

could have been detected, this gives an upper limit of 5×10^{-32} cm²/atom. The number of atoms/cm³ in the counter was calculated to be 6×10^{18} . The number of disintegrations per second in the tritium was 1.8×10^{11} , and it was estimated that one-twentieth of these passed through the counter. The average path length through the counter was 1.2 cm. Supposing the main means of scattering would be by the electrons and assuming eight electrons per atom would be effective in scattering, this gives an upper limit of 6×10^{-33} cm²/electron.

Using another Geiger counter filled with twenty atmospheres of helium, a gross counting rate of (28.95 ± 0.31) counts/min. and a background counting rate of (29.12 ± 0.34) counts/min. were obtained. The net counting rate in this case was (-0.17 ± 0.65) count/min. Using 0.65 count/min. as an upper limit on the counting rate, 7×10^{-34} cm²/atom was the upper limit on the cross section. In calculating this figure, the number of neutrinos and the fraction which passed through the counter were the same as above. The number of atoms/cm³ was 5×10^{20} , and the average path length through the counter was 3.5 cm. Assuming the two electrons in helium to be equally effective for scattering, the upper limit of the cross section is 4×10^{-34} cm²/electron.

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¹ H. R. Crane, Rev. Mod. Phys. 20, 278 (1948).

² M. E. Nahmias, Proc. Camb. Phil. Soc. 31, 99 (1935).

Neutron Binding Energies

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UP to the present, authors¹ who have calculated neutron binding energies in the heavy isotopes have bridged between the radioactive series by smooth interpolations or by use of the mass formula. There are now sufficient data to give unambiguous energy differences between the $4n$, $4n+3$, and $4n+2$ series, apart from experimental error. Although the possible formation of excited states casts doubt on the result of any single type of experimental neutron binding energy measurement, agreement between the results of two properly chosen methods removes it. In a (d, p) reaction, if (Z, A) is the target nucleus, then $E_n(Z, A+1) = Q_R + Q_d + E_\gamma$, where $E_n(Z, A+1)$ is the neutron binding energy in $(Z, A+1)$, Q_R is the Q -value for the reaction, Q_d is the deuteron binding energy and E_γ is the total gamma-energy emitted by the product nucleus, if formed in an excited state. Thus, if the total gamma-energy between the excited and ground states is not included, the calculated binding energy would be equal to or less than the true binding energy.

Conversely, for the (d, t) reaction, $E_n(Z, A) = -Q_R + Q_t - Q_d - E_\gamma$. Here the target nucleus is still called (Z, A) , and Q_t is the triton binding energy. If an excited state were formed and the total gamma-decay energy not included, the calculated binding energy would be greater than the true binding energy. Therefore agreement between the neutron binding energies in a given nucleus as measured by the (d, p) and (d, t) reactions gives this energy unambiguously. Similar considerations show that a (γ, n) reaction gives a result greater than or equal to the true energy, while the result from an (n, γ) reaction is ambiguous unless the gamma-decay scheme is determined. The energies listed in Table I are the results of various investigations for the last neutron in the isotope given. The last column gives conclusions based on the above reasoning. Thus the energy differences between the $4n$, $4n+3$, and $4n+2$ series are known.

Now it seems rather certain that the disintegration energies of Pb²⁰⁹, Pb²¹⁰, and Bi²¹⁰ are 0.69 Mev, 0.07 Mev, and 1.17 Mev, respectively.² The use of these, the disintegration energy^{2,3} of Po²¹⁴ and the neutron binding energies in Pb²⁰⁸ and Pb²⁰⁷, shows that about 0.4 Mev must be added to the sum of the measured

TABLE I. Neutron binding energies.

