about 1:12 from measurement of the associated γ-ray intensities.[2] If both measurements are to be reconciled, the most likely possibility is a strong $E2$ γ-ray transition from the 7.1-Mev to the 6.1-Mev level. The likelihood that this $E2$ could give serious competition to the normal 7.1-Mev $E1$ ground state transition is enhanced by the isotopic spin selection rule[3] forbidding $E1$ transitions with $\Delta T=N-Z=0$. In order to explain the quantitative discrepancy in this way, however, this selection rule would have to be much stronger[4] than suggested by simple estimates.

One check on this problem is to search for a strong 1-Mev γ-ray following N^{16} decay. The reaction $O^{16}(n,p)N^{16}$ was used to produce N^{16} in the Columbia cyclotron, using fast neutrons from $Be(d,n)$ on a water target. A flow system was installed to bring the water from a small chamber behind the Be cyclotron target to a measuring chamber. A 10-sec bombardment produced a very strong activity with the characteristic N^{16} half-life of 7 sec. After a waiting period of 5 sec to allow decay of any shorter activities, the γ-spectrum of N^{16} was measured with a scintillation counter consisting of a 1-inch NaI crystal. The pulse distribution from the crystal was photographed on a triggered oscilloscope.

A strong line was found in the 6-Mev region. In a weak exposure, a peak at 0.5 Mev is visible, owing to annihilation of positrons formed outside the crystal. Between these lines no γ-line can be seen. Assuming the scintillation to be caused by pair production for the 6-Mev line and photoelectric absorption for a hypothetical 1-Mev line, we find an upper intensity limit

$$I(1\text{ Mev})/I(6\text{ Mev})\leq 0.05. \quad (1)$$

To account for the above-mentioned discrepancy in the branching ratios, the ratio (1) should be 10 times larger than observed, which is certainly ruled out by the present measurements. An error in the β-decay branching ratio seems the most likely explanation, in view of the inherent inaccuracy of absorption methods. It is of interest to note that if we assume approximate equality of the β-decay matrix elements, the branching ratio is determined by the ratio of $(2J+1)f$. In this case the ratio is

$$3f(3.2)/7f(4.2)\sim 1/7, \quad (2)$$

in order of magnitude agreement with the intensity ratio of 7-Mev to 6-Mev γ-rays.

This measurement does not provide any information on the failure of the isotopic spin rule forbidding electric dipole transitions. The result (1) implies that $I(1\text{ Mev})/I(7\text{ Mev})\leq 0.6$. The ratio without restriction of the dipole transition is expected to be[5-7] of order 10^{-6} or 10^{-7}. Even if the isotopic spin selection rule reduces $I(7\text{ Mev})$ by a factor of 10^3, an increase of sensitivity of at least 10^3 is expected to be necessary before the 1-Mev line could be detected.

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† Now at Project Whitney, Livermore, California.

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Alpha-Particle Ionization in Pure Gases and the Average Energy to Make an Ion Pair

WILLIAM P. JESSE AND JOHN SADAUSKIS
Argonne National Laboratory, Lemont, Illinois
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FOR some time measurements have been in progress to determine the average energy required to make an ion pair by polonium alpha-particles in very carefully purified gases. Since some of the values obtained are in marked contrast to those found in the literature, it is hoped that the publication of them will be of interest to others working in the field.

In the measurements a short collimating system directed the polonium alpha-particles along the axis of a long cylindrical ionization chamber. The effective path length was about 20 cm. The ions produced by each alpha-particle were collected and measured by a method already described.[1,2] From a knowledge of the capacity of the system and the change of potential of the system produced by the ionization from each alpha-particle, the absolute number of ion pairs produced may be determined. The average energy W to produce an ion pair is, of course, the energy of the polonium alpha-particle (5.298 Mev) divided by this number. A very small correction is made for the energy lost in the collimating system.

The capacity of the chamber was determined at intervals by comparison with a standard double-ended capacitance. During the progress of the work this capacitance was calibrated twice at the National Bureau of Standards with concordant results. The estimated error in the final values of W, of the order of one-half percent, includes, of course, a consideration of errors in such auxiliary measurements.

Since previous work[2] had shown the marked effect of minute gaseous impurities, the greatest precautions were taken to insure the purity of the gases used. These, in general, were introduced from breaker flasks into the chamber and were continuously circulated during the progress of the readings over a purification system by means of a small metal-bellows pump. The chamber was initially baked and pumped for more than twelve hours at a temperature above 200°C.

