netism, of stimulus, of optimism. Teachers as well as leaders often work more influence by precept, example, and their own actions than by the spoken word. It is an indescribable quality, and a perfectly worded discourse in which every step rests on proven and established facts may leave the class busy with pencil and paper, whereas another teacher using imperfect diction and presenting his facts in a less orderly fashion may keep every eye and ear so busy that note-books remain untouched. The latter is the real teacher.

These, then, are the essential qualities for the ideal man in university medicine. One does not expect to see them all in full bloom in any individual; but to those of you who contemplate a university career in medicine or surgery, it is well to depict what may be expected of you.

The varied training necessitated will encompass roughly eight to ten years. These years may be divided in the ratio of three to the laboratory and seven to the clinic, and it is my impression that part of the clinical training should come first and part last. It is customary to advise first an interneship, then a resident's post using up perhaps three years; next comes the laboratory. Here the choice must be very wide. It might well be divided into a further training in one of the basic medical sciences followed by two years of experimental endeavor. These years completed, the man steps into the higher resident or assistants' posts in some clinic. From this time on, his mind having been trained in investigative methods, and a greater opportunity for clinical research both as regard material and time being offered, his publications should become true reflections of his value, tendencies, and promise. He now has greater occasion to teach and can well spend a large part of the next few years perfecting what qualities he has in this field. Such a person should now be ready for a high university post.

This is a long span of time, and we may well recollect that life is short. Moreover, the pecuniary reward is small. Still, such posts as those described, except for that of interneship, pay small stipends from five hundred dollars to fifteen hundred dollars. It is not, indeed, the easy task imagined by some of the great group of practitioners who look upon such people as peculiar individuals. But I can tell you that it has high rewards. In the first place, it is always a joy to do work well, and such a training almost insures this. In the next place, to find out the truth by an investigation is a tremendous stimulus. And lastly, it leads to a position in life that keeps one always in contact with vigorous, fresh, inquisitive minds; a position that both keeps one's own mind young as well as gives one the great happiness of seeing other minds grow under a little stimulus, a word of encouragement, or a proper example.

I have, as many of you must know, given much of my own ideas and experiences in this talk; and yet as I wrote it, I had piled on my desk clippings, books, and quotations covering most of the contributions on this subject during the past twenty years. In reading them, I found always the same undercurrent, a feeling that the teachers of medicine must be better trained. What I have written of the ideal man, of his qualities and abilities, is but a summary of the views of others also. It is a description of a field of endeavor for medical men that has been slow to arrive in this country, but which will certainly be in full swing before your generation has passed on.

I beg of you to remember that what I have said is purely from an idealistic point of view. No criticisms have been made. Do not for a moment carry away the idea that I belittle the practice of medicine as opposed to the field of medicine described. I would only have you remember that a university career should require a definite training, if we are to raise medicine to higher levels. Something of what that training must be, and that that training is necessary and logical, I have tried to show you to-night.

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IONIZATION AND RESONANCE POTENTIALS[1]

THE phenomena connected with luminous discharge in gases at low pressures have received a great deal of attention during the past twenty years. Many theories have been

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[1] Address presented at the Boston meeting of the American Association for the Advancement of Science, Section C.

worked out to explain these phenomena, but until very recently no satisfactory explanation of the relation between the energy necessary to produce ionization of gaseous molecules and the voltage required to produce luminosity in a gas had been advanced. The advent of the electron theory and more recently of the Bohr theory of atomic structure have greatly stimulated activities in this field and it seems likely that most of the facts hitherto regarded as simply empirical will be explained satisfactorily in the near future. It seems probable, at the present time, that a comprehensive theory of the luminous discharge will only be obtained by a thorough study of ionization and resonance potentials. Moreover, research in this field will undoubtedly aid in solving many of the complex problems of photochemistry.

