

In conclusion it should be noted that although most of the genetical work on *Oenothera*s has not been interpreted by the Mendelian system of notation there is, nevertheless, clear evidence of order in the sharply defined results of both inbreeding and crossing. A few cases are known of simple and clean cut segregation in ratios fairly close to Mendelian expectations, notably in crosses between *Lamarckiana* and *brevistylis* and probably in time more of these will be found. The difficulty has been to discover and to isolate simple material in the confusion of mixed and impure forms present in this group of plants. A great forward step will be taken in *Oenothera* genetics when types of proven purity have been established, since such forms as standard material in breeding tests may prove to be the keys that will open doors of mystery.

THE SPECTRA OF ISOTOPES AND THE VIBRATION OF ELECTRONS IN THE ATOM

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According to most of the recent theories of atomic structure and of the origin of light, the emission of light is due to the vibration of the non-nuclear electrons in the atom, but there is a difference of opinion in regard to the process by means of which the radiation takes place. The frequency of the light has usually been assumed to be that of the vibrating electron which emits it, but the theory of Bohr¹ indicates a less simple relationship according to which the frequency of the light varies as the increment of the two-thirds power of the electronic frequency.

The investigation reported in this paper was begun several years ago for the purpose of determining if the electronic periods are wholly dependent upon the *net* positive charge on the nucleus of the atom. In order to get a more definite statement of the problem, it may be assumed that the nucleus of any atom contains a positive electrons and b negative electrons. The net positive charge on the nucleus may be taken as $a - b$ or P . While P is not known exactly it is probably equal to or only slightly greater than the atomic number N . A single element, such as lead, is characterized by a single value of P . Isotopes are different atomic species of the same element, all with the same value of P , but with different values of a and b . Since $a - P = b$, the numerical value b gives not only the number of negative electrons, but also the

number of positive electrons in excess of the nuclear charge P . The fact that isotopes, with a constant value of P , but with a variable value of b , have almost exactly the same spectra, indicates that the non-nuclear electrons vibrate as might be expected if the b positive and b negative electrons were not present in the nucleus, that is as if it consisted of P positive electrons alone. Since, therefore, the vibration of the non-nuclear electrons depends almost entirely upon the net nuclear charge P , it is evident that both the effect (1) of the mass of the nucleus, and (2) of the bound b positive and b negative electrons, must be extremely small. The work here described was undertaken to see if either of these effects is large enough to produce a measureable deviation in the spectra of isotopes. It might be expected, even if there is no effect due to the mass, that if the positive and negative electrons in the nucleus are not coincident, their space arrangement should cause a slight, though possibly unmeasureable effect upon the spectrum.

The isotopes chosen for this work were ordinary lead and lead from radium (Radium G, or Uranio-lead 3). The atomic weight of the former is 207.18, and that of the latter, as determined by Prof. Theodore W. Richards, is 206.34 for this particular specimen used in this investigation. If ordinary lead is a single isotope this specimen of Uranio-lead 3 contains about 25% of ordinary lead as an impurity, since the atomic weight of pure uranio-lead 3 is about 206.05. The value of N for these isotopes is 82.

The spectra of isotopes were first investigated in 1912 by Russell and Rossi,² and by Exner and Haschek,³ who examined the spectra of ionium and thorium (isotopes of atomic number 90) but found no measureable differences. Isotopes of lead have been studied spectroscopically by Soddy and Hyman,⁴ by Baxter and by Richards and Lember,⁵ by Rutherford and Andrade,⁶ by Honigschmidt and St. Horovitz,⁷ by Merton,⁸ and by Siegbahn and Stenstrom,⁹ all of whom found the spectra of isotopes identical within the limits of accuracy of their work, except that Soddy obtained a slight difference in intensity for the line $\lambda = 4760.1$. While Merton used a higher dispersion than any of the other workers, he does not give the atomic weight of the uranio-lead which he used.

The measurements here presented were made by Dr. Aronberg, and the spectroscopic work was directed by Prof. H. G. Gale. Preliminary determinations with ordinary lead, and with ordinary lead mixed with about 20% of uranio-lead 3, when made on a six inch Rowland concave grating, gave no measureable differences in the spectra or in the

Zeeman effect. A quartz spectrograph with a dispersion of about 25 angstroms per millimeter gave a similar result when used with uranio-lead of atomic weight 206.34, but when the Michelson 10-inch plane grating was used in the sixth order, a difference of about 0.0043 A. U. was found, and as might have been predicted theoretically, the uranio-lead has the longer wave length and therefore the lower frequency. This difference was obtained for the line $\lambda = 4058$, the strongest line in the spectrum of lead. Unfortunately the other lines of lead are too weak to give a photograph with this grating as used in the higher orders, in any reasonable time of exposure.

