The resulting yield curve resembles the $Cu^{63}(\gamma, n)$ yield curve[5] up to the latter's maximum at 25 Mev, beyond which the former continues to rise to a maximum at 40 Mev. Above 40 Mev, k slowly decreases in the same manner as the (γ, n) yield, indicating that relatively few neutrons are generated by quanta above this energy.

The k-values in Fig. 1 are related to cross sections for photoneutron production, σ_n, by the formula

$$k = N \int_0^{50} \sigma_n(E)\phi(E)dE$$

where N is Avogadro's number and ϕ is the flux of quanta per r. This has been calculated[5] for 50-Mev x-rays to be $3.5\times10^7/E$. The carbon data give $\int \sigma_n dE = 1.4\pm0.3\times10^{-25}$ cm² Mev. As this is the value obtained by Lawson and Perlman for the (γ, n) cross section,[6] either no neutron-producing multiple disintegrations occur in carbon or this value of $\phi(E)$ is low.[7]

Measurements of the total cross section of graphite for neutrons detected by the rhodium-moderator combination employed indicate that the average energy of neutrons from carbon is nearly that of Ra-α-Be neutrons, and is appreciably higher than that of neutrons from lead.

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[4] M. L. Perlman and G. Friedlander, Phys. Rev. **74**, 442 (1948).
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Neutron Binding Energies in Pb^{207}, Pb^{208} and in Bi^{210}

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THE energies of the gamma-rays arising from neutron capture in Pb^{206}, Pb^{207} and Bi^{209} have been measured with the aid of a coincidence pair spectrometer. The technique of energy measurement has been described briefly in an earlier letter.[1] The coincidence spectra obtained by using lead oxide in an aluminum container and pure metallic lead are shown in Fig. 1. The capturing isotope is indicated for each radiation. The energy of the radiation is obtained by adding about 25 kev to the energy found by extrapolating the high energy slope to zero. With metallic bismuth a single weak but unusually broad coincidence peak was found. The energies are: (a) from lead, 6.68±0.04 Mev and 7.37±0.02 Mev; (b) from bismuth, 4.170±0.015 Mev.

Since the energy set free in the capture of a neutron by a nucleus with even charge and even mass number is always less than that produced by an adjacent even-odd type, the binding energy released by capture in Pb^{206} will be less than that released by capture in Pb^{207}. This suggests that the 6.68 Mev γ-ray arises from capture in Pb^{206}. Further, its energy is in good agreement with the threshold energy of the (γ, n) reaction,[2] *viz.*, 6.85±0.20 Mev. The 7.37 Mev radiation therefore must originate in capture in Pb^{207}. Since the first excited state of Pb^{208} lies at the unusually high level of 2.62 Mev, the 7.37 Mev radiation must be due to the direct transition to the ground state and its energy is equal to the binding energy.

As pointed out by K. Way,[3] the binding energy of a neutron in Pb^{209} is probably much lower than in the other isotopes of lead. A radiation with this energy could not be detected by the present method because of the low neutron capture cross section of Pb^{208} and because of the reduced sensitivity of the spectrometer at low energies. The neutron binding energy of Pb^{209} may be deduced from the present results, the energy of the decay of Pb^{209}, and the energy set free in the disintegrations by which RaD (Pb^{210}) passes to Pb^{206}. We obtain 4.81±0.08 Mev for the binding energy of the neutron in Pb^{210} and 4.35±0.12 Mev for that in Pb^{209}. The latter figure and the present results are in agreement with those obtained recently in a study of the (d, p) reactions in lead and bismuth.[4]

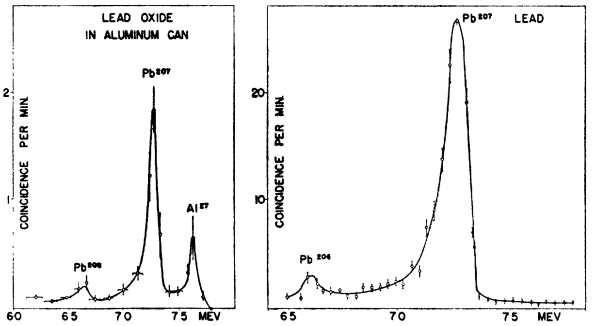

FIG. 1. Pair spectrogram of the neutron capture γ-rays produced by lead oxide and lead.

It is very surprising that no radiations of lower energy were observed in the spectrum of lead. The simplicity of the spectrum obtained is similar to that observed from the lightest elements; for example, from beryllium and carbon. No radiation was found at 4.75 Mev, which is the energy of the radiation to be expected from a transition to the 2.62 Mev level in Pb^{208}. Possibly such a radiation would be too weak to be detected unless the direct transition to the ground state was forbidden by selection rules. In the case of Pb^{208}, and possibly also of Pb^{207}, we conclude that the direct radiative transition to the ground state is allowed and that the level density in these isotopes is much less than at corresponding excitations in other heavy elements which we have studied, such as Au^{198}.

The ratio of the thermal neutron capture cross section of Pb^{207} to that of Pb^{206} can be estimated if it is assumed that only transitions to the ground state occur in significant amount. After correcting for the energy sensitivity of the pair spectrometer, we find this ratio to be about 7.

The unusual width of the bismuth peak may be due to the transitions to the low energy levels which are known to exist in Bi^{210} (RaE).

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The Possible Existence of a Constant Third-Order Difference among the Nuclear Magic Numbers

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THERE seems to be some indication that a constant third-order difference may possibly exist among the nuclear magic numbers. If, according to the explanation afforded by the linear oscillator of the nuclear model,[1] these numbers are taken to be 14, 28, 50, 82, and 126, then the first-order differences among them are 14, 22, 32, 44; the second-order differences, 8, 10, 12; and the third-order difference is constant at a value of 2.

On the assumption that this constant value of the third-order difference is a fundamental fact, the magic number, M, is computable from the readily derivable expression $M=(N^3+5N)/3$ in which N assumes the integer values 1, 2, 3, 4, 5, 6, 7, 8, etc. Then, according to this rule, the magic numbers should be 2, 6, 14, 28, 50, 82, 126, 184, etc.; 8 and 20 are notably absent. The terminal point of the series occurs, of course, at the magic number beyond which all others are proven or known to be physically impossible.

[1] Haxel, Jensen, and Suess, Phys. Rev. **75**, 1766 (1949).