Near Ultraviolet Band Spectra of Iodine

The emission spectrum of iodine vapor was examined under high frequency electrodeless discharge conditions. At the minimum maintaining potential the "continuum" referred to as "3460" developed a marked maximum at λ3414. This group can be shown to be a P branch, with head at 3414 degrading to higher frequencies. $\tilde{\nu}=29{,}949+222.5\,M+28.42\,M^2+2.000\,M^3+0.0833\,M^4$ with $-J''=M=-1,\ -2$, etc.: $B'=125.42$, $B''=97.08$, $D'=0.5416$, $D''=0.4584$. Its upper level 44,893 cm^{-1} or 5.59 volts, is coincident with Sponer and Watson's rearranged Kimura and Mignishi ultraviolet bands λ2094−2511. Its lower level is coincident with 15,598.3 cm^{-1} state BO_u^+.

An adjacent band with maximum at 31,129 cm^{-1} (λ3211) was found to be a headless P branch, whose $\tilde{\nu}=31{,}760+208.83\,M+0.167\,M^3$, where $B'=B''=104.50$ and $D'=D''=0.0417$. It is proposed as a 1→0 transition. Its R branch origin lies at or near 31,792 cm^{-1}. The maximum of the P branch coincides with its theoretical value. The low frequency end has a greater intensity than is expected from the rotational energy distribution in the upper state, if considered closely approximating thermal equilibrium. It was found to be the last band to disappear as the high frequency excitation potential is lowered.

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Scattering of High Speed Electrons of Varying Energy*

During recent years K. Lark-Horovitz and collaborators have carried out several investigations[1] on the determination of atom factors by electron diffraction. The experimental results have been compared with the theoretical expression derived from wave mechanics for the scattering of free electrons: in the first approximation the intensity of scattering as a function of $\sin\vartheta/\lambda$ is proportional to the electron form factor, E^2, given by

$$E^2=(Z-F)^2/[(\sin^4\theta/2)/\lambda^4]. \qquad (1)$$

This formula follows from the Born approximation of the wave-mechanical treatment of electron scattering as given by Bethe[2] and Mott.[3] In most cases the experimental results were in good agreement with the theoretical values derived from this formula. In the case of gold, the actual observed scattering appeared to differ from the one calculated by (1).

During a visit to this laboratory, Dr. H. A. Bethe, in a discussion of these results, pointed out that for heavy atoms the formula given above is not sufficient to calculate the scattering, but has to be replaced by the more accurate solution of the exact Schrödinger equation as given by Henneberg.[4] His investigation shows that the scattering power varies for different voltages and shows marked deviation from the simple formula, (1), with decreasing energy of the incoming electrons.

We have therefore investigated the atom factor of gold and silver at different voltages using the methods described previously.[1] The results are given in Figs. 1 and 2.

We have plotted E, in arbitrary units, as a function of $\sin\theta/\lambda$. The solid curve E_c, corrected for temperature, represents the values calculated from Eq. (1) using F, the x-ray atom factor, as calculated from the Thomas-Fermi distribution of electrons in the atoms. The observed values have been obtained from photographic intensity measurements and have been plotted (arbitrarily) so as to agree at large angles. Since only certain planes are reflecting, it is not possible to obtain the scattering for all angles but only for the Bragg angles under which the planes reflect.†

The curves show that the scattering power of the atom is not a monotonous function of the angle but shows maxima. The effect is particularly noticeable in the difference of the scattering between the (220) plane and the (311) plane. For the case of silver at a velocity of 42.5 kv, Henneberg has calculated the scattering as function

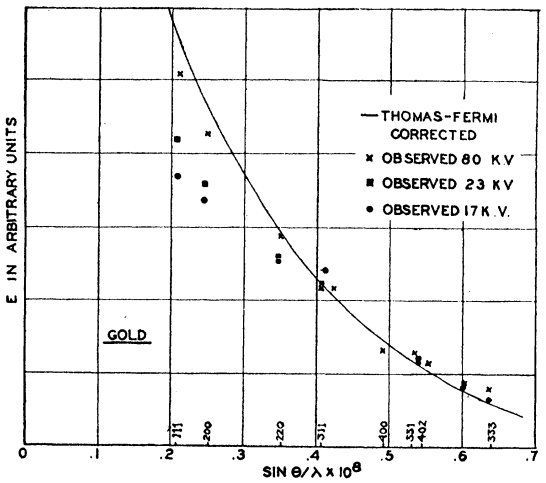

FIG. 1.

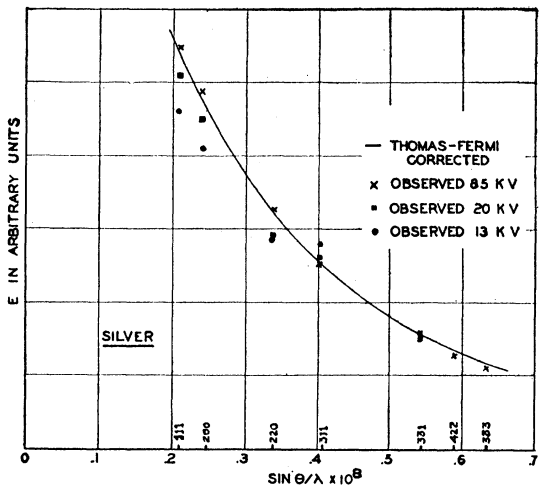

FIG. 2.

of angle. His values at this voltage already show a slight indication of the effect which we have observed much more pronounced at the still lower voltages.