The structure of the line $\lambda = 4058$ in ordinary lead was studied by Jonicke¹⁰ and by Wali-Mohamed,¹¹ who used a vacuum lead arc as a source of light. By the use of an echelon they found two satellites at $+0.032$ and -0.041 . In the present investigation it was found, however, that both the ordinary and the uranio-lead give only one satellite, at -0.0480 and -0.0501 for the uranio and ordinary lead respectively, the difference being within the experimental error of the measurement. The difficulty is due to the lack of definition of the satellite.

As a source of light a slightly modified form of the oxycathode arc in vacuo as employed by Wali-Mohamed, was used in the form shown in figure 1. This gives a bright source and at the same time very sharp and narrow lines, as is essential for work of such delicacy. Such an arc had the advantage too, that the extremely rare uranio-lead 3 was not wasted. It was first used with a Hilger quartz spectrograph, in which case the interesting observation was made that the lines $\lambda = 2823$ and 2833 had different intensities in the spectrum of the uranio-lead from what they had in the ordinary lead. This was similar to the result obtained by Soddy, but it was found to be due to the fact that after the arcs started the pressure in the lamp containing the uranio-lead rose from 0.05 mm. to 0.25 mm., and it was the small difference in pressure which caused the change in intensity. For this reason, when the grating was used, the two lamps were connected in parallel to the vacuum pump in order to keep the pressure in both the same, about 0.04 mm. In order to avoid mechanical shifts both exposures were made at the same time. The light from one lamp went through a right angle prism attached to the slit, thus forming a spectrum, the middle of which belongs to one kind of lead while the lines both above and below belong to the other. The voltage, 40 volts, was kept the same in both within one volt, and the amperage, 1.1 amperes, was kept within 0.05 ampere. In this way seven exposures were made in one position,

then the two lamps were interchanged and six more exposures were made, when the positions were again reversed and three more measurements were made. On the average the wave length of the uranio-lead was 0.0043 A. U. longer than that of the ordinary lead. The seventeen measurements were as follows, where all should have the positive sign: 0.0046, 0.0046, 0.0068, 0.0036, 0.0057, 0.0043, 0.0036, (shift of lamps)

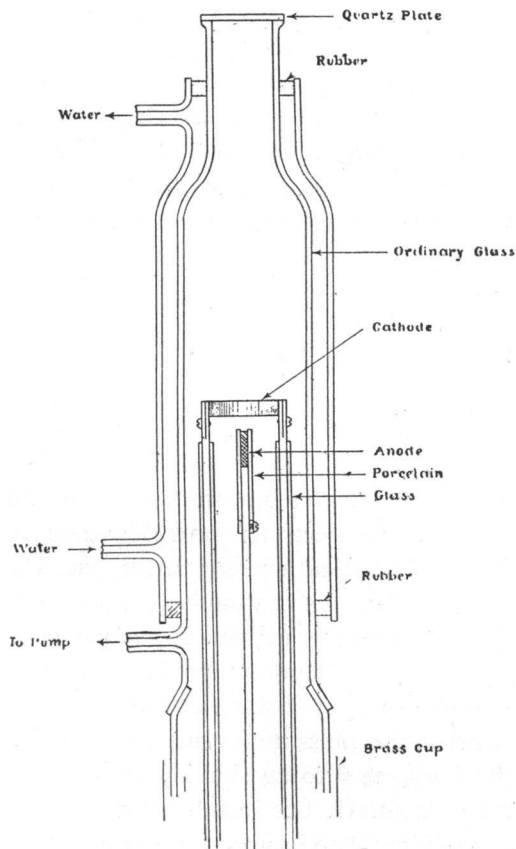


FIG. 1

0.0036, 0.0036, 0.0039, 0.0046, 0.0057, 0.0036, (shift) 0.0046, 0.0036, 0.0046 A. U. The average difference was 0.012 mm. on the plates, and the dispersion was 0.359 A. U. per millimeter. In experiments 6 and 7 the voltage of the ordinary lead was lowered, and in 12 and 13 that of the uranio-lead was lowered, in each case by 3 volts. In experiment 17 the amperage of the uranio-lead was lowered by 0.2 amperes. It

may be seen that these changes of voltage and amperage produced on noticeable changes in the shift of the lines. Finally, to establish the change in a new manner, the uranio-lead was removed from its lamp, and ordinary lead put in its place, and when this was done the shift was found to disappear.