Ionization and resonance potentials can be calculated from the corresponding spectrum lines by the simple relation

$$V = \frac{hc}{e\lambda 10^8}$$

c being the speed of light, λ the wave length of the spectrum line, e the charge on the electron and V the voltage. The resonance potential of an atom is the minimum potential through which an electron must be accelerated when started from rest in order, when it collides with the atom, to displace an electron to an orbit further from the nucleus. There are naturally a great number of resonance potentials for each type of atom, depending on the number of possible orbits to which the electron may be removed. Corresponding to each resonance potential there is a line in the spectrum of the element. Light is emitted when the electron returns to an orbit nearer to the nucleus than the one to which it had been displaced. The light may also be emitted with several frequencies. For example, if an electron had been displaced from the 1 orbit to the 3 orbit it might return to the 2 orbit and then fall back to the 1 orbit after another interval of time. Light of two frequencies would then be emitted instead of the single line corresponding to the 3—1 transition.

When one of the outer or valence electrons has been completely removed the corresponding speed of the impinging electron is called the ionization potential. The light emitted when the electron returns from infinity to its normal position is of the highest possible frequency and this line is the head of the principal series of the element in question. Here again, if the atom is ionized the electron may return by stages and the whole spectrum of the element may be emitted. There may be several ionization potentials corresponding to the removal of one, two or more electrons. Some determinations have been made of the energy necessary to remove a second electron from an atom, for example, to change He^+ to He^{++}, but in general we are concerned with the ionization potential corresponding to the elimination of one electron.

There are several methods of measuring ionization and resonance potentials, but few of the methods distinguish clearly between the two. One method consists in gradually increasing the potential between two electrodes and noting the production of radiation by its photoelectric effect on another electrode placed in the tube. While some idea of the frequency of the light emitted may be obtained by measuring the velocity of the photoelectrons produced, this method does not distinguish definitely between the two types of electron impact. If series relationships for the gas being studied are known, it is possible to obtain some idea of the voltage necessary to produce ionization, but the energy necessary to produce ionization when an atom has already suffered a resonance impact is less than the normal ionization potential, so that results obtained by this method must be interpreted with care. This method has been used by Franck[2] and his coworkers in studying the radiation potentials of mercury.

The three electrode, or even four electrode, tube has been used in measuring ionization and resonance potentials. Many modifications have been proposed. Among the most important might be mentioned those of Lenard,[3], Compton[4] and Davis and Goucher.[5] In most of the methods there is an element of uncertainty due to the velocity of thermal emission of the electrons. While tables have been made out giving the velocity distribution of the electrons at

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[2] *Z. Physik.*, 2, 18, 1920.

[3] See Hughes, "Report on Photoelectricity," *Bull. Nat. Res. Council*, 2, 83, 1921.

[4] *Phil. Mag.*, 40, 553, 1920.

[5] *Phys. Rev.*, 10, 101, 1917.

different temperatures, the correction due to this factor may be fairly large. One method of applying it is to place a negatively charged grid in front of the filament so that only those electrons with high velocity will pass through. By measuring the apparent ionization potential of a gas whose ionization potential is known, the magnitude of the correction may be determined. Results show wide variation, however, and the magnitude of the correction undoubtedly depends on the physical state of the filament, the nature of the gas being studied and the potential drop along the filament.

Foote, Meggars and Mohler[6] used a three electrode in which the grid was a spiral wound as closely as possible around the filament. The grid and plate were directly connected together. The electrons were accelerated by the potential on the grid and plate, passed through the grid into the force free space beyond. The radiation emitted between the grid and plate could be photographed and the potential determined at which a given radiation appeared. This method is probably the most accurate of those described.

Recently some work by Gibson and Noyes[7] has shown that in most cases the potential required to produce luminosity in a gas, using a heated cathode, is a simple integral multiple of the ionization potential. According to the theory advanced, it is necessary for positive ions produced in the discharge to reach the cathode in order for the glow to be maintained. The fall of potential in the region between the cathode and the positive column is small, so that the electrons are accelerated in a comparatively short distance. If there are several ionization regions they will be relatively close together. As the potential between the two electrodes is diminished the slowest moving positive ions will be the first to fail to reach the cathode, etc. When all of the positive ions combine with electrons before they reach the cathode, the glow disappears. This will occur when the positive ions formed in the ionization region nearest the anode no longer have sufficient velocity to reach the cathode. The voltage necessary to maintain the glow will, therefore, be equal to the energy of the electron when it arrives at the last ionization region plus whatever energy it may have lost due to inelastic impact before it reaches that point. By studying the disappearance voltage at various pressures with various length tubes it is possible to obtain various multiples of the ionization potential. Subtracting successive values will give the potential desired. Care must be taken in interpreting results obtained by this method, since various combinations of resonance and ionization potentials may be obtained.

