Letters to the Editor

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NOTES ON POINTS IN SOME OF THIS WEEK'S LETTERS APPEAR ON P. 956.

CORRESPONDENTS ARE INVITED TO ATTACH SIMILAR SUMMARIES TO THEIR COMMUNICATIONS.

Chemical Detection of Artificial Transmutation of Elements

IT has been our aim for years to prove the result of transmutation experiments by chemical analysis, and in a brief report[1] we have described our failure to find chemical evidence for the production of hydrogen or neon by bombardment with α-rays. In the meantime, many new ways of artificial transmutation have been found, and the discovery of artificial radio-elements has enabled Curie and Joliot[2] to use the methods of radio-chemistry, that is, the combination of radioactive measurement with chemical operations, for the investigation of the chemical character of products of artificial transmutation. This line of work has been extended by Fermi and his collaborators and by many others. The quantity of newly formed matter has in general been much too small for any attempt at a purely chemical detection; the claim[3] of having separated and spectroscopically observed helium of atomic weight 3, made from heavy hydrogen, has been disproved by later work[4].

At present, for various experimental reasons, the best choice for the chemical detection of an artificially-produced element seemed to be helium originating from boron according to the reaction[5]

$$_{5}B^{10} + {}_{0}n^{1} = {}_{3}Li^{7} + {}_{2}He^{4}.$$

In a closed copper vessel we bombarded the methyl ester of boron with neutrons. These were produced near the centre of the spherical vessel by the decay of radon, mixed with beryllium, and were slowed down by the hydrogen atoms of the ester and of the water surrounding the metal flask. In a first experiment, by the decay of 450 mC. of radon, sufficient helium was produced for a spectroscopic observation. During a second experiment, lasting seven weeks, we procured enough radon to allow 2,200 mC. of it to decay in our apparatus. This time we were able not only to observe spectroscopically the helium produced but also to measure it; we found, to an accuracy of about 20 per cent, $1 \cdot 3 \times 10^{-7}$ c.c. helium. A blank test run afterwards for nine weeks under exactly the same conditions, but without radon-beryllium tubes, showed not the slightest sign of helium production.

The copper vessel was a sphere of only 7·5 cm. radius; it is unlikely that more than half of the neutrons formed in the beryllium tubes were caught by the boron inside the vessel. A new experiment, making use of a larger flask, is in progress; but it can already be concluded from our preliminary figures (as one helium atom, according to the above equation, needs for its production one neutron) that a millicurie of radon, mixed with beryllium, produces more than 3,000 neutrons a second[6].

In this experiment—for the first time, so far as we are aware—an artificially produced element has been separated, spectroscopically observed, and measured. We presume that the old alchemistical goal can be achieved to-day in other cases also.

We wish to express our sincere thanks to Prof. F. L. Hopwood, director of the Radium Department, St. Bartholomew's Hospital, London, to Prof. S. R..., director of the Radium Department, Middlesex Hospital, London, and to Prof. Stefan Meyer, director of the Institute for Radium Research in Vienna, for kindly supplying the radon-beryllium tubes; and also to Dr. E. Glückauf for assistance in the experiments.

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Nov. 28.

[1] F. A. Paneth and P. L. Günther, NATURE, 131, 652; 1933; also *Z. phys. Chem.*, *A*, 173, 401; 1935.

[2] I. Curie and F. Joliot, *C.R.*, 198, 559; 1934.

[3] G. P. Harnwell, H. D. Smyth and W. D. Urry, *Phys. Rev.*, 46, 437; 1934.

[4] H. D. Smyth, G. P. Bleakney and W. W. Lozier, *Phys. Rev.*, 47, 800; 1935. F. A. Paneth and G. P. Thomson, NATURE, 136, 334; 1935.

[5] J. Chadwick and M. Goldhaber, NATURE, 135, 65; 1935. *Proc. Cam. Phil. Soc.*, 31, 612; 1935. H. J. Taylor and M. Goldhaber, NATURE, 135, 341; 1935. E. Amaldi, O. D'Agostino, E. Fermi, B. Pontecorvo, F. Rasetti and E. Segrè, *Proc. Roy. Soc.*, A, 149, 522; 1935.

[6] The ordinarily assumed yield of neutrons under these conditions is 1,000 neutrons per sec. (See, for example, E. Fermi and collaborators, *Proc. Roy. Soc.*, A, 146, 483; 1934.) According to R. Jaeckel's observations (*Z. Phys.*, 91, 493; 1934) the value 10,000 neutrons per sec. is more likely.

Absorption of Residual Neutrons

AMALDI, D'Agostino, Fermi, Pontecorvo, Rasetti and Segrè have discovered that certain elements strongly absorb neutrons which have been slowed down by paraffin wax[1]. They report, for example, that thin sheets of cadmium or indium of 0·013 gm./cm.² and 0·3 gm./cm.² thickness respectively cut down the intensity of a beam of slow neutrons to half its value and find for iodine a half-value thickness of 4 gm./cm.².

Thick sheets of a strongly absorbing element, such as cadmium, will, however, still transmit an appreciable fraction of the incident heterogeneous beam, and in these circumstances it appeared to be of interest to investigate the absorption of such residual neutrons in some elements.

