to a higher order of approximation, and including $\Delta I=0$, 2 (yes) as well as no parity change transitions with their cross terms, energy dependence, and plane wave approximations will soon be submitted for publication.

* Assisted by the joint program of the ONR and AEC.
† AEC predoctoral fellow.
[1] In the pseudoscalar treatment of the neutron decay the $\boldsymbol{\sigma}\cdot(\boldsymbol{\nabla}L)$ term gives the same energy correction to the allowed spectrum as the rigorous relativistic matrix element, while the second term gives no contribution. The rigorous matrix element has been worked out in a paper by Yamaguchi, Umezawa, Takebe, and Koiani to appear soon; reference to previous work on the neutron decay is given there.
[2] T. Ahrens and E. Feenberg, Phys. Rev. **86**, 64 (1952); D. L. Pursey, Phil. Mag. **42**, 1193 (1951); these references give

$$\int\gamma_5=(i\Lambda\alpha Z/2\rho)\int\boldsymbol{\sigma}\cdot\kappa$$

and in the same manner it can be shown that

$$2M\int\beta\gamma_5=(\Lambda\alpha Z/2\rho)\int\gamma_5.$$

[3] E. J. Konopinski and G. E. Uhlenbeck, Phys. Rev. **60**, 308 (1941).
[4] A. G. Petschek and R. E. Marshak, Phys. Rev. **85**, 698 (1952).

The Spin and Magnetic Moment of V^{50}

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In the $j-j$ spin orbit coupling model, V^{50}, with 23 protons and 27 neutrons, has 3 protons in the $1f\ 7/2$ shell and 7 neutrons in the $1f\ 7/2$ shell. There are 42 different states available to such a configuration, with spins ranging from 0 to 11. The interaction energy of these states has bee \ calculated. It is found that, for very short range forces, the 4 lowest states have spins 6, 4, 3, and 5, respectively. The energy of these 4 states and of the lowest state of spin 7 has further been calculated for the following forms of an extended range interaction \ ith convenient corresponding radial wave functions:

$$V(\mathbf{r}_{12})=\delta(\mathbf{r}_{12})P,\text{—radial wave function } R_f(r) \text{ irrelevant.} \quad (1)$$

This case is denoted by δ in the table, for a δ-function potential.

$$V(r_{12})=V_0\,[\exp(-\alpha r_{12})/r_{12}]P, \quad (2)$$

where

$$V_0=89\times10^{-13}\text{ Mev cm},\quad \alpha=0.858\times10^{13}\text{ cm}^{-1}.^1$$
$$R_f=N_f r^3\exp(-\beta r),\quad \beta_1=0.6435\times10^{13}\text{ cm}^{-1},$$
$$\beta_2=1.2122\times10^{13}\text{ cm}^{-1}.$$

These cases are denoted by $Y1$ and $Y2$ respectively in Table I, for Yukawa potential.

$$V(r_{12})=V_0[\exp(-\alpha r_{12}^2)]P,\quad V_0=42\text{ Mev},$$
$$\alpha=0.317\times10^{-26}\text{ cm}^{-2}.^1\quad R_f=N_f'r^3\exp(-\beta r^2),\quad (3)$$
$$\beta=0.1089\times10^{+26}\text{ cm}^{-2}.$$

This is denoted by G in the table, for Gaussian potential.

In each case the following forms of the exchange operator P were considered:

(a) $P=(0.8M+0.2H)$, called MH in the table.
(b) $P=(0.3W+0.4M+0.1B+0.1H)$, called Se in the table (Serber mixture).
(c) $P=(0.5W+0.3M-0.3B+0.5H)$, called Sy in the table ("Symmetric" mixture), where W, M, B, and H denote the usual Wigner, Majorana, Bartlett, and Heisenberg exchange operators.

Comparison of wave functions indicates that the region of physical interest corresponds to that between the cases $Y1$ and $Y2$, and probably to the region $0.65<\beta\times10^{-13}<0.75$ for the Yukawa potential.

