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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 twentieth of the preceding month; for the second issue, the fifth of the month. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents.

Negative Protons in the Nucleus?

In an attempt to construct a building-up scheme for atomic nuclei heavier than A^{36}, the writer[1] has pointed out that, in the field of A^{36}, a neutron is apparently not as stable as a configuration of mass $+1$ and charge -1. This configuration was supposed to be a neutron plus an electron. However, the possibility of its being a negative proton does not seem to be excluded, especially since there appears to be evidence[2] for the existence of such particles among the cosmic rays. Gamow[3] has mentioned the possibility that negative protons may be constituents of the nucleus. In this note, we wish to investigate the matter somewhat more in detail, and in particular to call attention to a certain regularity in the isotope pattern which may show how the negative protons become incorporated into the nucleus.

Let us consider the isotope pattern of zinc, which is more or less typical for heavy elements with even atomic number. The known isotopes have mass numbers (M) equal to 64, 66, 67, 68 and 70, respectively. The vacancy at $M=65$ is filled by Cu^{65}, and that at $M=69$ is filled by Ga^{69}. That is, if an odd mass number is vacant at the lighter end of the pattern, then there is a stable isotope of the same mass number, but with atomic number one less. If the vacancy is at the heavier end, then a stable isotope of the same mass number exists, but with atomic number greater by one. (The word "vacancy" applies only to mass numbers between the two known extremes, e.g between 64 and 70 in the above case.) An application of this rule accounts for the following isotopes: Cl^{37}, K^{39}, K^{41}, V^{51}, Mn^{55}, Co^{59}, Cu^{65}, Ga^{69}, Ga^{71}, As^{75}, Br^{79}, Br^{81}, Rb^{85}, Nb^{93}, Rh^{103}, Ag^{107}, Ag^{109}, In^{113}, In^{115}, Sb^{123}, I^{127}, Cs^{133}, Pr^{141}, Eu^{153}, Tb^{159}, Tu^{169}, Cp^{175} and Re^{185}. Assuming the general validity of the rule, one can predict the isotopes Nb^{95}, Ma^{97}, Ma^{99}, I^{125}, I^{129}, Cs^{135}, Il^{145} and Ir^{191}. Indeed, although the experimental information is still rather insufficient for definite prediction, it is not unlikely that several elements, including indium, antimony and iodine, will be found to have three odd isotopes.

On the assumption that negative protons do exist in the nucleus, we may re-formulate the above rule. According to our view, the sequence Zn^{64}, Cu^{65}, Zn^{66}, Zn^{67}, Zn^{68}, Ga^{69}, Zn^{70} may be obtained by the successive addition to Zn^{64} of a negative proton, a positive proton, a neutron, another neutron, a positive proton, and a negative proton. For a given (even) atomic number, the most stable particle of mass unity in the field of one of the lighter isotopes is either a neutron or a negative proton; the most stable one in the field of one of the heavier isotopes is either a neutron or a positive proton. For the lighter isotopes of such an element, a positive proton cannot be added until a negative proton has already been added; for the heavier isotopes, the reverse is true. It may be that we shall have to have more information about the masses of the isotopes heavier than A^{36} before the underlying reasons for the above rules become apparent.

Finally, if this model be essentially correct, one would expect the nuclear spins to be integral or half-integral according as the mass number is even or odd (and not as suggested in reference 1).

JAMES H. BARTLETT, JR.

Cambridge, England,
July 24, 1934.

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[1] J. H. Bartlett, Jr., Phys. Rev. **42**, 145 (1932).
[2] E. J. Williams, Phys. Rev. **45**, 729 (1934).
[3] G. Gamow, Phys. Rev. **45**, 728 (1934).

Ruled Grating Wave-Length of the Copper $K\alpha_1$ Line

The existence of a discrepancy of about 0.25 percent between x-ray wave-lengths as measured by ruled and crystal gratings has been confirmed by many investigators. In all of the measurements in which this discrepancy has been observed the x-rays which were incident on the ruled grating were collimated by slits. In the original experiment of Compton and Doan[1] a calcite crystal and a slit were used to collimate the x-rays and separate a particular wave-length. While no great accuracy was claimed for these initial results (0.4 percent) the wave-length obtained was about 0.1 percent lower than the crystal values. Wadlund[2] using a similar arrangement in a more precise determination obtained results which agreed well with the crystal values. He estimated his error to be about 0.08 percent. Since no explanation has been given of the discrepancy between ruled and crystal grating values as found by all the other observers it was thought worth while to repeat the experiments in which a crystal and slit were used for collimating the x-rays before they fell on the ruled grating.

