LETTERS TO THE EDITOR

Prompt publication of brief reports of important discoveries in physics may be secured by addressing them to this department. Closing dates for this department are, for the first issue of the month, the twenty-eighth of the preceding month; for the second issue, the thirteenth of the month. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents.

Mass Defects of C^{13}, O^{18}, N^{15}, from Band Spectra, and the Relativity Relation of Mass and Energy

Chadwick, Constable and Pollard,[1] in a recent article, give on page 482 a plot of the "mass defect" of a number of atomic species, as a function of the number of α-particles in the nucleus. It is of considerable interest to add to this plot certain atomic species recently discovered by means of band spectra. In the case of C^{13}, O^{18} and N^{15}, the mass of the new isotope, relative to the mass of the more abundant species, has been calculated from the band spectra data. Thus King and Birge[2] find that the mass of C^{13} relative to C^{12} is 13:12 exact, to about one part in 10,000. The mass defect plot just mentioned is based on the atomic masses obtained by Aston.[3] Accepting his results, one obtains 10.7×10^{-3} as the mass defect of C^{13}. (Henceforth all mass defects will be given in 10^{-3} mass units). This result is given (as 11×10^{-3}) in a footnote, page 481 by *C.C.P.*

For O^{18} Babcock and Birge[4] have obtained a mass of 18.0065, based on $O^{16}=16$ exactly, which is also Aston's basis. The probable error is only about one part in 10^5. The resulting mass defect of O^{18} is 17.7.

Herzberg[5] has obtained the mass ratio N^{15}/N^{14}, from his measured isotope shift for the heads of the 1–0 and 2–0 bands of the second positive group of nitrogen, the molecules concerned being $N^{15}\cdot N^{14}$ and $N^{14}\cdot N^{14}$. The measured shifts are appreciably less than his calculated values, but unfortunately he made a theoretical error in his calculations which definitely affects his conclusion. All isotope shifts are expressed as a function of (ρ^n-1) where n is some positive integer. $\rho=(\mu_1/\mu_2)^{1/2}$ and μ, is the reduced mass of the *more* abundant molecule. Thus for the band systems containing O^{18}, C^{13} and N^{15}, the value of ρ is *less* than unity, and the vibrational shift is to the red, for bands located on the violet side of the origin of the system.

Herzberg, however, calculated ρ as $(\mu_2/\mu_1)^{1/2}$ and so obtained a value greater than unity. This leads not only to a shift in the direction opposite to that observed, but also to an incorrect absolute magnitude. In order to obtain the calculated shift Herzberg made new measurements of certain band heads of this system. He thus derived a new vibrational energy function $f(v')$ for the upper state, and combined this with the writer's $f(v'')$ of the lower state, to get an energy equation of the system. Birge and Sponer[6] had already given a $f(v')$ for this system, based on all available data, reduced where necessary to the I. A. system. The two $f(v')$ appear somewhat different, but fortunately lead to practically the same calculated vibrational shifts for the $1-0$ and $2-0$ bands. The correct value of ρ, assuming even 14 and 15 masses, is 0.98319, and the vibrational shifts are, from the Birge and Sponer equation, -35.16 and -65.79 cm^{-1}, and from Herzberg's equation, -35.19 and -65.72 cm^{-1}. It seems best to adopt the average values -35.17 and -65.76 cm^{-1}.

Since a fine structure analysis of these two bands has not been carried out, one must use for the rotational isotope shift the sufficiently

[1] J. Chadwick, J. E. R. Constable and E. C. Pollard, Proc. Roy. Soc. **A130,** 463 (1931). To be called *C.C.P.*

[2] A. S. King and R. T. Birge, Astrophys. J. **72,** 19 (1930).

[3] F. W. Aston, Proc. Roy. Soc. **A115,** 487 (1927).

[4] H. D. Babcock and R. T. Birge, (abstract) Phys. Rev. **37,** 233 (1931).

[5] G. Herzberg, Zeits. f. phys. Chemie **B9,** 43 (1930).

