Letters to the Editor

PUBLICATION of brief reports of important discoveries in physics may be secured by addressing them to this department. The closing date for this department is five weeks prior to the date of issue. No proof will be sent to the authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents. Communications should not exceed 600 words in length.

Evidence for Neutrons Associated with the Stopping of Sea Level Mesons in Lead*

R. D. SARD, W. B. ITTNER III, A. M. CONFORTO,** AND M. F. CROUCH***
Washington University, St. Louis, Missouri
May 17, 1948

WE are carrying out an experiment designed to bring to light neutrons emitted by nuclei that have captured negative light mesons. In our first measurements we have found a time correlation between the stopping of a penetrating charged particle, indicated by a Geiger-Mueller tube anticoincidence, and the detection of a neutron.

The arrangement used is shown in Fig. 1. Counter trays A and B select a cone of charged particles capable of penetrating 12.7 cm Pb. Some of these stop in the 7-cm Pb absorber, resulting in failure of tray C to discharge except in the small (2 percent) fraction of the cases in which a decay electron reaches C. Tray C more than covers the cone defined by A and B. The circuit records coincidences (AB) (B within 0.7 μsec. before to 1.0 μsec. after A) as well as anticoincidences ($AB-C$) (C within 2.1 μsec. before to 7.2 μsec. after the coincidence (AB)). Underneath C is placed a group of slow neutron counters, N, surrounded by paraffin. These are proportional counters coated on the inside with boron enriched in B^{10}.[1] They are connected in parallel to the input of an amplifier and pulse-shaping circuit biased to respond only to input pulses stronger than about 20 millivolts. The output drives a recording circuit giving the N counting rate.

An anticoincidence ($AB-C$) initiates a rectangular pulse 80 μsec. in length. This "gate" is placed in coincidence with the N pulse; the coincidence output drives a recording circuit giving the ($AB-C{:}N$) rate. This coincidence circuit responds only when the neutron pulse occurs within 4 to 84 μsec. after the (AB) coincidence. Thus N pulses simultaneous with ($AB-C$), such as might be produced by an electron shower that happens to miss C, cannot contribute to the ($AB-C{:}N$) rate. As it takes several microseconds for a neutron of several Mev to be brought to thermal speed in the paraffin and the mean life of the thermal neutron is of the order of 150 μsec., the late start incurs only a small loss of counts from neutrons associated in time with the incident charged particle.

The dimensions of the paraffin "moderator" were those determined empirically to give maximum neutron counting rate for the fission neutrons from a 41- $\times$51-cm tray of uranium oxide placed at the level of the middle of the 7-cm Pb absorber.

Our preliminary results are given in Table I. Subtracting the ($AB-C$) rate without the lead absorber from the rate with it in place, one obtains 0.86/min. for the apparent rate of stopping in the lead. This gives an absorption coefficient of 3.8×10^{-4} per g/cm^2, in excellent agreement with counter telescope data.[2] Apparently 55 percent of the anticoincidences recorded are not due to the stopping or scattering of particles in the lead absorber, corresponding to an anticoincidence efficiency of 96.5 percent.

In order to separate N pulses due to neutrons from N pulses due to showers and contamination, data were taken with and without 1-mm cadmium shields around the counters. The sixth and seventh rows give the ($AB-C{:}N$) rates in the two cases. There is seen to be a definite effect, far exceeding the expected accidental rate of $1.89\times7.43\times80\times10^{-6}=1.12\times10^{-3}$ per hour.

The one ($AB-C{:}N$) count in the absence of absorber (eighth row) could be accidental or due to a particle stopped in the G-M tube walls (0.8-mm brass) or aluminum shielding (1.6 mm).

Since a considerable fraction of the anticoincidences are not due to stopping in the lead, it is not yet certain on the basis of the data thus far discussed that the neutrons are associated with meson stoppings. In order to settle this point, data were taken with no voltage on counters C. The ($AB{:}N$) rate so obtained should be almost thirty times higher than the ($AB-C{:}N$) rate if the effect is due to penetrating events, while it should be the same if the effect is due *entirely* to mesons stopped in the lead. As shown in the ninth and tenth rows, the neutron coincidence rate is about doubled. We take this to mean that the stopping of mesons in the lead results in the production of neutrons. The doubling of the rate could be due to neutrons produced by or contained in penetrating ionizing events[3] or to neutrons produced by mesons stopping beneath the C tray, in the paraffin or the neutron counters themselves (these would be detected with considerably higher efficiency than neutrons made in the lead). Ac-

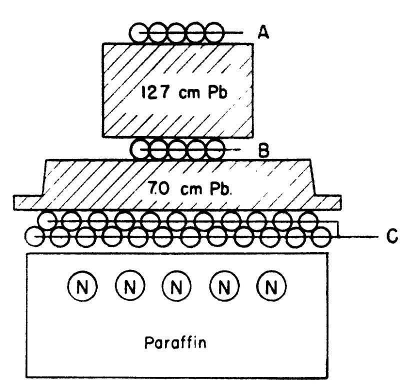

FIG. 1. Counter arrangement. Search for fast neutron associated with meson stopping.

TABLE I.

