years ago these hydrolytic cleavage products were represented mainly by leucine, tryosine, aspartic and glutaminic acid; but now, as a result of efforts in many quarters, the number of such decomposition products has risen to at least seventeen. The significance of this statement is apparent when we remember that these cleavage products represent the building stones which make up the finished structure of the protein molecule, and if the time ever comes when we know all of these building stones, we shall then without doubt be able to construct or synthesize this most important substance.

MAGNITUDE OF THE LIGHTING INDUSTRIES.*

A REVIEW OF A GREAT INDUSTRY.

BY E. L. ELLIOTT.

ARTIFICIAL lighting ranks third in order of importance among the necessities of civilization, being superseded only by clothing and shelter. That the industries connected with the production and use of light should therefore present a large aggregate is readily apparent; and yet the real magnitude of these enterprises is doubtless far beyond the conception of those who have not had their attention particularly directed to the subject.

At the present time the production of artificial light can be divided into the following distinct classes: Candles, oil lamps, illuminating gas, electricity, and acetylene. This enumeration is in the order of their development. A candle is often used to symbolize an epoch, or a means of doing things, that has long since passed away; and it will doubtless come in the nature of a surprise to many to learn that the candle industry in this country at the present time is larger than it has ever been before, and is increasing regularly at the rate of about 10 per cent a year. This increase, of course, is due primarily to the large increase in population, which increases the total output of any commodity in general sale; but aside from this there are two factors to which the increasing popularity of the candle is largely due. The first of these is its use in religious celebrations. This use has come down from extremely ancient times, and is likely to persist for centuries longer. The use of candles in the rites of Catholic churches is a familiar fact to Protestants; but it will surprise many Christians of all faiths to learn that the use of candles forms an important element in the rites of the Jewish religion. For religious purposes candles are frequently made of enormous size. Mr. W. J. Calkins, the head of the candle department of the Standard Oil Company, to whom we are indebted for most of the information which we give on this subject, states that they have made candles 10 feet high, and capable of burning continuously for several years. From these giants the sizes and shapes vary through all dimensions down to a minute taper less than an inch long, and a quarter of an inch in diameter. Candles were formerly made in connection with the soap industry, but at the present time paraffin, a product of mineral oil, is the principal constituent, and hence their manufacture has been entirely separate from its original connection. The two materials used in the manufacture of candles are paraffin and stearin. The latter forms the principal portion of tallow, and has a considerably higher melting point than the former. The composition of candles is varied according to the climate in which they are marketed. Thus, for the southern markets a considerable portion of stearin must be used in order to make the candles withstand the natural heat without softening so as to bend or run down; while for the northern markets pure paraffin can be used; and for intermediate sections proportionate compositions. The pure tallow candle is practically a thing of the past, there being only one small manufacturer of such candles still doing a limited business in New York.

On account of the sentiment connected with its historical associations, as well as upon its very soft and small amount of light, the use of candles is increasing for decorative purposes. As a Christmas tree decoration, the candle is indispensable, and for the purpose of supplying the demand for such candles the Standard Oil Company alone runs three factories continuously the year round.

Aside from its use for religious and decorative purposes, the candle still finds favor for general purposes on account of its convenience and extreme portability. A statement of one of the great electrical inventors, which has been so often quoted as to doubtless be familiar to the reader, is to the effect that had the electric light existed for centuries, and the candle were to be newly discovered, it would be hailed as one of the greatest inventions of the age, being entirely self-contained, cheap, and extremely portable, and requiring no accessories in the way of chimneys or shades.

From their New York office alone the Standard Oil Company last year sold over 4,000,000 pounds of candles, while their total sales reached 30,000,000 pounds.

The estimated value is 10 cents a pound, which gives an aggregate of \$3,000,000. This represents, according to Mr. Calkins, about a third of the entire product of the country, so that a fair estimate of the total amount of candles used per year is 100,000,000 pounds, having a total value of from ten to twelve million dollars.

The manufacture of shades and candlesticks and candelabra is also an industry of considerable proportions, and one which is increasing at a fairly rapid rate. It has been impossible, however, to obtain any accurate figures, owing to the fact that the manufacture of such goods is one of the items among more general lines of manufacture.