[6] R. T. Birge and H. Sponer, Phys. Rev. **28,** 259 (1926).

accurate approximation $(\rho^2-1)\nu_m$, where ν_m is the distance from the origin to the head, for the *middle* component of the triplet series found in these bands. Fortunately the desired origin can be located, by mere inspection, on spectrograms of an "effective low temperature" source. The resulting rotational shifts, as given by Herzberg, are $+0.6$ cm^{-1} and $+0.8$ cm^{-1} respectively, corresponding to *origin-head* distances of 18 and 24 cm^{-1}. (This distance in the 0−0 band is 13.3 cm^{-1}, according to the writer's fine structure analysis.)

Now the $f(v')$ to which reference has been made are based on measurements of the heads, and are slightly in error, due to the varying distance of origin to head. The resulting correction to the vibrational shift I find to be -0.08 and -0.18 cm^{-1}, for the 1−0 and 2−0 bands, respectively. The final calculated shifts for the *heads* are then -34.65 and -65.14 cm^{-1}, as compared with Herzberg's *observed* shifts -34.6 and -64.6 cm^{-1}. One thus obtains the result that the mass ratio N^{15}/N^{14} is *less* than 15/14 by one part in 10,000, and one part in 1700, from the 1−0 and 2−0 bands, respectively. Then, using Aston's value $N^{14}=14.008$, one obtains $N^{15}=15.0065$ and 14.999 respectively. From these figures there results a mass defect for N^{15} of 23.3 and 30.6, or an average value of 27.0

We may now place these mass defects on the plot previously mentioned. The C^{13} defect (10.7) lies just above the value obtained from α-ray disintegration experiments (given as 9.9 by *C.C.P.* but calculated as 9.8 by the writer). This mass defect, 9.8, is obtained from Aston's mass defect 6.38 for B^{10} combined with an energy loss equivalent to 3.42 (in 10^{-3} mass units), as observed by *C.C.P.* in the transformation $B^{10}\rightarrow C^{13}$. The close agreement of the two mass defect values for C^{13} (10.7 and 9.8) is of more than passing interest, for it constitutes a *very* rough, but direct experimental check of the accepted relation between mass and energy $\Delta E=c^2\Delta m$. So far as I am aware, it is the first experimental check by this very direct method.

The mass defect for O^{18} (17.7) may be compared with that for O^{17} (12.6), as evaluated by *C.C.P.* from their disintegration experiments,[7] for O^{16} (8.64). The fact that these three points (corresponding to masses of 18.0065, 17.0029 and 16.0000) are nearly equally spaced is probably significant. The spectral data for O^{17} are very meager, as compared to O^{18}, but the mass of O^{17} is now being calculated from such data and the result, if of sufficient accuracy, will constitute a second check on the mass-energy relation.

Finally, the mass defect of N^{15} should lie on the curve passing through B^{11}, F^{19} etc. The predicted value, from the published curve, is 24.5, agreeing well within limits of error with the average observed value of 27.0. Other interesting relations may be deduced from the mass defect graphs published by *C.C.P.* but it is the primary purpose of this letter merely to locate on these graphs the new data for C^{13}, O^{18} and N^{15}.

RAYMOND T. BIRGE

University of California,
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[7] The first calculation of the mass of O^{17} by such a process, with the result 17.0033 ± 0.0009, was made by W. F. Giauque, Nature **124,** 265 (1929).

Momentum Transfer to Cathode Surfaces by Impacting Positive Ions in a Helium Arc

The present problem was suggested by K. T. Compton and may best be introduced by the following quotation from one of his papers (Phys. Rev. **36,** 706, 1930). "Although, as we have seen, the impact of a charged ion against the cathode contributes nothing to the pressure against it (on account of the counterbalancing pull during its attraction to the cathode), nevertheless if the neutralized ion leaves the cathode with any momentum there is imparted to the cathode an equal opposite momentum." In the experiment here reported this hypothesis is tested by studying the momentum imparted to an auxiliary cathode in a helium arc.

The auxiliary cathode (or plane collector) was suspended from a vertical side tube in the negative glow of a hot cathode helium arc. The collector was a flat molybdenum plate one centimeter in diameter, insulated on one side by a glass plate. This collector was nonvolatilizing so that there was no possibility of a pressure as a result of a stream of metal vapor leaving the collector. The suspension consisted of a long period glass pendulum supported on two steel points and carrying a small