The disposition of the apparatus is shown in Fig. 1. The apparatus is essentially the same as that previously used[3] except the two collimating slits have been replaced by a calcite crystal and one slit. The accurate adjustment of the plateholders and the grating was accomplished exactly as previously described. The cleaved surface of

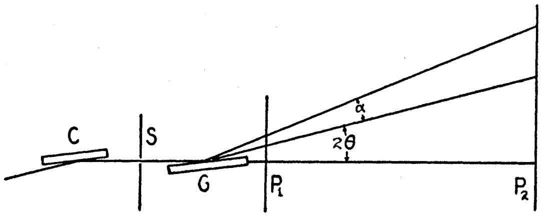

FIG. 1. Schematic diagram of apparatus. *C*, calcite crystal; *S*, slit 0.01 mm; *G*, grating ruled 143 lines per mm; P_1, P_2 photographic plates. The distance from P_1 to P_2 was 1843 mm.

the calcite crystal was placed parallel to the axis of rotation of the grating and then the slit was adjusted until the $K\alpha_1$ line from the crystal was parallel to the surface of the grating. The spectral line was made to pass over the axis of rotation of the grating by displacing the slit and x-ray tube in a horizontal plane. The crystal was then moved in a direction perpendicular to its surface until the x-rays from the most intense portion of the focal spot passed through the slit. In this adjustment only the intensity of the $K\alpha_1$ line was considered.

The grating used had 143 lines per mm and was coated with a thin layer of silver. The silver coating increased the angle of total reflection and also increased the intensity of the diffracted spectra. The direct and reflected $K\alpha_1$ line was recorded on x-ray plates placed in each plateholder. The diffracted lines were recorded only on the second plate. All of the lines were much wider than those obtained with the two-slit method of collimation. The increased width is due to the divergence of the x-ray beam reflected by the crystal which is much greater than that obtained when narrow slits are used. A representative plate is shown in Fig. 2. The separations of the lines on the plates were first measured with the plate in one direction and then remeasured with the direction of the plate reversed. On account of the width and low density of some of the lines it was difficult to make the two sets of measurements agree to better than 0.005 mm. Repeated measurements were made on most of the plates.

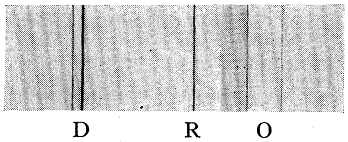

FIG. 2. Representative photograph. *D* is the direct beams of the α_1 and α_2 lines, *R* is the reflected α_1 line, *O* designates the first and second orders of the α_1 line.

Since the x-rays were first reflected from a crystal, the intensity of each wave-length was reduced. This together with the dispersion introduced by the crystal decreased the intensity of the lines on the photographic plates by at least a factor of five over that obtained when slit collimation was used. The increased time of exposure made it difficult to maintain the apparatus in good adjustment and this was probably the cause of the fluctuation in the results from different plates.

The wave-length values were calculated from the equation

$$n=2d\sin[(2\theta+\alpha)/2]\sin(\alpha/2),$$

where θ is the angle between the surface of the grating and the direction of the incident beam, α is the angle between the reflected and diffracted beams, and d is the grating space. The errors introduced by the divergence of the x-rays were calculated and taken into account.

The results obtained from 27 sets of plates are shown in Table I. It will be noticed that on some plates the second order was not recorded. There is a considerable difference between the first and second order results but this probably represents the limited precision of the present results rather than indicating any dependence of the wave-length on the order of diffraction. The average of the results is in good agreement with the results that have been obtained using slits for collimating the incident x-rays. The crystal value of this wave-length was 1.5367A which is obtained from the grating constant[4] of calcite $d_\infty = 3.02810$A. Even with the wide fluctuation of the above results not a single one came as low as the crystal value. Thus it appears that the agreement between ruled and crystal values as obtained in the previous measurements by this method was due to some consistent undetected error.

TABLE I.

Plate No.	1st Order	Weight	2nd Order	Weight
1	1.5406	4		
2	1.5437	3		
3	1.5408	4		
4	1.5410	3		
5	1.5396	3		
6	1.5401	4	1.5403	2
7	1.5428	4	1.5387	3
8	1.5438	4		
9	1.5398	4		
10	1.5424	4	1.5382	3
11	1.5406	4		
12	1.5405	4	1.5402	3
13	1.5410	3	1.5395	3
14	1.5429	3	1.5427	2
15	1.5395	1	1.5392	3
16	1.5420	3	1.5421	2
17	1.5406	3	1.5425	1
18	1.5382	1	1.5410	2
19	1.5408	2	1.5399	3
20	1.5386	2		
21	1.5400	2		
22	1.5418	2	1.5397	1
23	1.5424	1		
24	1.5432	1		
25	1.5444	1		
26	1.5425	1		
27	1.5429	1		
weighted mean	1.5413		1.5401	
	0.299%		0.221%	

P. F. GOTTLING
J. A. BEARDEN

Rowland Physical Laboratory,
Johns Hopkins University,
July 28, 1934.

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[1] A. H. Compton and R. L. Doan, Proc. Nat. Acad. Sci. **11**, 598 (1925).

[2] C. P. R. Wadlund, Phys. Rev. **32**, 841 (1928).

[3] J. A. Bearden, Phys. Rev. **37**, 1210 (1931).

[4] J. A. Bearden, Phys. Rev. **38**, 2089 (1931).

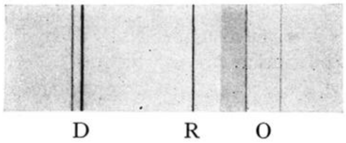

FIG. 2. Representative photograph. D is the direct beams of the α_1 and α_2 lines, R is the reflected α_1 line, O designates the first and second orders of the α_1 line.