Hyperfine Structure of Elements in Mercury Arc—I.

NUCLEAR MOMENT OF ZINC 67.

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THE mass-spectrograph analysis of the isotopic constitution of zinc by Aston (*P.R.S.*, **130**, 302, 1931) has revealed the existence of seven isotopes with relative abundance as given below:

Mass Number	64	65	66	67	68	69	70
Percentage abundance	48.0	2.5	25.9	5.3	17.1	0.85	0.38

Recently, Bainbridge (*Phys. Rev.*, **39**, 848, 1932) has shown that the ions of mass numbers 65 and 69 measured by Aston were hydrides of Zn 64 and Zn 68. Bainbridge's densitometer curve of the mass-spectrogram seems to indicate that the percentage abundance of Zn 67 is considerably greater than Aston's estimate. It can, however, be safely assumed that this odd isotope has an abundance not exceeding 10%. If as in the case of cadmium the odd isotopes give rise to the satellites, in zinc they must be expected to be far less intense relative to the main lines than in cadmium or mercury, where the relative abundance of the odd isotopes is 23% and 30% respectively. The small percentage of the odd isotope 67 along with its comparatively low atomic weight renders the satellites of zinc lines faint and fuzzy. The failure of the early observers to obtain hyperfine structure in zinc lines is to be traced to this cause. Schüler and Brück (*Z.P.*, 56, 291. 1929) finding the lines simple concluded that the result was due to the absence of odd isotopes, Zn 67 being then unknown. Snoek and Bouma (*Z.P.*, **38**, 368, 1926), Wali Mohammed (*P.M.*, p. 1112, 1928) and McLennan and Allin (*P.M.*, **8**, 515, 1929) had even earlier found the lines to be single. More recently Schüler and Keyston (*Z.P.*, **68**, 174, 1931) and Murakawa (*Z.P.*, **72**, 793, 1931) have independently come to the conclusion that the nuclei of all the isotopes of zinc have zero moment based on the fact that the lines show no structure. Hence in this re-examination of the zinc lines it was thought necessary to devise an experimental arrangement in which the satellites are relatively enhanced without introducing complications arising from self-reversal.

The source used is a long column mercury arc, more than 30 cms. long, with a current density of about 1.5 amperes per sq. cm., through which a slow stream of zinc vapour is continuously passed. The apparatus in Fig. 1 is made of Pyrex glass with a detachable fused quartz window W at one

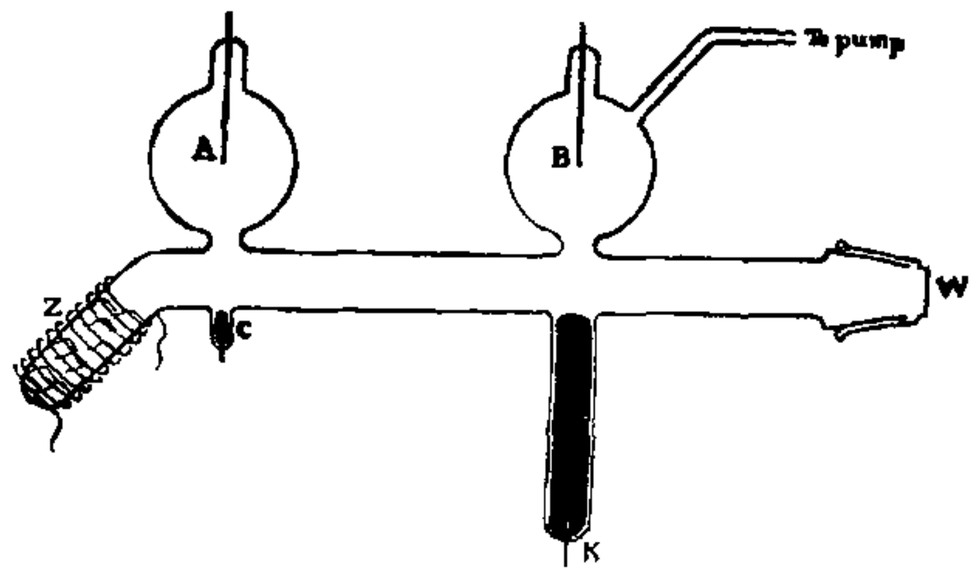

Fig. 1.