The oil lamp, or as it is more familiarly known, the kerosene lamp, furnishes almost exclusively the light for the farmers and the inhabitants of villages and small towns at the present time. Before the discovery of petroleum in commercial quantities, the problem of light for this large class of consumers had begun to assume a serious aspect. The practical extinction of the sperm whale, which had been a source of illuminating oil in the years preceding, was already in sight, and there was no other immediate source which promised to furnish an available burning oil at a reasonable price. The drilling of a single experimental well in northwestern Pennsylvania in 1837 revolutionized the whole situation at a single stroke. It demonstrated that there was an entirely new source of supply; the extent of which could not even be surmised, but which was available in perhaps almost inexhaustible supply at a far less cost than attendant upon the production of illuminating oils which it was to supersede.

Petroleum had been known in Pennsylvania for many years previous to the putting down of this first well. It had been observed floating upon the surface of certain streams, and the census of 1810 reports the production of 550 gallons of this "spring oil" in Venango County. In 1890 there were 94 companies engaged in refining petroleum, having an aggregate capital of \$77,416,290, and turning out an annual product valued at \$185,001,198. In 1900, there were 67 companies, capitalized at \$95,327,892, and turning out an annual product valued at \$123,929,384. In 1899 there were produced 25,171,289 barrels of illuminating oils valued at \$74,694,297. Assuming that the illuminating oils have the same general ratio to the entire product of the refineries as shown in 1890, the value of illuminating oil produced in 1900 would be \$100,000,000, and if the production has increased at the same rate, the present annual value of illuminating oil would be \$133,000,000.

The illuminating gas industry in this country dates from 1806, at which time David Melville, of Newport, R. I., lighted his premises by means of coal gas which he manufactured. This was nine years after the first experiments in England. Melville kept on improving his apparatus, and secured a patent in 1813, and later introduced gas lighting into a cotton mill in Watertown, Mass. New York city adopted gas lighting in 1823. Since that time the industry has been threatened with extinction by two strong competitors, namely, kerosene oil and the electric light. It has not only survived the competition thus introduced, but has shown a continuous growth up to the present time. At the time of its first introduction, illuminating gas was sold in New York at \$10 per 1,000 feet. At the present time, the average price of gas throughout the United States is probably not far from \$1 per 1,000 feet.

In 1890 there were 742 companies engaged in furnishing gas, with a capital of \$258,771,795, and an annual product valued at \$56,987,290. In 1900 there were 877 companies with a capital of \$567,000,506, and products valued at \$75,716,693. At the same rate of increase the annual value of the productions of the gas industry at the present time would aggregate \$80,000,000. This includes all the gas used for heating, cooking, and lighting purposes. The best information obtainable gives the proportion used for lighting as 75 per cent, which would give a value of \$60,000,000 as the annual value of illuminating gas.

The exact figures representing the capital invested, and annual production of electricity generated for il-

luminating purposes are impossible to obtain, owing to the fact that in the majority of stations at the present time current is sold for power and other purposes. In 1902 there were 3,620 central stations, the cost of construction and equipment of which amounted to \$504,740,352, whose gross income was \$85,700,605. These supplied 585,698 arc lamps, and 18,194,044 incandescent lamps. No authentic figures are available as to the amount invested in private isolated plants, but it is generally assumed, and doubtless with a fair degree of accuracy, that their total product is about equal to the product of the central stations. It is assumed by competent authority that there has been a 20 per cent increase in the output since the compilation of the figures given, thus bringing the annual product of the central stations to practically \$100,000,000. It is also fair to assume that 75 per cent of this total is devoted to the production of light. We thus arrive at the round figure of \$75,000,000 as the present annual expenditure for electric current produced by central stations for generating light; and assuming that the current privately generated is equal to this, we have the total of \$150,000,000 as the annual value of electricity used for lighting purposes.