In one set of experiments, I filtered slow neutrons by a sheet of cadmium, 1·6 mm. (1·4 gm./cm.²) thick, and determined the absorption of the residual neutrons in several elements, using radioactivity induced in indium (54 min. period) as an indicator of the neutron intensity. The residual neutrons from the thick cadmium filter are scarcely absorbed by cadmium itself—a 0·5 mm. thick cadmium absorber will absorb perhaps less than 10 per cent of the residual neutrons. Yet I find that these residual neutrons are strongly absorbed by some elements; for example, a thin indium absorber of less than

3 gm./cm.^{2} (0·4 mm.) thickness absorbs more than o thirds of the intensity.

Cadmium absorbs the bulk of the unfiltered beam ich more strongly than indium, but as we see, it is insparent for some component of the unfiltered am which in its turn is strongly absorbed by indium. is fact is in contradiction to the current consions drawn from the theory of radiative capture. Fermi *et al.*, Bethe, Perrin and Elsasser attempted explain the observed large absorbing cross-sections elements such as cadmium without assuming longnge forces of the nucleus. They have assumed that range of these forces is small compared with the ve-length λ of the slow neutron and that the utron is captured in a deep energy level of the cleus, the excess energy of several million volts ing carried away by an emitted photon. They ve demonstrated that large effective absorbing ss-sections result if resonance occurs, and it can shown that the degree of this resonance will not inge appreciably with the neutron energy between rmal energies and some 10,000 electron volts. nsequently, if an element has an absorbing crosstion larger than another element for one particular utron energy, it should not have a smaller absorb- cross-section for any other energy within this ergy range.

The present observation on indium contradicts s conclusion. It cannot be argued in defence of theory that the observed effect might be due to utrons of energies higher than some 10,000 volts, ce the observed very large absorbing cross-section the indium atom for the residual neutrons would en have to exceed λ^2/π—the limit set by the theory.

In our experiments, use was made of the fact at slow neutrons will diffuse through a paraffin x tube in much the same way as a gas will diffuse rough a tube, if the mean free path in the gas is ge compared with the diameter of the tube. The utrons were led from a radon-beryllium source of out 200 mC. through a paraffin wax tube of 13 cm. er diameter and 20–40 cm. in length to filter, sorber and indicator sheets and passed only once rough these sheets.

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It would be interesting to know the energy values which correspond to these absorbing regions. An attempt is now being made to determine them by studying the absorption in boron and lithium of the 'highly absorbable' components of the residual beam.

The observed strong absorption of residual neutrons makes it possible to construct efficient slits or shutters for the purpose of stopping out a well defined beam.

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[1] *Proc. Roy. Soc.*, A, 149, 522 ; 1935.
[2] Artsimovitch, T. Kourtschatov, Miccowskii and Palibin, *C.R.*, 200, 2159 ; 1935. Bjerge and Westcott, *Proc. Roy. Soc.*, A, 150, 709 ; 1935. Amaldi, D'Agostino, Fermi, Pontecorvo and Segrè, *Ric. Sci.*, (vi), 1, No. 11–12. Moon and Tillman, NATURE, 135, 904 ; 1935. Tillman and Moon, NATURE, 136, 66, July 13, 1935. Ridenour and Yost, *Phys. Rev.*, 48, 383 ; 1935.

The Slowing Down of Neutrons by Collisions with Protons

FERMI and others[1] showed that neutrons, passing through substances containing hydrogen, loose their energy by collisions with protons. It is of interest to discuss this process of slowing down somewhat further. So long as the energy of the neutron is higher than the energy with which the protons are bound in the molecules of the substance through which the neutrons pass, it seems evident that the latter give, on the average, half their energy to the proton at every collision. But when the neutrons are slowed down below this binding energy, they must excite rotation and oscillation of the hydrogen atom in the molecule in order to lose energy.

It is not certain whether the cross-section of protons for neutrons is a uniform function of the velocity of the neutrons, or if it shows discontinuities for energies comparable with the molecular bindings. In the latter case, it is possible that two substances, containing hydrogen held by different linkages, would show differences in slowing down the neutrons. We have carried out some experiments which indicate the existence of such differences.

Spheres with different radii (5–15 cm.) were alternately filled with water (0·11 gm. H/cm.^{3}), ethyl alcohol (0·10 gm. H/cm.^{3}), benzene (0·067 gm. H/cm.^{3}) and a liquid paraffin (0·14 gm. H/cm.^{3}). In the centre of the sphere a neutron source (radon + beryllium) was placed. The activation of a silver plate, which was fixed on the surface of the spheres and exposed for five minutes to irradiation, served as a measure of the intensity of slow neutrons.

Fig. 1 shows the number of slow neutrons per unit of the solid angle plotted against $r\,d$, where r is the radius of the sphere and d the quantity of hydrogen contained by 1 cm.^{3} of the liquid in question. The general aspect of these curves is already known. For small radii a rapid increase of the intensity with increasing radius is observed, due to the slowing down of neutrons by collisions with protons. After a certain point, an increase of the radius causes a reduction of the intensity. This clearly shows that not all neutrons which pass the surface of a sphere are reaching the next bigger sphere. The vanishing of slow neutrons must be ascribed to absorption.

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