

sets of energy states, and these two sets may be thought of as forming the "phases" above mentioned. This may conveniently be taken as a picture of the second-order phase transition, i.e., the crystal oscillators going from one state of bounding to another. Also because the quantum of transition between two states of the oscillator is no longer $h\nu$, a shift or a new line may be possible in the Raman spectrum or infra-red absorption of the *crystal* near the λ -temperature. As there are many substances whose λ -temperatures are near room temperature, the investigation of the Raman spectrum may provide a test of the above ideas. Also, one must consider the current theory that the specific heat change may arise from molecular rotation within the crystal. Experiments on the Raman or infra-red absorption spectrum may lead to a decision between the two conceptions.

¹ E. M. Corson and I. Kaplan, *Phys. Rev.* **71**, 130 (1947).

² F. S. Auluck and D. S. Kothari, *Proc. Camb. Phil. Soc.* **41**, 175 (1945).

³ P. Ehrenfest, *Proc. K. Acad. Wet. Amsterdam* **36**, 153 (1933); *Comm. No. 75b from the K. Onnes Laboratory, Leyden.*

On the Distribution of Electric Charge in Nuclei

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IN a recent letter¹ by J. G. Winans entitled "A Classical Model for the Nucleus," attention was drawn to the striking relation between the atomic numbers (Z) and corresponding masses (A) of stable nuclei. Winans suggested a crystalline model in which the protons occupy surface positions as an obvious way of explaining the simple relation between Z and A .

The existence of this relation and its possible explanation by surface concentration of protons was already known to us, and we had gone so far as to test the hypothesis that protons are concentrated on or near the surface in the following simple way. In fission, if protons and neutrons are uniformly mixed the (charge/mass) ratios of the fragments should be roughly equal; whereas we should expect a higher relative concentration of charge on the light fragments, if the protons are concentrated near the surface of the nucleus before fission. We have investigated this on the basis of Coryell's tables² and have found that the ratio (charge/mass) is very closely the same for the light and heavy fragments. This fact, therefore, coupled with the hydrodynamical explanation³ of the asymmetry of fission in analogy with the splitting of a classical liquid drop, seems to invalidate the idea that the protons are concentrated on the surface. In principle it is possible that some mechanism might exist to ensure constancy of Z/A for the fragments, but we know of no other nuclear phenomenon which would require such a mechanism.

¹ J. G. Winans, *Phys. Rev.* **71**, 379 (1947).

² J. A. Chem. Soc. **68**, 2411 (1946).

³ J. A. Wheeler, unpublished lecture notes, August, 1946.

A Note on the Long-Lived Radio-Iodine

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THE radioactive iodine isotope of half-life about 56 days, reported by Reid and Keston,¹ has been observed in an iodine sample separated from deuterium-bombarded Te in April, 1946, furnished by the M.I.T. Radioactivity Center.

Chemical identity of the activity was established by a series of extractions with iodine carrier. Iodide in aqueous solution was oxidized with nitrite, and the iodine extracted into CCl_4 ; re-extraction to water was performed with bisulfite as reducing agent. Through three such cycles, the specific activity as AgI remained constant within experimental error.

By use of a Kr-filled Geiger counter, critical absorption measurements of the x-radiations were made in Ag, Cd, In, and Sn foils. The energy of the radiations was observed to lie between the K -edges of Cd and In, characteristic of tellurium $K\alpha$ x-rays. Absorption in Al showed a small amount of an extremely soft component, and a half-thickness of 485 mg/cm^2 for the major fraction of the radiations. This corresponds to an x-ray energy of 27.5 keV, within experimental error of that expected for $K\alpha$ x-rays of Te. The soft component showed a half-thickness of 1.9 mg/cm^2 in Al, and 19 mg/cm^2 in C (polystyrene). The corresponding x-ray energies are 3.8 and 3.7 keV, respectively. The $L\alpha$ x-ray energy for Te is 3.8 keV. No particle radiations were observable from 20 mg samples (AgI or NaI) with a thin window counter, and no γ -rays of energy greater than 30 keV were apparent in the Al absorption curve. The mode of decay of the 56d I, therefore, appears to be pure orbital electron capture, with no accompanying particle or γ -radiations.

It can be shown by various considerations that the mass number of the long-lived iodine is more probably 125 than 129 as proposed by Reid and Keston.¹ The formation of I^{125} directly in the Te targets at the cyclotron is to be expected from the $d, 2n$ reaction on Te^{125} (6 percent abundance) and the (d, n) reaction on Te^{124} (4.5 percent abundance). Considerations which render improbable the mass assignment of 129 are: (a) the proposed decay scheme¹ requires either that Te^{129} have a stable isomer, or (for the chain to reach a stable end product) that a unique chain of K -capture followed by two β^- decays occur (i.e., $\text{I}^{129} \rightarrow \text{Te}^{129} \rightarrow \beta^- \rightarrow \text{I}^{129} \rightarrow \beta^- \rightarrow \text{Xe}^{129}$ stable); (b) according to Bohr and Wheeler² the most stable nuclear charge (Z_A) for mass 129 is near 54 (Xe); thus I^{129} should have no appreciable probability for decay by K -capture, but should decay by β^- emission to stable Xe^{129} ; (c) no radio-iodine of half-life near 56 days is reported among the U^{235} fission products,³ whereas I^{129} must certainly be formed; the latter is listed as a very long-lived, hypothetical descendant of 70m Te^{129} .