Of the industries engaged in the production of lighting apparatus, those in the electrical field represent the largest investment of capital and value of product. In 1905 there were reported 195,157 arc lamps produced, having a value of \$1,574,422. The number produced during the past year probably was close to 200,000. In the same year there were produced 112,711,558 standard incandescent lamps, 1,584,495 miniature and decorative lamps. The value of the standard lamps was \$6,308,294, and of the miniatures, \$544,906. The value of this product was practically double that of the value of 1900; but the increase in the number of lamps during the same time was practically four times. It is conservative to estimate the increase in production and value since 1905 as 25 per cent a year, which would bring the total during the past year up to 168,853,869 standard lamps, and an aggregate value of \$10,429,307.

In 1905 there were 784 establishments engaged in the manufacture of electrical apparatus and supplies, having a capital of \$174,066,026, the annual value of whose product was \$115,730,089. The value of the products shows an increase over 1900 of a little more than 10 per cent a year. On the same basis of increase the present value of the products would be \$138,876,105.

The manufacture of lighting fixtures is an industry of large proportions. There were reported in 1905, 263 establishments making gas and lamp fixtures, having a capital of \$20,206,975, and turning out a product valued at \$17,560,386. In the same year electric lighting fixtures, including sockets and receptacles, etc., were valued at \$5,304,466.

Of apparatus connected with oil lighting there were manufactured in 1900, 807,765 dozen glass lamps, valued at \$1,498,675; and in the same year the lamp chimneys made were valued at \$2,719,583, and the lantern globes at \$497,021. Allowing for increase the present value must be about \$3,500,000.

In 1905 the value of lamps and reflectors, which included metal lamps and their accessories, was \$8,999,874.

We may then tabulate the several amounts, given in round numbers, as follows:

ANNUAL VALUE OF ILLUMINANTS.	
Candles	\$11,000,000
Kerosene	133,000,000
Illuminating gas	60,000,000
Electricity	150,000,000
Acetylene (estimated)	6,000,000
Total	\$360,000,000
LIGHTING APPARATUS.	
Electrical supplies	\$139,000,000
Electrical lamps	12,000,000
Fixtures	18,000,000
Lamps and accessories.....	13,000,000
Total	\$182,000,000

Taking 90,000,000 as the present population of the United States, we find that, according to the above figures, the cost of luminants for one year is equivalent

* Illuminating Engineer.

to \$4 for every man, woman, and child. To say that 10 per cent of the light generated is wasted through misuse and ignorance is certainly a conservative estimate; this gives \$36,000,000 as the total amount of

loss from this source, or an average of 40 cents per capita for the entire population of this country. Aside from candles and kerosene oil, the waste is probably nearer twice this amount. If all items could be in-

cluded which pertain to the lighting industry, it appears likely that the grand total of expenditure per year would reach half a billion dollars. A portion of this, however, is in the line of permanent investment.

GASES AND VAPORS.

A SIMPLE STATEMENT OF THEIR PHENOMENA.

BY PROF. O. N. WITT.

At one time the name of vapors was restricted to the emanations which rose from volatile liquids on the application of heat, and could be condensed to the liquid form by cooling, and the name of gases to substances which were in the gaseous state at ordinary atmospheric temperatures and which resisted all attempts at condensation. At a later period, after Thilonier and others had shown that many gases could be liquefied by cold and pressure combined, a distinction was made between coercible and non-coercible gases. It was then demonstrated by Andrews, whose researches and deductions have been completely confirmed by more recent experiments, that non-coercible gases do not exist and that it must be possible to liquefy any gas if a sufficiently high pressure and low temperature can be obtained. This law apparently annihilated the distinction between gases and vapors.

But the distinction remained in popular speech and its propriety is now again conceded by science. The distinction which is now recognized, however, is purely one of physical condition, not one of material substance. In other words, the same substance may present itself as a gas or as a vapor.

Guy-Lussac's law of the expansion of gases is expressed by the equation $V = V_0 (1 + aT)$, where V and V_0 denote the volumes occupied by a given mass of a gas at T degrees and at 0 degrees Centigrade (the pressure being the same in both cases) and a is the coefficient of expansion. This law is obeyed almost exactly by every gas so long as its temperature is much higher than the temperature at which it liquefies (at the pressure employed in the experiment), and for every gas under these conditions the coefficient of expansion is nearly the same and equal approximately to $1/273$. Hence for all gases under these conditions the equation

may be written $V = V_0 (1 + \frac{T}{273})$. If we suppose the

law to hold true down to the temperature of liquefaction, where the volume is reduced very nearly to zero,

we find $1 + \frac{T}{273}$ nearly equal to zero or T nearly equal

to -273 deg. C. For this and other reasons a temperature of approximately -273 deg. C. is called the absolute zero, and on the assumption made above the liquefying points of all gases should be very near this temperature.