Diagram of Source.

end for observation. When the necessary vacuum is reached, the main arc between the mercury cathode K and the tungsten anode B is started, and a few minutes later the long column arc between K and A lights up. The main arc is then switched off. The zinc in the side tube Z is then gradually heated electrically and a stream of zinc vapour is passed through the long arc. The axial radiation is first analysed by a Hilger E_1 spectrograph with a glass train and each line of the zinc triplet $4^3P_{012}—5^3S_1$ is separately examined by three Lummer plates, all of them definitely known to give ghost-free patterns. Assuming that the ratio $\frac{\text{emission}}{\text{absorption}}$ is the same for all the components of a line, it follows that in a long column the weak satellites, suffering little absorption relative to the main line, are enhanced. An examination of the photographs of the triplet patterns reveals indubitably the existence of hyperfine structure in zinc, but because of the faintness and diffuse character of the satellites the following values require further confirmation:—

Line		Structure $\Delta\nu$ in cm.$^{-1}$ (Int.)
4810	$4^3P_2-5^3S_1$	+0·319 (1)
		+0·147 (2)
		0·000 (10)
		−0·177 (1½)
		−0·315 (0)

Line		Structure $\Delta\nu$ in cm.$^{-1}$ (Int.)
4722	$4^3P_1 - 5^3S_1$	+0·342 (1)
		+0·131 (2)
		0·000 (10)
		−0·153 ($\frac{3}{4}$)
		−0·288 (0)
		−0·365 ($\frac{3}{4}$)
4680	$4^3P_0 - 5^3S_1$	+0·271 (0)
		+0·087 (1)
		0·000 (10)
		−0·155 (1)
		−0·409 ($\frac{1}{2}$)

Figure 2 gives the densitometer curve of Zn I 4680 Å $4^3P_0 - 5^3S_1$ kindly taken by

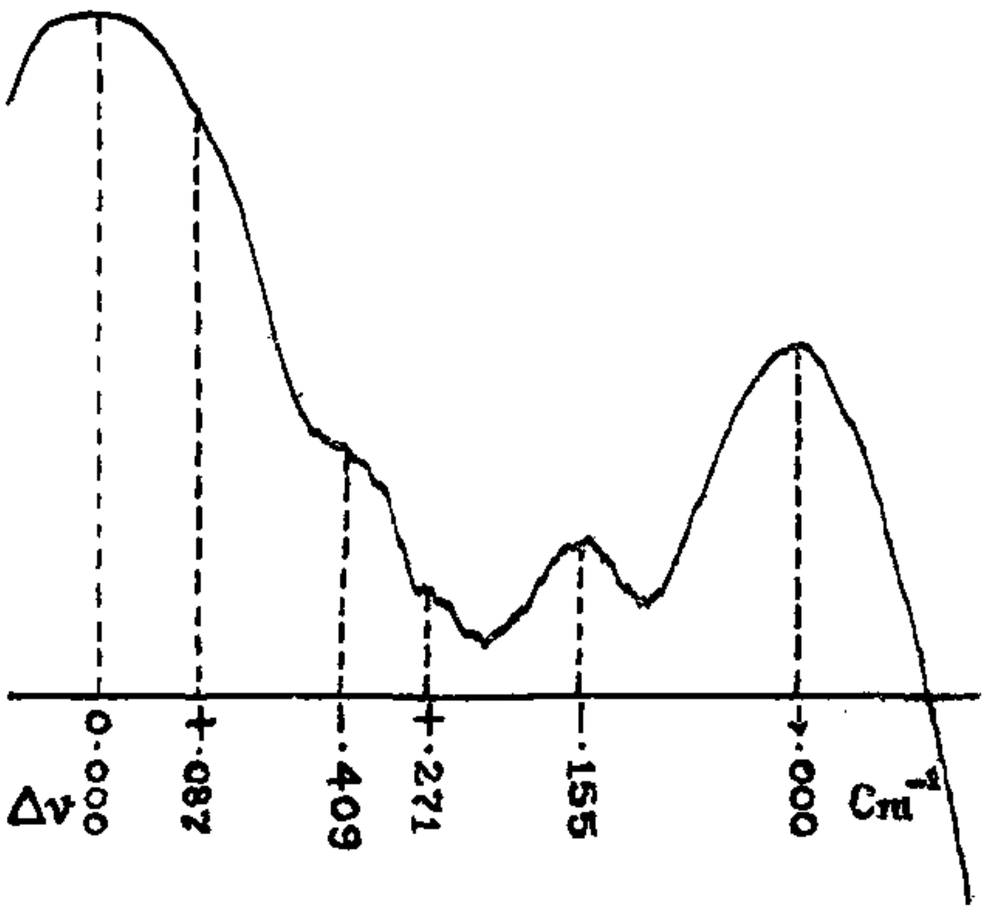

Fig. 2.