In Table I are shown the values of W obtained for the various gases used and for comparison very recent results of three other investigators. Two of these determinations were with polonium alpha-particles, and the third, that of Sharpe, was with Pu^{239}. Two values of W are given for each gas. First is given the absolute value of W, and then in parentheses is given the value relative to argon as a standard. In general, the agreement in the table is good, particularly between our own results and those of J. Sharpe.

In the case of helium there is a wide disagreement between the Argonne value and the other two values shown.[3] As has been discussed elsewhere,[2] this is no doubt due to impurities in the gas samples used, since in the other two determinations no extraordinary precautions seem to have been adopted to insure extreme gas purity. By reaction with the impurities the metastable atoms of helium are discharged with the production of additional ion pairs. For the same reason the Argonne value for neon is much higher than the older values found in the literature (about 29 ev/ion pair).

The agreement for argon in the table is good, particularly for three of the determinations. The effect of impurities is much less marked in argon, since the ionization potentials of the common

TABLE I. Values of W, in ev/ion pair. Values relative to argon are given in parentheses.

Gas	Argonne	Sharpe[a]	Valentine and Curran[b]	Haeberli, Huber, and Baldinger[c]
He	42.7 (1.617)		31.7 (1.22)	30.86 (1.176)
Ne	36.8 (1.394)			
A	26.4 (1.000)	26.3 (1.000)	25.9 (1.000)	26.25 (1.000)
Kr	24.1 (0.913)			
Xe	21.9 (0.830)			
H_2	36.3 (1.375)		37.0 (1.43)	
CO_2	34.5 (1.307)	34.2 (1.300)		33.5 (1.276)
Air	35.5 (1.345)	35.6 (1.354)	35.2 (1.36)	
O_2	32.5 (1.231)	32.9 (1.251)	32.2 (1.24)	32.17 (1.226)
N_2	36.6 (1.386)	36.4 (1.384)	36.0 (1.39)	36.3 (1.383)
CH_4	29.2 (1.106)	29.1 (1.106)	29.0 (1.12)	
C_2H_2	27.5 (1.042)			
C_2H_6	26.6 (1.008)			
C_2H_4	28.0 (1.061)			

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impurities, nitrogen and oxygen, are much above the energy available for the metastable state of argon (11.6 ev). However, by a well-chosen contaminant with an ionization potential below this value one can obtain a large increase in the ionization in argon. Thus, 0.2 percent of acetylene (ionization potential 11.2 ev) added to pure argon will produce an increase in ionization of 25 percent and a W of 21 ev/ion pair.

In view of the well-known difficulties of obtaining saturation for alpha-particle ionization measurements for air and probably oxygen, the corresponding values in the table may well be accepted with some degree of reserve. These difficulties have been emphasized by recent work,[4] where saturation was attained only at fields above 10 000 volts/cm. Alder, Huber, and Metzger,[5] also using fields of this order, employed a method of extrapolation to obtain a value of W for air at saturation of 34.7±0.5 ev/ion pair.

A ratio often calculated is that of W to the ionization potential of the gas in question. Such ratios, based on the W values for the five noble gases in column two of Table I, yield for the first four gases values which are almost constant at about 1.71. The ratio for xenon is only slightly higher. All semblance of constancy is lost if one uses in this way the older values of W found in the literature for helium and neon.

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The Neutron Activation of Ca^{46}

L. G. Cook and K. D. Shafer
Chemistry Branch, Atomic Energy of Canada, Limited, Chalk River, Ontario, Canada
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THE natural abundance of Ca^{46} is low, and Ca^{47} has never been reported as observed in neutron-irradiated calcium. Sc^{47} has been observed as a product of $Ca(\alpha,p)$, (d,n), (p,γ),[1] $Ti(n,p)$,[2] $Ti(d,\alpha)$,[3] and Ca^{47} as a product of $Ca(d,p)$.[4] Ca^{47} has been observed directly in the calcium fraction from Cu spallation with 340-Mev protons, and the decay of Sc^{47} observed.[5] We have observed the decay of Ca^{47} in neutron-irradiated calcium indirectly, by observing the decrease in yield of Sc^{47} on successive milkings.

The irradiated calcium was spiked with Sc^{46} tracer, and the Sc fraction was removed, purified by T.T.A.-benzene extraction and ion exchange on Dowex-50, and estimated. This was repeated at weekly intervals for eight weeks.