The nucleus I^{128} , however, would certainly decay by K -capture or positron emission to stable Te^{128} and would not be formed in appreciable yield as a U^{235} fission product since it is shielded by stable Te^{128} from formation by β^- decay. Its predicted decay energy for K -capture, calculated from

the equation of Bohr and Wheeler,² is about 0.2 Mev. This is concordant with the fact that no energetic radiations are observed.

Possible mass assignments⁴ other than 125 may be tentatively ruled out. On the basis of the Bohr-Wheeler² picture, I¹²³ and isomeric states of the nuclei of mass 124, 126, 128, and 130 would be expected to have high decay energies (>1 Mev). A radioactive isomer of stable I¹²⁷ would decay by isomeric transition, and thus would yield no Te x-rays. Iodine isotopes of mass number greater than 130 have been conclusively characterized as energetic β^- emitters.³

The yield of the 56d I in deuteron-bombarded Te targets at the M.I.T. cyclotron is about $15\mu\text{c}/\mu$ amp. hr. of 14-Mev deuterons, calculated on an assumption of one *K* x-ray per disintegration, and an experimentally determined counting efficiency of about 1 percent in the usual argon-filled Geiger counter. The corresponding yield of 12h I¹³⁰ is $750\mu\text{c}/\mu$ amp. hr. (for short bombardments). The yield ratio of 12h I to 56d I at saturation is 4.5. The abundance ratio of Te¹³⁰ to Te¹²⁵, from which I¹³⁰ and I¹²⁵ are formed by the (*d*, 2*n*) reaction, is 5.5. Assuming the (*d*, *n*) reaction on Te¹²⁴ to be less probable than (*d*, 2*n*) on Te¹²⁵, the proposed mass assignment of 125 for the long-lived I is consistent with the observed yield.

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² N. Bohr and J. A. Wheeler, *Phys. Rev.* **56**, 426 (1939).

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55-Hour Element 61 Formed in Fission*

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ACHEMICAL separation of element 61 from fission products was made to verify the mass assignment and to study the activity of 49-hr. 61¹⁴⁹, as summarized in fission tables.¹ This activity has been assumed to have a mass of 149 from fission yield data.

An aliquot of the element 61 sample was placed on the filament of a mass spectrograph, and normal neodymium was added to serve as a mass standard. By operation of the

spectrograph the isotopes were separated according to mass and deposited on a photographic plate. A second "transfer" photographic plate was placed face to face with the first plate, and four developable images were obtained from its radioactive isotopes which by comparison with the normal neodymium spectrum on the first plate were shown to have masses 147, 149, 163, and 165. The metal lines at 147 and 149 were very weak in comparison with the metal oxide lines at 163 and 165 but appeared in approximately the same ratio. Since the ratios of metal to metal oxide are different for the different elements which might have given these masses, this indicates that all lines are due to the same element.

To verify that the activity at the mass 149 position was 49-hr. 61¹⁴⁹ the following technique was used. The photographic plate containing the active isotopes was placed successively against various parts of a larger photographic plate for times calculated to give equal intensity at the mass 149 position if the half-life were 49 hours. Five exposures were taken for successive times of 13.4 hours, 16.5 hours, 21.6 hours, 31.0 hours, and 57.3 hours. These transfers showed the 61¹⁴⁹ to be decaying with a half-life of slightly more than 49 hours, while the 147 showed no detectable decay. A decay curve taken simultaneously on another aliquot of the element 61 sample showed it to contain a 55-hour activity and a long-lived activity. Thus the 147 and 163 lines are due to the metal and metal oxide ions of 3.7-year 61¹⁴⁷ as shown previously by Hayden,² and the lines at 149 and 165 are due to the metal and metal oxide ions of 55-hr. 61¹⁴⁹.

The samarium-europium fraction of the original fission sample was also analyzed by this method. It showed activities at masses 151, 153, 155, 156, 167, and 169. The active lines at mass numbers 153 and 169 were found to decay with a half-life of 47 hours. Since the ratio of intensities of the 153 to 169 is that characteristic of Sm⁺ and SmO⁺ this activity is 47-hr. Sm¹⁵³ as was shown previously by neutron irradiation of samarium.³ The lines at 151 and 167 were also ascribed to samarium since the ratio of the intensities was the same as the 153 and 169. This is the activity first found in fission by Lewis and Hayden. From intensity considerations the half-life of this activity has been estimated at roughly 20 years. The lines at 155 and 156 were assigned to europium since only the metal ion lines appeared. The 156 decayed with a half-life of about 15.4 days and the 155 showed no detectable decay. Thus these activities are due to 2 to 3 year Eu¹⁵⁵ and 15.4-day Eu¹⁵⁶.

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¹ *Rev. Mod. Phys.* **18**, 513 (1946).

² Richard J. Hayden, *Phys. Rev.* (1947), to be published.

³ Richard J. Hayden and Mark G. Ingram, *Phys. Rev.* **70**, 89 (1946).