was better than 0.1°C, although the absolute accuracy was not this great since the thermocouple was not individually calibrated.

A step in the heating curve was observed indicating a thermal anomaly between 128.2 and 128.7°C. Essentially the same temperature limits were observed for different heating rates from 0.32°C per min to 2.8°C per min. Upon cooling, the anomaly was observed in a different temperature range, 126.5 to 127.1°C. These anomalies each occur within a much smaller temperature range than that observed by Blattner and Merz, however, they still do not give unequivocal evidence of a latent heat.

Temperature changes could be observed when an electric field was applied. When the temperature reached 130°C, an electric field of 600 v/mm was suddenly impressed. This produced an immediate temperature rise of 0.5°C. When the voltage was turned off, the temperature fell the same amount. This temperature change may be interpreted as that accompanying an adiabatic transition from the cubic to the tetragonal phase.

Upon cooling to 127.7°C the voltage was applied again for one second. This produced an irreversible temperature rise of about 0.5°C, and the usual thermal anomaly between 126.5 and 127.1°C was not observed as cooling continued. These observations indicate that the electric field in this case produced a permanent transition before the material had cooled enough for the transition to take place spontaneously. The temperature change of 0.5°C indicates that the transition has a latent heat. If this figure is multiplied by the average specific heat,[2,4,5] $c_p=0.13$ cal/g°C and by the molecular weight, a lower limit of 15 cal/mole is obtained for the latent heat of the transition.

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Slow Neutron Liquid Scintillation Detector

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Aside from the possibility of discovering a fluorescent boron compound, the problem of detecting slow neutrons with boron at very high efficiencies (~100 percent) reduces to the problem of discovering a boron compound which may be introduced into a fluorescent medium without quenching the fluorescence. The series of esters: methyl, ethyl, propyl, etc.—borate when added to a standard fluorescent solution of phenylcyclohexane, terphenyl, and diphenylhexatriene—satisfies the above requirement. The only effect on the "alpha" pulse height due to the addition of these borates to the "phenyl" solution is to reduce it in proportion to the dilution of the original fluorescent solution. Even this loss of pulse height may be regained by addition of more terphenyl.

Enriched (B^{10}) methyl borate contains the least number of extraneous atoms and has the highest density of the series. A one-to-one solution by volume of methyl borate-"phenyl" used in conjunction with a 5819 photomultiplier tube has the following properties: (1) "alpha" pulse height of ~30 electrons at the cathode; (2) neutron lifetime in the medium of ~0.4 μsec.

It should be observed that with this short a lifetime, the presence of hydrogen is no obstacle to the use of such a counter for slow neutron time-of-flight velocity selection. In fact, the presence of hydrogen aids in keeping faster neutrons in the detecting medium. To use the counter in a practical way, however, it is desirable to use either liquid air cooling of the photomultiplier tube or to employ coincidences, and to bias out electrons of ~100 kev and higher in energy.

Relative Probabilities of Diverse Photonuclear Reactions from Zn^{64} and Fe^{54}

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By the use of a high energy x-ray beam from the Iowa State College synchrotron with the maximum energy adjustable up to 67 Mev, measurements have been made leading to relative cross sections as a function of quantum energy for (γ, n), (γ, pn), and $(\gamma, 2np)$ reactions[1] on the same parent isotope Zn^{64} or Fe^{54}. The curves obtained are shown in Figs. 1 and 2.

The values for the integrated cross sections are evaluated and listed in Table I. The values for zinc agree well with the values reported by Strauch[2] from transition curves in lead for 330-Mev bremsstrahlung. The relative values for $\sigma_{\gamma,2n}$ and $\sigma_{\gamma,pn}$ also agree well with those given by Ghoshal,[3] who produced the compound nucleus Zn^{64} by Ni+α and Cu+p reactions. In addition, the shapes