It is of particular interest to note that a slight indication of the effect has been already observed by us for gold at 80 kv (the K excitation potential for gold being 80.5 kv). The effect is quite pronounced for silver at 20 kv (the K excitation potential for silver being 25.5 kv). Our results therefore show that in the calculation of the intensity in electron diffraction the solution of the exact wave equation has to be used taking into account the potential of the scattering atom. For energies great as compared with the K excitation potential the approximative formula (1) fits the experimental data.

The experiments are being continued with other materials so as to investigate more systematically the dependence of scattering upon the atomic number and are also being extended to still lower voltages. They will also be compared with values calculated from Henneberg's theory for the different scatterers and different electron energies.

We are indebted to Dr. Bethe for his suggestion and to Dr. Lark-Horovitz for his interest in this research and valuable discussions, and for the use of equipment made available by a grant-in-aid from the American Philosophical Society.

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† Following the suggestion of K. Lark-Horovitz we are investigating now elements with lower crystal symmetry so as to obtain a greater number of reflecting angles.

[1] K. Lark-Horovitz, H. J. Yearian and J. D. Howe, Phys. Rev. **47**, 331 (1935); H. J. Yearian, Phys. Rev. **47**, 200 (1935); K. Lark-Horovitz, E. M. Purcell and H. J. Yearian, Phys. Rev. **45**, 123 (1934); K. Lark-Horovitz and H. J. Yearian, Phys. Rev. **43**, 376 (1933); K. Lark-Horovitz and H. J. Yearian, Phys. Rev. **42**, 905 (1932).
[2] H. A. Bethe, Ann. d. Physik **87**, 55 (1928).
[3] Mott, Proc. Roy. Soc. **A127**, 658 (1930).
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Evidence Against He^5

The expectation that He^5 should be stable, since apparently every other atomic weight in the entire range to 238 can be stable, seems still to be quite general, but a considerable body of evidence has accumulated against this view.

(1) The mass excesses of the light nuclei all fall very near (though certainly not quite on) two smooth curves, as Aston originally found (Fig. 1); curve A is for those nuclei in which the numbers of protons and nuclei are both even, and curve B for all others. (The figures are Bethe's, except that the masses of all circumnuclear electrons have been subtracted.) It is remarkable how nearly the mass excesses of all stable class B nuclei lie on one curve, however they are constituted, but the fact is evident; even though we have no explanation of it as yet, it would appear reasonable to expect He^5 to lie on the curve also; but if it did, it would certainly be violently unstable because of the great difference between the ordinates of curves A and B in this region. The result is not much different if we confine ourselves to nuclei of the type $A=4N+1$, $Z=2N$, $(N=0, 1, \ldots)$.

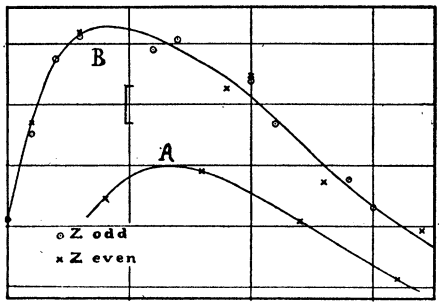

FIG. 1. Nuclear mass excess as a function of mass.

(2) Since the mass excess of He^4+n is 10.77 ± 0.7, He^5 cannot be above 10.8 ± 0.7 itself; and even if we take 12.0 for its mass excess (it can scarcely be more), at least 3 nuclear reactions which ought to have produced it with appreciable energy have been studied among the lightest elements, and no He^5 was noticed. They are as follows: $Li^6.H^2\rightarrow He^5.He^3+0.3$; $Li^7.H^2\rightarrow He^5.He^4+14.7$; $B^{11}.H^2\rightarrow Be^8.He^5+5.6$. In addition the following reactions might be expected to produce it with small energy: $He^4.n\rightarrow He^5$; $He^4.H^1\rightarrow He^5.p$; $Li^6.n\rightarrow He^5.H^2$; $Li^7.n\rightarrow He^5.H^3$; $Be^9.n\rightarrow 2He^5$; $Be^9.H^2\rightarrow Li^6.He^5$; $B^{10}.H^2\rightarrow Li^7.He^5.p$; $N^{14}.H^2\rightarrow B^{11}.He^5.p$. Some of these might well be endothermic, but some at least would show if He^5 has a mass excess of 10 or less. The $He^4.n$ reaction could occur in all regular neutron-sources, if at all.

(3) In addition to the upper limit for He^5 there is a lower limit, derived from the condition that Be^9 must be stable against $He^5.He^4$, and not merely against $2He^4.n$. If we take the mass of Be^9 from the six concordant reactions listed by Bonner and Brubaker[1] we obtain for its mass excess (after deducting the extranuclear electrons) the value 11.4 ± 0.3; if we subtract the mass excess of He^4, 2.3, we find 9.0 ± 0.5 for the lower limit for He^5. There seems no very good reason to expect He^5 to hit the rather narrow range between these two limits; at least, if it does, it will not fit well onto any curve at all. Thus the evidence seems against the possibility that He^5 should be capable of existence. Since Li^5 is even less likely (it would contain more protons than neutrons), progressive synthesis from He upwards under stellar conditions apparently can occur only with the help of H^2 or H^3. The great abundance of He in the stars is thus no longer a special source of difficulty on nuclear grounds.

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June 28, 1935.

[1] Bonner and Brubaker, Phys. Rev. **47**, 913 (1935).