levels show a progressive increase with bombarding energy as the top of the potential barrier is approached.

It is interesting to notice that whilst resonant phenomena associated with the emission of particles from elements bombarded with α-particles have frequently been observed, such processes have hitherto, with one exception, not been found for bombardment with protons or deuterons.

P. I. DEE.
S. C. CURRAN.
J. E. STROTHERS.

Cavendish Laboratory,
Cambridge.
April 22.

[1] Hafstad and Tuve, *Phys. Rev.*, **48**, 306 (1935). Bernet, Herb and Parkinson, *Phys. Rev.*, **54**, 398 (1938). Curran, Dee and Petrzilka, *Proc. Roy. Soc.*, A, **169**, 269 (1938).
[2] Halpern and Crane, *Phys. Rev.*, **55**, 206 (1939).
[3] Delsasso, Fowler and Lauritsen, *Phys. Rev.*, **51**, 527 (1937).
[4] Burcham and Smith, NATURE, in the press.

Production of Neutrons by the Fission of Uranium

As a result of the discovery of the fission of the uranium nucleus after absorption of a neutron, we have made experiments to see if other neutrons are emitted in the process, and to measure their number. The results are comparable with those recently published by Joliot[1] and others.

Our apparatus consists of four concentric copper spheres (*a*), (*b*), (*b'*), (*c*) of radii 7·5, 10·5, 11·5, 12·5 cm., at the centre of which a source of radon plus beryllium of the order of 200 mc. was placed. The space between (*b*) and (*b'*) was an air gap left for structural reasons. In the first set of experiments, the inner sphere (*a*) was filled with paraffin wax and the space between (*b'*) and (*c*) with boron carbide. The apparatus was placed in a tank filled with water, and the activity detected by a dysprosium detector about 15 cm. from the surface of the outer sphere. Measurements were taken with the space between (*a*) and (*b*) empty, giving a count v, and full of uranium oxide (U_3O_8), giving a count u. In the second set of experiments the paraffin wax was removed, and the source surrounded with cadmium so that only fast neutrons were used. Again, experiments were made with, u_1, and without, v_1, the uranium oxide. Finally, experiments were made with the tank empty and the paraffin wax in place, but no boron carbide, to determine the absorption of the layer of uranium oxide for slow neutrons.

We considered that the production of neutrons might be due either to the slow or fast neutrons, or to both, and our experiments enable us to separate the two effects.

We found the following counts: $u = 0{\cdot}81 \pm 0{\cdot}015$; $v = 0{\cdot}75 \pm 0{\cdot}02$; $u_1 = 1{\cdot}24 \pm 0{\cdot}03$; $v_1 = 1{\cdot}11 \pm 0{\cdot}025$; while the absorption for slow neutrons corresponds to a cross-section of $5{\cdot}9 \times 10^{-24}$, assuming a cross-section[2] of scattering of the order of 40×10^{-24} for these neutrons.

Let ν be the number of fast neutrons produced by the fission of one uranium nucleus when caused by a slow neutron, and σ_F the cross-section for this process, and ν^1, σ^1_F be the corresponding quantities for fission caused by fast neutrons; let σ_C be the effective cross-section for all capture processes, including fission and resonance, for slow neutrons (for our purposes the resonance neutrons count as slow, but owing to their small 'numerosity' the effective cross-section for the resonance process will be considerably less than the cross-section at resonance (25 volts)). Let σ_C' be the corresponding quantity for fast neutrons. We find the following results: $\nu'\sigma_F' - \sigma_C' = (4{\cdot}0 \pm 1)\ 10^{-24}$ cm.^{2}; $\nu\sigma_F = (2{\cdot}1 \pm 1{\cdot}6)\ 10^{-24} + 0{\cdot}78\,\sigma_C'$; $\sigma_C = (5{\cdot}9 \pm 1)\ 10^{-24}$. In calculating $\nu\sigma_F$ we have assumed that the number of fast and slow neutrons which reach the surface of our paraffin sphere are respectively 50 per cent and 20 per cent of the number emitted by the source[3].

It will be seen that there is a net increase in the number of fast neutrons considered separately. As regards the slow neutrons the result is less certain; there is apparently a decrease for these neutrons considered separately unless σ_C' is taken as at least 3×10^{-24}. We believe, however, that our method tends to give too large a value for σ_C owing to scattering. It is in fact larger than that used by Joliot in his recent paper[1], $(8{\cdot}7 - 1{\cdot}2) \div 1{\cdot}6 = 4{\cdot}7$. If we assume Joliot's result is due to fission by slow neutrons, the value of σ_C' becomes at least 4×10^{-24}.

We hope shortly to make similar measurements with thorium.

J. L. MICHIELS.
G. PARRY.
G. P. THOMSON.

Imperial College of Science
and Technology,
London, S.W.7.
April 28.

[1] v. Halban, Joliot and Kowarski, NATURE, **143**, 470, 680 (1939). Haenny and Rosenberg, *C. R.*, **208**, 898 (1939). Dodé, v. Halban, Joliot and Kowarski, *C. R.*, **208**, 995 (1939).
[2] Dunning, Pegram, Fink and Mitchell, *Phys. Rev.*, **48**, 265 (1935)
[3] Fink, Dunning and Pegram, *Phys. Rev.*, **49**, 642 (1939); and "Kernphysik", 18 (Springer, 1936).

Absorption Method for Determining the Range of Recoil Atoms

THE determination of the recoil ranges of atoms resulting from radioactive disintegrations has hitherto been restricted almost entirely to gases, on account of the extremely short range of recoil atoms in solids; in silver, for example, the range of α-particle recoil atoms is of the order of a few hundred angstroms, whilst that of β-particle recoil atoms is many thousandfold less. It is clear, therefore, that absorption measurements and subsequent range determination in solids are possible only if the thickness of the absorbing layer can be varied by amounts corresponding to a small number of molecular layers. It occurred to us that the built-up molecular films prepared by the method of Blodgett and Langmuir[1] might serve as adjustable absorption screens of this kind; we have now demonstrated the feasibility of this idea and have obtained preliminary quantitative results.

In the first instance, we have confined our attention to α-particle disintegrations which immediately precede a β-particle disintegration, and have devised two methods, (1) suitable for thorium A, radium A and actinium A, and (2) convenient for thorium C, radium C' and actinium C.

In method (1), a built-up film is prepared, containing a known number n of molecular layers of barium stearate deposited on stainless steel, and therefore having a known thickness. The film is exposed for a short time to a source of radio-thorium, when thorium A (half-life 0·14 sec.) is deposited on the outermost layer of the film and decays immediately into thorium B. Some of the recoil atoms are ejected downwards