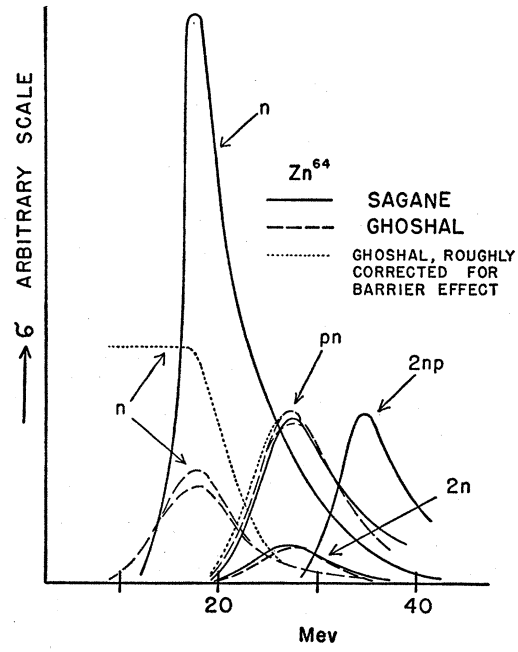

Fig. 1. Relative cross sections *vs* $E_{h\nu}$ for (γ, n), (γ, pn), $(\gamma, 2n)$, and $(\gamma, 2np)$ reactions on Zn^{64}. Excitation functions for n, pn, and $2n$ emission from the same compound nucleus, Zn^{64*}, as reported by Ghoshal are also given.

of these cross section curves *vs* energy agree with the shapes of Ghoshal's curves. Since he showed that his results are in good accord with the statistical theory of the compound nucleus excited to an energy of the order of 30 Mev, this agreement with the present data shows that competition in the excited nucleus can satisfactorily explain the results for $(\gamma, 2n)$ and (γ, pn) processes. It is also to be noted, however, that the (γ, n) cross section reported here is relatively seven times higher than that obtained by Ghoshal. Since the processes of excitation are different and it is known that the cross section for excitation to 18 Mev by charged particles will be lower than that for excitation to 30 Mev (by a factor of 1.5 to 2, because of the potential barrier which is particularly significant for incoming particles with large l values), this difference in $\sigma_{\gamma,n}/(\sigma_{\gamma,2n}+\sigma_{\gamma,pn})$ must indicate that the cross section for gamma-ray absorption is several times larger at 18 Mev than at 30 Mev. In addition, it is to be noted that, for Zn^{64}, $\sigma_{\gamma,p}$ is probably at least as large as $\sigma_{\gamma,n}$ in the region of 18 Mev.[4] It seems

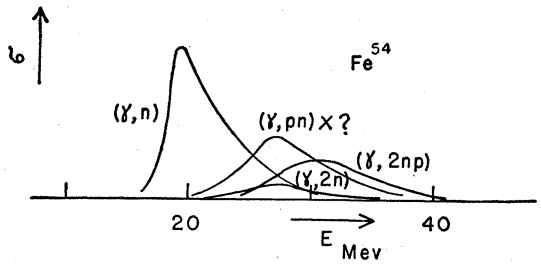

FIG. 2. Relative cross sections *vs* $E_{h\nu}$ for (γ, n), (γ, pn), $(\gamma, 2n)$, and $(\gamma, 2np)$ reactions on Fe^{54}.

definite, therefore, that the total cross section for gamma-ray absorption by the Zn^{64} nucleus has a peak in the neighborhood of 20 Mev and falls off above this. Such a behavior is suggested by the dipole resonance of Goldhaber and Teller.[5] To state the matter in another way, the results reported here show that the fall-off

TABLE I. Relative integrated cross sections for (γ, n), (γ, pn), $(\gamma, 2n)$, and $(\gamma, 2np)$ reactions on Zn^{64}, Fe^{54}, Ge^{70}, and Ni^{58}, together with the same for $(\gamma, 2p)$ and $(\gamma, 2np)$ for Al^{27}.[a]

Outgoing particle	Product isotope	Half-life	Relative integrated cross sections: Strauch $\sigma_{int.}$	Strauch Rel.	Sagane Measured	Sagane Corrected for $Nh\nu$	Ghoshal
n	Zn^{63}	38 min	0.89	300	500±200	300±150	40
Zn^{64} $2n$	Zn^{62}	9.5 hr	0.067	23	23^{+10}_{-5}	23^{+10}_{-5}	24
pn	Cu^{62}	10 min	0.37	125	100	100	100
$2np$[b]	Cu^{61}	3.4 hr	0.17	60	70±20	80±20	···
n	Fe^{53}	8.9 min			100	65	
$2n$	Fe^{52}	7.8 hr			14±8	14±8	
Fe^{54} pn	Mn^{52}	20 min			8		
		6 day			?	?	
$2np$	Mn^{51}	46 min			20±10	20±10	
Al^{27} $2p$	Na^{25}	60 sec			100		
$2pn$	Na^{24}	14.8 hr			50±25		
n[b]	Ge^{69}	40 hr			100		
Ge^{70} $2n$	Ge^{68}	250 day			?		
pn[b]	Ga^{68}	68 min			12		
$2np$	Ga^{67}	78 hr			small		
n[b]	Ni^{57}	36 hr			100		
Ni^{58} pn	Co^{56}	80 day			?		
$2np$[b]	Co^{55}	18 hr			2		