But if any gas is gradually cooled, a point is reached below which the contraction becomes perceptibly greater than $1/273$ for each degree of cooling and continues to increase as the temperature sinks. If the increased coefficients of expansion (or contraction) thus indicated are introduced into the equation, we shall have $V = 0$ at a temperature considerably above -273 deg. C. And as the rapidity of increase of the coefficient and the point at which it becomes perceptible vary with different gases it is evident that the temperatures of liquefaction (under the same assumed pressure) must be different.

Of course, the point at which this phenomenon—the increase in the rate of expansion—commences cannot be determined with great precision, but it is obvious that this point marks the boundary between the gaseous and vaporous states.

An "ideal gas," to use a term of recent introduction, is characterized by strict obedience to Gay-Lussac's law of equal dilatation and to the law of Mariotte (or Boyle), according to which the volume of a given mass of gas varies inversely as the pressure of the temperature remains unchanged. A vapor obeys neither of these laws with strictness.

Very few substances are ideal gases even at the mean atmospheric temperature of 15 deg. C. (59 deg. F.). At this temperature hydrogen and helium are unquestionably ideal gases, but oxygen and nitrogen have probably reached the lower limit of the ideal gaseous state, while chlorine, carbon dioxide, sulphur dioxide and most other gases show so marked a divergence from that state that they must, in strictness, be classed as vapors.

At one or another higher temperature, however, every vapor acquires the character of an ideal gas and, at all still higher temperatures below the point of chemical dissociation, the substance strictly obeys

the laws of Gay-Lussac and Mariotte, and also the law of Avogadro, which expresses the fact that equal volumes of all gases at the same temperature and pressure contain equal numbers of molecules.

The transformation of gases into vapors at temperatures near their points of liquefaction is obviously a consequence of the essential nature of matter. We are ignorant of its mechanism and special causes, but they may, perhaps, be roughly sketched as follows: The molecules of a gas are pictured as perfectly elastic bodies which move, in virtue of their inherent energy, in straight lines, until they are deflected by impact against each other or the walls of the containing vessel. The conditions are similar to those of a great number of balls rolling in all directions on a billiard table, except that the motions of the molecules are not confined to one plane. Sir William Crookes, the Nestor of molecular physics, has compared the gas molecules to an imprisoned swarm of bees. If we imagine the bees to be untiring and elastic, so that they rebound after collision, the image is a fairly complete one. If the vessel is enlarged the bees will distribute themselves pretty uniformly throughout the larger space and will collide less frequently than before. If the space is contracted, the collisions will become more frequent. Now let us suppose that the bees, like real bees, lose energy and become fatigued. In default of other support, they cling to each other after collision, and the uniformity of distribution and the strict obedience to the laws of elasticity are destroyed. Soon all the bees cling together in one compact mass which falls to the floor of the prison. Here we have illustrations of the transformation of a gas into a vapor and the condensation of the vapor to a liquid. Another illustration is afforded by billiard balls covered with an adhesive substance which prevents them from rebounding after collision.

These illustrations suggest that the form of energy which is manifested in cohesion is peculiar to certain states of matter. It is not present in an ideal gas, but makes its appearance at the temperature below which the gas becomes a vapor. Gravitation between large masses, cohesion between molecules, and chemical affinity between atoms are only different forms of the universal force of attraction.

We know nothing of the atomistic state of matter, in which the atoms are not combined to form molecules. This state appears to be unattainable by human means, and since the development of the electronic theory it can hardly be even pictured in the form to which we had been accustomed. A molecular state of matter, in which the molecules exhibit no tendency to adhere to each other, is the state of an ideal gas. When cohesion commences and the molecules "coagulate," so to speak, the gas begins to be a vapor, and when the process of coagulation has been completed, the substance is a liquid or a solid. Of the molecular structure of liquids and solids we know nothing whatever.—Prometheus.