Microphotogram of the Lummer plate pattern of the Zn I 4680 Å.

Messrs. Carl Zeiss and shows clearly all the satellites of this line. The observed structures for these lines indicate that the nuclear spin moment of the zinc isotope Zn 67 is most probably $\frac{1}{2}\frac{h}{2\pi}$ and the hyperfine levels are all regular and not inverted as in the case of cadmium. Based on these assumptions a tentative scheme of levels proposed is indicated in Fig. 3. This accounts for most of the observed satellites, only a few relatively fainter ones remaining unexplained. The main lines as in the case of cadmium have to be ascribed to the even isotopes of zinc. The observed hyperfine structure cannot be the result of the shift due to the several even isotopes, as the relative intensities of the components bear no resemblance to the relative abundance of the even isotopes.

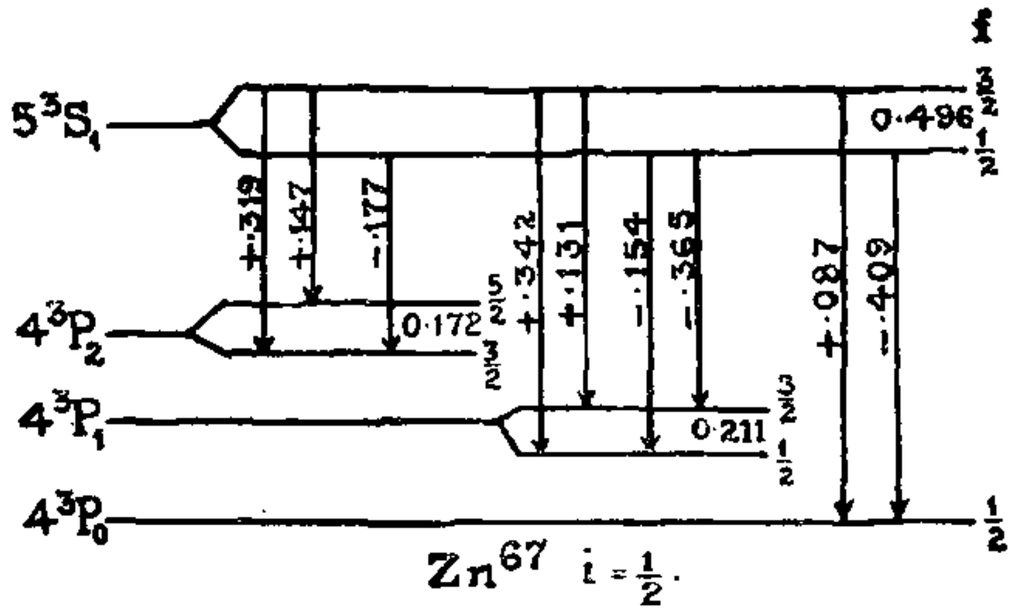

Fig. 3.

The fact that other investigators have almost invariably reported the absence of structure in the prominent arc lines of zinc raises the question whether in the present case, the large admixture of mercury vapour has not any influence in bringing up the satellites. We raise this question because in the case of cadmium under similar conditions of excitation we have observed additional satellites which do not work into the Schüler scheme. The same is the case with the line 5351 Å of Tl I. It must, however, be admitted that one has to establish beyond doubt that the presence of a foreign substance such as mercury is a necessary condition for the appearance of these additional satellites. There is always the possibility that these faint satellites may be caused by isotopes present in such small relative abundance that the mass-spectrograph has not been able to reveal them. Or on the other hand if the conditions of excitation, the presence of a foreign vapour and other factors influence the structure so far as the faint satellites are concerned, we shall have to trace their occurrence to a cause hitherto not considered. For on the hypothesis of a nuclear spin alone, it becomes increasingly difficult to understand why a change in the conditions of excitation should bring out new satellites. The insufficiency of the present theory to account for the hyperfine structure phenomenon in all its aspects has, however, been pointed out by other investigators.