[a] Corrections were made for self-absorption, back scattering, and the percentage of K-capture.
[b] Because of the experimental difficulties, the accuracy of these values is poor.

of the (γ, n) cross section above 20 Mev is caused not only by competition from other reactions, but also by a fall-off in the total cross section for gamma-ray absorption.

The result of another type of experiment may be of interest. The ratio of production of two isomers, Mo^{91} (70 sec) and Mo^{91} (16 min), by (γ, n) reactions on Mo^{92} was measured over the energy range from 15 Mev to 67 Mev. As shown in Fig. 3, this ratio remains constant for the whole range of measurement, including the region close to 18 Mev where the $Mo^{92}(\gamma, n)$ reaction shows a very sharp resonance.[6] This result may be regarded as an indication that the sharp resonance found in the $Mo^{92}(\gamma, n)$ reaction is not sensitive to the final states.

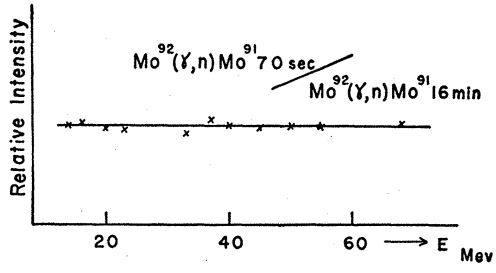

FIG. 3. Relative intensities of the two isomers, Mo^{91} (70 sec) and Mo^{91} (16 min), produced from Mo^{92} by the (γ, n) reaction *vs* the maximum energy of the x-ray beam.

No results similar to those given by Ghoshal are available for Fe^{54} at present. The very high intensity of the (γ, n) reaction, however, appears to indicate a situation similar to that for Zn^{64}.

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The Magnetic Moment of Zn^{67}*

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NUCLEAR induction signals of Zn^{67} with a natural line width at half-maxima of about one gauss were detected in an approximately two molar solution containing the complex ion $Zn(NH_3)_4^{++}$. Signals were also observed in other solutions of Zn salts; e.g., $ZnCl_2$, $ZnSO_4$, and $ZnNO_3$. The resonant frequency was compared to that of N^{14} with the result

$$\nu(Zn^{67})/\nu(N^{14}) = 0.86580 \pm 0.00001. \quad (1)$$

Assuming the spin of Zn^{67} to be 5/2,[1] and with the known value of the magnetic moment of N^{14},[2] the sign and value of the magnetic moment was found to be

$$\mu(Zn^{67}) = +0.87378 \pm 0.00013. \quad (2)$$

No diamagnetic corrections were made in obtaining this value.

The earlier determination of $\mu(Zn^{67}) = +0.9$ by Lyshede and Rasmussen[1] is in agreement with the more precise value of Eq. (2).

The fact that signals of relatively narrow line width were obtained in solutions which did not contain additional paramagnetic ions may be an indication that the necessary relaxation mechanism was provided by the interaction of a relatively weak quadrupole moment of the Zn nucleus with the molecular field gradients.

Careful measurements were made of the signal amplitudes and line widths of Zn^{67} in $ZnSO_4$ and of H^2 in a 0.5-percent solution of D_2O in 8-molar $MnCl_2$. Saturation curves were taken for Zn^{67} in $ZnSO_4$ with the result that the longitudinal and transverse relaxation times were found to have approximately the same value. Applying the phenomenological equation[3] to this case, the spin of Zn^{67} was determined by comparing the obtained signals with those from H^2 and was found to be 2.2 with a standard error of 12 percent. Considering that the nearest other possible spins 3/2 and 7/2 are well outside the experimental value, this result represents a verification of a spin of 5/2[1] for the Zn^{67} nucleus.

The authors wish to express their thanks to Professor F. Bloch for his continued interest in their work.

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