When Merton did his work on the isotopes of lead, J. W. Nicholson calculated for him the shift in a lead line at $\lambda = 4000$, which would be caused by an atomic weight difference of 0.5 unit according to Professor Hicks' theory that the atomic weight term enters exactly into the separation of doublets and triplets in series spectra, and assuming that at this wave length lead has a doublet series spectrum with a separation of 50 A. U. The calculation showed that the shift should be 0.15 angstroms which is very much larger than the shift actually found. On the other hand the theoretical formula developed by Bohr

$$\nu = \frac{2\pi^2 e^2 E^2 m}{h^3 \left(1 + \frac{m}{M}\right)} \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

gives a much smaller value (0.00005 angstroms) but of the same sign as that found experimentally. However, Bohr's calculation was made for an extremely simple atomic system, while the lead atom contains a large number of non-nuclear electrons (probably about 82).

Since this is the first investigation reported in which a shift has been found in the spectra of isotopes it would seem advisable to check the experimental work by an altogether new investigation, especially since the shift as determined is extremely small. However, it should be stated that the difference in the position of the lines is easily observable under the measuring microscope. One remarkable feature of the photographs is that the lines seem to be shifted, and not to be broadened.

We wish to thank Prof. H. G. Gale for directing the spectroscopic work and Prof. Theodore W. Richards for the extremely rare Radium G which he placed at our disposal for this work.

¹ Bohr, *Phil. Mag., London*, 26, 1913, (1, 476, 857); 29, 1915, (332).

² Russell and Rossi, *London, Proc. R. Soc. (A)*, 87, 1912, (478).

³ Berlin, *SitzBer. Ak. Wiss.* 121, IIa, 1912, (175).

⁴ *Trans. Chem. Soc.*, 105, 1914, (140).

⁵ *J. Amer. Chem. Soc., Easton, Pa.*, 38, 1914, (1329).

⁶ *Phil. Mag., London*, 27, 1914, (854-68).

⁷ Berlin, *SitzBer. Ak. Wiss.* 123, IIa, 1914.

⁸ *London, Proc. R. Soc. (A)*, 91, 1914, (198).

⁹ *Paris, C. R., Acad. Sci.*, 163, 1914, (428).

¹⁰ *Ann. Physik., Leipzig*, 29, 1909, (833).

¹¹ *Astroph. J., Chicago, Ill.*, 39, 1914, (189).

THE EFFECT OF OXYGEN TENSION ON THE METABOLISM OF CASSIOPEA

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It was shown by Verzár (*J. Physiol.*, 45, 1912, 39) that decreased oxygen tension in the blood capillaries decreased the metabolism of muscle but not of salivary glands. The animal died before the oxygen tension in the salivary glands was reduced sufficiently to cause a noticeable fall in metabolism. In order to avoid complications in circulation, as in Verzár's experiments, I used the umbrella of *Cassiopea* in such a manner as to maintain a thin layer of cells of uniform activity constantly bathed with sea water at 30°. It had been determined in preliminary experiments that a rise of 10° in temperature doubled the metabolism, but that the hydrogen ion concentration could be changed within certain limits without changing the metabolism to a degree that could be measured with certainty. The average of a large number of determinations placed the respiratory quotient at 0.95, but whether it was constant could not be determined. From the heat produced and nitrogen lost it was concluded that proteins with a small admixture of carbohydrates and fats were burned.

Since the temperature was constant, the oxygen-tension was proportional to the O₂-concentration, as determined by the Winkler method, the mean of the values at the beginning and end of the experiment being used. The metabolism was measured by the oxygen used, as that was determined more accurately than the heat and CO₂ eliminated. *The metabolism varied with oxygen concentration.* This may be true of the cells of all animals. It seems possible that Verzár did not succeed in markedly changing the O₂-tension in the salivary gland, owing to the great store of oxygen in the hemoglobin. There is, however, a distinction between the metabolism of vertebrate muscle cells and *Cassiopea*. If vertebrates are asphyxiated, the muscles give out lactic acid. A *Cassiopea* may remain without oxygen for seven hours without giving out CO₂ or any other acid causing a noticeable change in hydrogen ion concentration, although in the presence of O₂ such a change appears in