Isotope	Neutron binding energy (Mev) measured by				Neutron binding energy (Mev)
	$(d, p)^a$	$(d, t)^a$	$(\gamma, n)^b$	$(n, \gamma)^c$	
83210	4.14 ± 0.03			4.170 ± 0.015	≥ 4.17
83209		7.44 ± 0.05	7.45 ± 0.2		≤ 7.44
82209	3.87 ± 0.05				≥ 3.87
82208	7.37 ± 0.03	7.37 ± 0.05	7.44 ± 0.10	7.380 ± 0.008	≥ 7.38
82207	6.71 ± 0.03	6.69 ± 0.05	6.95 ± 0.10	6.719 ± 0.016	6.72
82206		8.10 ± 0.05	8.25 ± 0.10		≤ 8.10

^a J. A. Harvøy, Phys. Rev. 79, 241 (1950).

^b McElhinney, Hanson, Becker, Duffield, and Diven, Phys. Rev. 75, 542 (1949); H. Palevsky and A. O. Hanson, Phys. Rev. 79, 242 (1950).

^c Kinsey, Bartholomew, and Walker, Phys. Rev. 78, 77 (1950); Phys. Rev. 78, 481 (1950); private communication.

binding energies in Pb²⁰⁹ and Bi²¹⁰. If it is assumed that *only one* of these measurements is in error, the following arguments lead to the choice of 3.87 Mev for the binding energy of Pb²⁰⁹. First, if the 0.4 Mev were added to the experimental binding energy in Pb²⁰⁹, the resultant energy would be greater than that in Bi²¹⁰. However, it is expected that the addition of an odd proton outside the closed Pb²⁰⁸ shell would *increase* the binding energy of an odd neutron outside that shell. Second, the neutron binding energy in Pb²⁰⁹ would be only 0.5 Mev less than that of the neutron in Pb²¹⁰. This difference is expected to be 1.0 Mev or more. Third, if 4.17 Mev were the binding energy of the odd neutron in Bi²¹⁰, it would be less than that in Bi²¹², contrary to expectations. The latter (4.36 Mev) is derived from the binding energy in Pb²⁰⁸, the disintegration energies of Th C (2.25 Mev), Ac C'' (1.44 Mev),⁴ and known alpha-energies.^{2,3}

These experimental energy differences between the four series make it possible to determine other binding energies using energy cycles. Knowledge of these energies may serve as a means of refining the empirical mass formulas. More importantly, they can provide a check on the validity of total decay energies. Arguments like those in the preceding paragraph are also being made for the latter purpose. Work along these lines at present indicates that some of the most critical decay energies are those of Ra B, Ra C, Bi²¹³, MsTh₁ and MsTh₂.

¹ A. Berthelot, J. de phys. et rad. (VIII) 3, 17 (1942); K. Way, Phys. Rev. 75, 1448 (1949); M. O. Stern, Rev. Mod. Phys. 21, 316 (1949); A. H. Wapstra, Physica 16, 33 (1950).

² See G. T. Seaborg and I. Perlman, Rev. Mod. Phys. 20, 585 (1948) for references.

³ Perlman, Ghiorso, and Seaborg, Phys. Rev. 77, 26 (1950).

⁴ H. D. Evans, Proc. Phys. Soc. London 63, 575 (1950).

The Solar Flare of November 19, 1949 and Cosmic Rays

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WITHIN recent years a great number of physicists, among them Forbush,¹ Ehmert,² and Unsöld,³ have investigated extensively with ion chambers and counters the sudden variations in cosmic-ray intensity coincident with disturbances of the earth's magnetic field, changes in radiofrequency waves from the sun, and ionospheric disturbances and their correlation with solar flares.

As to our contribution to the investigation with the former method, our recording apparatus consists of 3 ion chambers containing Ar at up to 60 atmospheres; one of the chambers is unshielded, one shielded with 12 cm Fe, and one with 110 cm Fe. Normally we have a fourth vessel, likewise under 110 cm Fe, but this one was not in use for the moment. The charge required to compensate the ionization in the vessels is measured every two hours for the unshielded vessel, every hour for the other two, in the form of an excess over a well-known compensation charge.