The exact method by which the energy of the impinging electron is transferred to the atom is not clear. Whittaker[8] has recently made an attempt at an explanation, but the whole question is in an unsettled state. One fact stands out, however, as a general survey of the field is made, namely, that the agreement between the observed ionization and resonance potentials and the theoretical values computed from spectroscopic data is excellent, leaving little doubt as to the validity of the relationship used.

A large amount of work has been done on hydrogen, due probably to the complete picture which Bohr has given of its atom. Many critical potentials have been noticed, but since the Bohr picture of the hydrogen molecule is apparently considerably in error, the exact interpretation of these potentials is still in doubt. The lowest radiating potential for the hydrogen atom, according to the Bohr theory, should be 10.2 volts. A critical potential of this order of magnitude has been observed by several workers, but, as has been pointed out by Foote and Mohler, there would scarcely be enough monatomic hydrogen present to give this value. The ionization potential of the atom, according to Bohr, should be 13.5 volts and recently Duffenback,[9] by using hydrogen at sufficiently high temperatures, has shown that this value coincides well with experiment. Bohr states that elimination of one electron from the hydrogen molecule without dissociation would leave an unstable ion. There is some evidence, although not at all conclusive, that ionization does occur according to this mechanism. The main ionization potential of

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[6] *Phil. Mag.*, 42, 1002, 1921.

[7] *Jour. Amer. Chem. Soc.*, 44, 2091, 1922.

[8] *Proc. Roy. Soc. Edinburgh*, 42, 129, 1922.

[9] SCIENCE, 55, 210, 1922.

hydrogen should occur, however, when the hydrogen molecule is dissociated and one of the two atoms ionized. The heat of dissociation of hydrogen, as determined by Langmuir,[10] is 84,000 calories, which corresponds to 3.6 volts. The main ionization potential of hydrogen should be, therefore, $13.5 + 3.6 = 17.1$ volts. This potential has been observed by certain workers, while other workers have obtained lower values. A second ionization potential has been observed in the neighborhood of 30 volts. This would be obtained by the dissociation of the molecule and ionization of both of the atoms. There is some evidence that this is the principle ionization process in hydrogen in long tubes. The difficulty of interpreting the critical potentials in this case is largely increased due to the fact that the gas is diatomic.

The variation of ionization potential with atomic weight for the elements of the first two groups of the Periodic System is approximately what one would predict. The most electropositive elements occur at the bottom of the periodic table and they have the lowest ionization potentials. Little success has been attained in measuring the ionization potentials of the elements in the center of the table. Those which lend themselves to study due to their ready vaporization exist as polyatomic molecules and the interpretation of the critical potentials is exceedingly difficult. Of the so-called electronegative gases, iodine is the only one which has been studied sufficiently to warrant our drawing any conclusions. It would seem that the principle ionization potential of iodine is about 10.0 volts, corresponding to the dissociation of the molecule and ionization of one of the atoms. Since the energy required to dissociate the molecule is 1.6 volts, the ionization potential of the atom should be 8.4 volts. This would correspond to a wave length of 1470 A., but sufficient spectroscopic data are not available to verify this measurement. It is interesting to note that Compton and Smyth[11] have obtained a lower ionization potential for fluorescing iodine than for normal iodine. This agrees with accepted principles, since the fluorescing molecules should be in an unstable state.

Bohr has pointed out that the ionization potentional is not necessarily a function of the electropositive or electronegative character of the elements, but depends on the configuration of the atoms.

The ionization potentials of several compounds have been measured, but it is doubtful whether the data are reliable in many cases. Many compounds are completely dissociated into their elements by electronic bombardment, and the value of the ionization potential as measured may be due to any one of several possibilities. In general the ionization potential of an atom will be different from that of the same atom in combination. It would seem that further careful investigation in this field should be carried out, as it might give us an insight into the real nature of chemical combination.

Foote and Mohler[12] have studied the ionization potential of hydrochloric acid gas and find that it corresponds to simply disrupting the HCl molecule into H^+ and Cl^-. This ionization potential is lower than would be expected, due to the tendency of the chlorine to hold an electron, or in other words to its electron affinity. This agrees well with the idea that HCl is a polar compound.