LIFE OF A RADIO-ACTIVE ELEMENT.*

By A. T. CAMERON.

A TYPICAL radioactive element gives rise continually to a radioactive product, together with one or more kinds of rays; radium gives rise to its emanation, and to α rays. In addition, heat in comparatively large quantity is continually liberated.

This continuous production of both energy and matter is explained by Rutherford by the assumption that atoms of the parent element are continually being broken down, or disintegrated, into simpler atoms, the heat and rays being the difference in energy-content in the two atomic systems. When gun cotton is exploded a complex molecule is broken up into simpler ones, heat and light being also emitted. The two cases are parallel, the one being atomic, the other molecular.

It is found that the emanations, and many other active products, lose their activity almost completely in a measurable time. From studies of the rate at which the activity is lost, the conclusion is reached that in any one time a certain fixed proportion of the total number of atoms present spontaneously disintegrates. An actual illustration will make this clearer.

The activity of any fixed quantity of radium emanation falls to half the initial value in approximately four days. In the second four days it falls to half of this second value, i. e., one quarter of the original. We therefore suppose that the emanation has decomposed to a corresponding extent. In the unit of time chosen, four days, the same quantity, one-half the amount at the beginning of that period, always disappears. Similarly in any other definite period of time a certain quantity, bearing a definite ratio to the original amount, will disappear. Again, at the end of eight days one quarter of the whole amount remains; at the end of twelve days, one-eighth; of sixteen days, one-sixteenth. But at the end of infinite time there will always remain some quantity, however small. Similarly, in all cases of active matter some remains undisintegrated after infinite time; the radio-active elements have an *infinite life*. Though they may have *died* for all practical purposes at the end of some measurable time, an unmeasurable but definite amount remains. However, we can always find when half a given quantity of active substance has disappeared. And it is this period which is termed the *half-life period* of such substances. It varies from four seconds in the case of actinium emanation to millions of years in the case of uranium.

Another term constantly used is the *average life* of a substance. It can be conveniently illustrated by a human parallel. A church filled with people on any fixed date contains a fair assortment of men, women, and children of all ages. If we know the total number of years each person will live after leaving that church we can calculate the *average life* of the congregation, counting from the definite time fixed by that church attendance. This is quite different from the *average life* of some number of persons from the time of birth of each, which is the basis of the data employed to calculate insurance rates.

The *average life* of a radio-active element at any definite time corresponds to the first of these illustrations. If we take a definite quantity of radium salt, then the atoms of radium it contains are of all ages. If they have just previously been separated from their uranium ore some may have been born only a few weeks previously, others have existed thousands of years, just as the church congregation may include infants and old men of ninety. Of the radium atoms a certain number will *expire* in a definite time, just as in so many years a number of the worshipers will have died. And we can calculate the average life of the congregation of atoms with as much certainty as that of people.

The application of the second kind of *average life* to radio-active substances was recently worked out in some detail by Sir William Ramsay as a lecture illustration. Though it has just been stated that the life of a radio-active atom is infinite, yet infinity is only a relative term; in this connection it only means a longer time than we can measure. It is extremely probable that just as the human life is measurable and definite, so is, let us say, the life of an atom of radium. One may go further. For there is much more regularity in the life of this dead matter; the life of human beings is variable, dependent on "all the ills that flesh is heir to," microbes, the bearers of disease, and accidents, the ills of fortune. We have no ground to suppose that the life of a radio-active atom varies from any similar cause. For example, the rate of decay—the death rate—of radium emanation is unaltered within the limits of measurement between the temperatures of -180 deg. and $+1,600$ deg. C. (90 to $1,870$ deg. in the absolute scale), the extremes at which, so far, it has been experimentally tested. If this tremendous difference of temperature does not hasten the decay of a single atom of emanation we can at least postulate that its life is not easily influenced by external causes. So far experimental work has shown that we cannot hasten or retard the death of a radio-active atom; consequently we cannot alter its life. For its birth is but the death of its parent atom, to which the preceding statement likewise applies. And we are justified in stating that the average life of a radio-active atom, as used in the second sense above, is in all probability the actual life of that atom.

* Science Progress.