For the Gaussian potential the region of interest corresponds to $0.08<\beta\times10^{-26}<0.14$. As the table shows, the ground state is in all cases of extended range, one of spin 5. The effect of the Coulomb force, which is not included in the given results, is not great enough to affect this result. The values in the table are subject to a maximum error estimated in the column ME.

The transition to the ground state of either Cr^{50} or Ti^{50} is, therefore, on Gamow-Teller rules, 4th forbidden, corresponding to a half-life of 10^{11} years at least, which is adequate to explain the occurrence of the isotope in nature.

The gyromagnetic ratio of the calculated lowest state has also been obtained, and is shown in the table as "g." This should be compared with the experimental value of 0.557.[2] The calculated value is subject to an estimated maximum error of 3 percent.

It is worthy of note that the experimental gyromagnetic ratio is within 0.2 percent of that which would be expected for any state ($J\neq0$) in which proton angular momentum and neutron angular momentum are separately constants of the motion, having eigenvalues $(7/2)\hbar$. This would be so in the spin 5 state if the proton-neutron force were some 10 times weaker, relative to the proton-proton force. For the state of spin 7 it is very nearly the case without such adjustment, but spin 7 is not in the competition for the ground state.

Finally it may be pointed out that the predicted spin does not agree with the rule of "parallel intrinsic spins" proposed by Scott[3] and in modified form by Nordheim.[4]

It is a pleasure to record that this work has been assisted by the University of Chicago, and by Trinity College, Cambridge.

Table I. Relative energy and gyroscopic ratio of g states of V^{50}. Energies are in Mev, except for case δ, where energies are in arbitrary units. A large positive energy means a tightly bound state. $E(7)$ = energy of state of spin 7, etc. ME is the estimated maximum error.

$V(r_{12})$	P	$E(7)$	$E(6)^a$	$E(5)^a$	$E(4)$	$E(3)$	ME	g^b
δ	any	195	*230*	217	207	221	2	0.542
$Y1$	MH	−2.32	0.06	*0.15*	0.10	0.07	0.02	0.414
$Y1$	Se	−2.36	0.03	*0.09*	0.01	0.02	0.02	0.456
$Y1$	Sy	−2.26	0.05	*0.09*	0.05	0.05	0.02	0.450
$Y2$	MH	−17.62	10.69	*25.45*	19.30	14.70	0.20	0.419
$Y2$	Se	−11.52	3.14	*10.38*	5.99	5.45	0.10	0.440
$Y2$	Sy	−10.34	7.59	*13.63*	11.82	10.42	0.10	0.440
G	MH	−1.52	−1.22	*−0.49*	−2.03	−1.83	0.01	0.407
G	Se	−0.94	−0.25	*0.77*	−0.89	−0.77	0.01	0.421
G	Sy	−2.03	−1.12	*0.08*	−1.81	−1.51	0.01	0.420

[a] The lowest state for each interaction is italicized.
[b] Experimental value = 0.557.

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[1] These values are derived from those given by J. M. Blatt and J. D. Jackson, Phys. Rev. **76**, 18 (1950) and Revs. Modern Phys. **22**, 77 (1950).
[2] Walchi, Leysohn, and Scheitlen, Phys. Rev. **85**, 922 (1952).
[3] J. M. C. Scott "On the Spins of Odd-Odd Nuclei," privately circulated.
[4] L. N. Nordheim, Revs. Modern Phys. **23**, 322 (1951).

A Note on the ζ^0-Meson

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Danysz, Lock, and Yekutieli[1] have recently reported evidence for the existence of a new particle, the ζ^0-meson. From observations on the angular correlation of pairs of charged π-mesons emitted in showers characterized by $2\leqslant n_s\leqslant6$, they present evidence for the existence of an unstable particle with a lifetime less than 10^{-16} second which decays according to the scheme $\zeta^0\rightarrow\pi^++\pi^-+Q$; according to their data Q is several Mev. We have examined a different class of showers[2,3] characterized by a median charged multiplicity of the order of ~20 particles with a median energy of $\sim5\times10^{12}$ ev in an effort to obtain evidence relating to this proposed new particle.

