

e. Theories of fission

The basic data for a good theory of fission in detail are not yet completely assembled, but any theory that aims at completeness must certainly account for the remarkable fact that symmetric fission, the splitting of a nucleus into two fragments of equal mass, is a relatively rare occurrence, and that asymmetric fission with the ratio of the masses of the fission products approximately 3:2 seems most favored. In addition to this fact is the experimental observation that the charge/mass ratios of both heavy and light fission products are sensibly equal. Finally the instability against beta-decay of the fission products themselves gives some light on how these products are formed from the nucleus of the split nucleus.

On the assumption that the charge density of the fissionable nucleus is not a constant, but a function of the radial distance from its center, calculations have been made of the charge/mass ratios for various types of asymmetric fission, and of the expected lengths of the radioactive chains for each mass number among the fission products (22). The chain length is the number of beta-decays that a given fission product isotope will undergo before arriving at a stable isotope. No detailed comparison with experimental findings is made. Another study taking its origin from the asymmetric nature of observed fission starts from the fact that immediately after fission the products are definite isotopes with a definite structure, and hence must possess a definite potential energy. The available kinetic energy for a given pair of product isotopes is computed from mass differences; by equating to this kinetic energy the Coulombian potential energy of the fragments, a distance of zero kinetic energy is determined. Unfortunately, for all modes of splitting the nucleus this distance comes out to be much larger than the sum of the radii of the fission products, the latter radii being calculated by the liquid drop model (23).

Several theories were developed in the hope of finding a reasonable explanation of the asymmetry of fission. One model proposed consisted in a crystalline structure for all nuclei: a closely packed array of protons and neutrons. The process of fission would correspond to the cleavage of the crystal between some pair of crystal planes; since this split must be above or below, but not through ,the central plane of symmetry, fragments of unequal mass would naturally result from this process (24). Against the objection that in such a model one would expect that heavy and light products would have different charge/mass ratios (25), it is urged that all observation of the charge/mass ratios takes place after an interval sufficiently long for any large excess of neutrons to have evaporated off the nucleus (26). Further confirmation of this viewpoint is sought in the regularities found in the number of stable isotopes for a given atomic number.

Another model assumes that in the excited nucleus, for example, U^{234} (that is U^{233} which has absorbed a neutron), two cores are formed, one of mass 60, the other of mass 16 (their difference, 44, corresponding to the difference of the mass numbers of the two peaks in the fission yield curve). Then the remaining 158 nucleons in the original nucleus are distributed, under thermal agitation, between the two cores; assuming equal probability for each nucleon to be in either fragment a statistical distribution of possible resulting pairs of fission fragments is obtained. This distribution resembles in striking fashion the observed yield curve. The widths of the maxima in the distribution are attributable to the Heisenberg uncertainty principle, and in this respect show a close resemblance to the line widths of atomic spectra (27).

The well-known Bohr-Wheeler development of the liquid drop model of nuclei has been studied with the assistance of the Eniac apparatus and detailed calculations made (28). This study confirms the results of earlier computations, and provides results which agree with observation of the fission threshold (minimum energy necessary to cause fission) and of the life-times of spontaneous fission. However, the authors of this investigation conclude that this model gives no indication of containing any source for the explanation of the asymmetry of fission. For the solution of this problem more experimental evidence is a prime necessity.

(To be continued)

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