The decrease in yield of Sc^{47} gave a half-life for Ca^{47} of 4.8±0.5 days, agreeing with the half-life quoted by Batzel, Miller, and Seaborg,[5] but not with the 5.8 days quoted by Matthews and Pool.[4] The thermal neutron activation cross section $Ca^{46}\rightarrow Ca^{47}$ was $0.25\pm0.1\times10^{-24}$ cm²/atom.

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Neutron Capture Cross Section of Em^{222}

A. P. Baerg
Chemistry Branch, Atomic Energy of Canada, Limited, Chalk River, Ontario, Canada
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MEASUREMENTS have been made of the cross section of Em^{222}(Rn) for slow neutron capture in the NRX reactor, to form Em^{223} which has not been previously reported. This nuclide is expected to be a β-emitter with a calculated disintegration energy of 1.58 Mev,[1] and from this it may be estimated to have a half-life of about 5 minutes. Fr^{223}, the β-decay daughter of Em^{223}, is also short-lived but decays to Ra^{223}(AcX) which is an α-emitter with a half-life of 11.2 days. It seemed convenient to measure the production of Em^{223} by the growth of Ra^{223} during the neutron irradiation of the Em^{222}.

TABLE I. Data for cross-section calculation.

Expt.	$(Em^{222})_0$ mC	t hr	F n/cm²/sec	$(Ra^{223})_t$ dis/min	$\sigma(n,\gamma)Em^{222}$ barn
1	0.32_7	239	4.8×10^{13}	2460	0.7_6
2	0.27_2	264	4.7	1640	0.6_3
3	0.36_4	222	5.19	3035	0.7_8

The Em^{222} was extracted from an acid solution of $RaCl_2$, purified and sealed in a small quartz bulb for irradiation. A slow stream of helium gas was used to sweep the Em^{222} from the heated $RaCl_2$ solution. The gas was passed through two dry ice traps to remove water vapor and through an Ascarite absorber to remove hydrochloric acid gas. The Em^{222} was then adsorbed in a charcoal trap in a dry ice—acetone mixture. The charcoal trap was then heated and a small volume of helium gas used to sweep the Em^{222} into a small U-shaped quartz bulb immersed in liquid nitrogen to condense the Em^{222}. The bulb was finally evacuated and quickly sealed with a small flame just above the liquid nitrogen level. Some of the Em^{222} was lost in the evacuation, but sufficient was retained for the irradiation.

After about ten days irradiation in a high-flux position of the NRX reactor, the quartz bulb was crushed in a vacuum system and the residual Em^{222} removed. The Ra^{223} and the decay products of Em^{222} were taken up in nitric acid. The Po, Bi, and Pb decay products were separated from the Ra^{223} by two sulfide precipitations using 1 mg each of Bi and Pb carrier. About 25 μg of Ba was used as holdback carrier for the Ra^{223}. The solution was evaporated on a platinum disk for α-counting. The sulfide precipitates were dissolved in nitric acid, and an aliquot was evaporated on platinum for α-counting of the Po^{210} to determine the initial quantity of Em^{222} sealed in the quartz bulb.

The Ra^{223} was identified by α-pulse analysis which showed the three α-groups with energies of 5.72, 5.61, and 5.53 Mev characteristic of Ra^{223}. The α-activity decayed with a half-life of 11.1±0.2 days over a period of at least two half-lives.

The (n,γ) cross section of Em^{222} was calculated from the following equation:

$$\frac{(Ra^{223})_t}{(Em^{222})_0}=\frac{\sigma F\lambda_0}{(\lambda_0-\lambda_1)\lambda_1}(e^{-\lambda_1 t}-e^{-\lambda_0 t}),$$

where $(Em^{222})_0$ is the disintegration rate of the Em^{222} at the beginning of the irradiation, $(Ra^{223})_t$ that of Ra^{223} at the end, and λ_1 and λ_0 are the respective decay constants. F is the neutron flux during the time t of irradiation and was obtained from the calculated neutron distribution within the reactor and the reactor power log.

In three experiments an average value of 0.7_2 barn was found for the cross section σ of Em^{222}. The pertinent data are given in Table I.

The author is greatly indebted to B. G. Harvey for continued guidance and assistance throughout the course of this work.

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The β-Decay of Li^8

D. Stp. Bunbury
Department of Physics, Imperial College, London, England
(Received April 22, 1953)

THE β-decay of Li^8 is known to lead predominantly to the broad excited state of Be^8 at 3 Mev.[1] This provides an opportunity for studying the β-decay by observing the angular