An atom should be ionized by absorbing radiation of the proper wave length, namely, the same wave length as would be emitted by the reverse process. It may also be ionized by absorbing successive resonance radiations. The principal question before the photochemist at present is whether the action of light is to remove electrons and render the atoms or molecules more "active" or whether they are rendered "active" by displacement of the electrons to different orbits without ionization. It is probable that the rate of reaction of the "active" molecules is extremely rapid, and that the speed of a photochemical reaction depends to a large extent on the speed of ativation. It is impossible to say, at the present time, whether the action of light in chemical reactions is to remove electrons, but it seems probable that this is true in at least some cases. If

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[10] *Jour. Amer. Chem. Soc.*, 37, 417, 1915.

[11] *Phys. Rev.*, 16, 501, 1920.

[12] *Jour. Amer. Chem. Soc.*, 42, 1832, 1920.

this is the case, the radiation emitted by a positive ion combining with an electron should be the most efficient in aiding a photochemical action involving the same atom. Here again the problem is complicated if polyatomic molecules are considered. Radiation emitted by a hydrogen atom would probably be without effect on a hydrogen molecule. It has been shown that hydrogen is not activated in the Lyman region. It has been suggested that the study of band spectra might aid in the understanding of this field. Atoms are extremely accurately tuned systems and might not respond to radiation differing in frequency by one part in ten thousand. Whether the same holds true for molecules remains to be determined.

Reactions involving the halogens are peculiarly photosensitive. This may be due to the electron affinity of the halogens, especially in the monatomic state. It is rather difficult to understand why a diatomic halogen molecule should have an electron affinity, and there may be room for difference of opinion on this point. The atoms tend to take up electrons in order to complete their outer shells. The theory at once suggests itself that the effect of light is to disrupt the bond between the halogen atoms, permitting them to combine readily with substances having less electron affinity. As Nernst[13] has suggested, the fact that these reactions do not obey the law of photochemical equivalents can probably be attributed to the fact that one free chlorine atom is formed each time a molecule of chlorine reacts and that this free chlorine atom may disrupt a molecule of the other reacting substance leaving another unstable intermediate product. This series could be continued indefinitely until it came to an accidental end. He tried the use of acceptors in the case of bromine for the purpose of removing the free bromine atoms and found that the law of photochemical equivalents was then obeyed.

In conclusion, it may be stated that while the work done in the field of ionization and resonance potentials has done much to aid our ideas of atomic structure, it has done little from the standpoint of chemical combination. We may look for its development along these lines in the future.

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ARTHUR LALANNE KIMBALL

Although Professor Kimball had been in delicate health for several years, and his friends knew that before long he would have to retire from active teaching, the end came with little warning. On the afternoon of October 21 he worked as usual at the laboratory. In the early evening of the following day he passed away.

He was born at Succasunna, N. J., October 16, 1856. Graduating from Princeton in '81 with high honors, he won the experimental science fellowship and was a graduate student and fellow in physics there the following year. From 1882 to 1884 he was fellow at Johns Hopkins, working under Professor Rowland. Here he received in 1884 his doctor's degree, having completed a research on the absolute determination of the ohm. Immediately thereafter he was appointed associate in physics at Johns Hopkins. In 1888 he became associate professor and filled this position with distinguished success until 1891, when he was called to Amherst. Here a new laboratory was built under his direction and for thirty-one years to the day of his death he was conspicuous for ability, friendliness and whole-hearted devotion to the college.

It is probable that his Princeton classmates could have predicted pretty accurately his future. When a man of keen intellect and indomitable will starts in a certain direction his course can be charted in advance. One who knew him intimately writes: "Since the excellence of his moral character, in purity, sincerity, kindness and courage was as marked as his intellectual ability, his studious habits did not keep him out of friendly touch with his classmates, and he shared in our affection no less than in our admiration." At Johns Hopkins his knowledge, his simplicity, honesty and kindliness endeared him to all. With self-sacrificing consecration and high ideals he entered upon his work at Amherst. His clear thinking was matched by his gift for clear

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[13] *Z. Elektrochem.*, 24, 335, 1919.