	Counts	Duration	Rate
(AB)	765,606	26,920 min.	28.44±0.03/min.
$(AB-C)$ with 7-cm Pb absorber	26,313	13,925 min.	1.89±0.01/min.
$(AB-C)$ sans 7-cm Pb absorber	7,859	7,597 min.	1.03±0.01/min.
N with 7-cm Pb absorber	116,666	15,707 min.	7.43±0.02/min.
N with 1-mm Cd sheaths around N counters	6,744	5,850 min.	1.15±0.01/min.
$(AB-C:N)$ with 7-cm Pb absorber and sans Cd sheaths	61	181.33 hr.	0.34±0.04/hr.
$(AB-C:N)$ with 7-cm Pb absorber and with Cd sheaths	0	50.75 hr.	—
$(AB-C:N)$ sans 7-cm Pb absorber and sans Cd sheaths	1	44.13 hr.	0.02±0.02/hr.
$(AB:N)$ with 7-cm Pb absorber and sans Cd sheaths	56	80.45 hr.	0.70±0.09/hr.
$(AB:N)$ with 7-cm Pb absorber and with Cd sheaths	0	46.75 hr.	—

cording to present views, there should be no neutrons from mesons stopped in paraffin.

The ratio of particles stopped in the lead to neutron coincidences is 51.6:0.34, or 152. Allowing for a 20 percent positive excess, we conclude that there is one neutron coincidence per 61 negative mesons stopped. The solid angle subtended by the neutron detecting arrangement is approximately π-steradians. If there is one neutron produced per negative meson stopped, the efficiency of the neutron detecting arrangement is 6.5 percent per incident neutron. Before any conclusion can be drawn as to the multiplicity of the neutron production, it will be necessary to determine experimentally the efficiency of the neutron detecting arrangement for incident neutrons of various energies. We are preparing to do this for Po-Be and Ra-Be neutrons. It is also not entirely impossible that the neutron coincidences are due to stopped protons, which may amount to as much as 5 percent of the number of stopped mesons.[4] This would, however, imply an improbably high efficiency for the neutron detecting arrangement.

We are continuing our investigation of the effects reported, and are, in particular, trying to find out whether the neutrons result from capture or decay (neutral mesons producing neutrons?).

* Research assisted by the Office of Naval Research through Contract N6onr-202, T.O. 3.
** International Study Fellow of the American Association of University Women.
*** Now at Harvard University, Cambridge, Massachusetts.
[1] We are indebted to the Argonne National Laboratory for the loan of these counters; we understand that their efficiency for room-temperature neutrons incident at right angles to the axis is about 10 percent.
[2] B. Rossi, N. W. Hilberry, and J. B. Hoag, Phys. Rev. **57**, 464 (1940).
[3] V. Tongiorgi [Phys. Rev. **73**, 923 (1948)], using a technique similar to ours, finds neutrons associated with extensive showers. We have recently taken data with extra anticoincidence counters of the C group, C^1, placed next to trays A and B. The $(AB-C^1:N)$ rate is not significantly less than the $(AB:N)$ rate, indicating that the doubling cannot be ascribed to showers incident on the apparatus.
[4] B. Rossi, *Interpretation of Cosmic Ray Phenomena* (Technical Report No. 7 of the Massachusetts Institute of Technology Laboratory of Nuclear Science and Engineering, March 22, (1948).

The Isotopic Constitution of Praseodymium and Neodymium

MARK G. INGHRAM, DAVID C. HESS, JR., AND RICHARD J. HAYDEN
Argonne National Laboratory, Chicago, Illinois
May 17, 1948

OUR mass spectrometric measurements of rare earth isotopic constitutions[1,2] have been extended to include praseodymium and neodymium. Methods of analysis were similar to those discussed in the first reference.

Praseodymium was first studied by Aston,[3] who reported a single isotope of mass 141. He gave no upper limits for possible existence of other stable isotopes. No other studies of this element have been reported.

For this investigation a nitric acid solution of praseodymium oxide (Hilger Laboratory No. 1533) was pipetted onto a tungsten filament and heated in air to form an adherent oxide coat. This filament was then inserted into the source of a 60° mass spectrometer. Upon heating, ion currents were obtained at masses 157, 158, and 159, corresponding to $Pr^{141}O^{16+}$, $Pr^{141}O^{17+}$, and $Pr^{141}O^{18+}$. Negligible ion currents were observed of the type Pr^{141+}. From the ratios of the ion currents observed we can conclude that other stable praseodymium isotopes, if they exist, are present to less than the following percentages:

138	<0.002 percent	142	<0.005 percent
139	<0.003 percent	143	<0.010 percent
140	<0.005 percent	144	<0.001 percent
		145	<0.001 percent

The limits of the abundances of the isotopes at masses 142 and 143 were obtained by comparison of the observed ion currents with those predicted from the known abundances of O^{17} and O^{18} and, therefore, these limits are not as low as are the rest. Assuming a packing fraction of -3.0×10^{-4} and a conversion factor of 1.000275, the chemical atomic weight is 140.92, which is in complete agreement with the international chemical value.

Neodymium was first investigated by Aston[4] who found isotopes at masses 143, 143, 144, 145, and 146. Later Dempster[5] discovered rarer isotopes at masses 148 and 150. Mattauch and Hauk[6] on the basis of photometric analysis of photographic plates gave the abundances shown in Table I.

For this investigation neodymium oxide (Hilger Laboratory No. 6783) was applied to the source in a manner similar to that used for praseodymium. The ion currents consisted principally of NdO^+ ions with very much weaker currents of the type Nd^+. The results tabulated in Table I are the average of 200 separate determinations in the oxide position. A typical recorder curve is shown in Fig. 1. The uncertainty quoted is not the mean deviation of these results, but is larger than this by an amount sufficient to

TABLE I. Isotopic constitution of neodymium.

Observer	142	143	144	145	146	148	150
Mattauch and Hauk	25.95	13.0	22.6	9.2	16.5	6.8	5.95
This work	27.13 ±0.2	12.20 ±0.1	23.87 ±0.2	8.30 ±0.05	17.18 ±0.2	5.72 ±0.06	5.60 ±0.06