If we assume the existence of this particle decaying in its rest frame according to the above scheme, then if $Q\ll\mu(\equiv$ mass of π-meson), the maximum angular separation between the two mesons is given by $\theta_M=2(Q/\mu)^{\frac{1}{2}}/\gamma_0$, where γ_0 is the energy of the ζ^0-meson (in units of its rest mass) in the laboratory system. From the target diagrams of our showers we have determined the angular separation θ_s of pairs of shower particles (presumed π-mesons) in the diffuse part of the shower and the polar angle θ with respect to the shower axis of the line bisecting θ_s. We have assumed that the ζ^0-meson is emitted at this angle θ with an energy γ_0 given by[4]

$$\gamma_0(\theta) = \frac{\bar{\gamma}_0\bar{\gamma}(1+\tan^2\theta)\pm(\bar{\gamma}_0-1)^{\frac{1}{2}}(\bar{\gamma}-1)^{\frac{1}{2}}[1-(\bar{\beta}^2/\bar{\beta}_0^2-1)\bar{\gamma}^2\tan^2\theta]^{\frac{1}{2}}}{1+\bar{\gamma}^2\tan^2\theta}.$$

A monoenergetic spectrum for $\bar{\gamma}_0$ in the center-of-mass system was assumed and the variation of γ_0 with θ was calculated for $20\leqslant\bar{\gamma}\leqslant 50$ with $\bar{\gamma}\geqslant 5$. In this way it was possible with a given θ_s and θ to determined $\gamma_0(\theta)$ and therefore θ_M; Q was taken as 6 Mev. Thus if $\theta_s\leqslant\theta_M$ this pair of mesons could presumably have arisen from the proposed ζ^0 decay scheme.

A total of 21 showers were examined encompassing 278 diffuse shower particles. It was found that the angular separation θ_s for 31 pairs of these particles was such that they could have arisen from ζ^0-meson decay; the criterion $\theta_s\leqslant\theta_M$ was insensitive to the particular choice of parameters given above. On the other hand we expected a certain number of electron-positron pairs arising from the conversion of γ-rays resulting from the two photon decay of the neutral meson. Using the value[3] of 0.41 for the ratio of neutral mesons to charged particles and taking into account a finite lifetime for the π^0-meson,[5] we find that at least 26 electron-positron pairs are expected to appear in the observation area: we find then on the assumption that all the charged shower particles observed are π-mesons that 4 ± 4 percent[6] of these mesons can arise via the scheme $\zeta^0\rightarrow\pi^++\pi^-+Q(<6$ Mev). We believe, however, that our data do not require the introduction of this new particle to explain the observed angular correlations.

A possible explanation of the observations of Danysz, Locke, and Yekutieli has been suggested by Brueckner and Watson.[7] They suggested that the observed angular correlations of Danysz *et al.* are due to distortions introduced in the outgoing meson wave function by an attractive meson-meson potential: this might be expected to have a relatively strong influence for the relatively low energy mesons observed in low multiplicity showers, whereas it would be expected to be a very small effect in the very high energy showers reported on in this note.

[1] Danysz, Lock, and Yekutieli, Nature 169, 364 (1952).
[2] M. F. Kaplon and D. M. Ritson, Phys. Rev. 85, 932 (1952).
[3] M. F. Kaplon and D. M. Ritson, Phys. Rev. to be published.
[4] Bradt, Kaplon, and Peters, Helv. Phys. Acta 23, 24 (1950).
[5] Kaplon, Peters, and Ritson, Phys. Rev. 85, 900 (1952).
[6] B. Peters (private communication) has made an analysis similar to ours in the diffuse cone of energetic showers and finds no evidence for the existence of the ζ^0-meson. Danysz and co-workers find on the assumption of the existence of the ζ^0-meson that 10 percent of the charged π-mesons arise from its decay; J. Y. Mei and E. Pickup, Phys. Rev. 86, 796 (1952) report a similar figure if the ζ^0 is assumed to exist.
[7] K. A. Brueckner and K. M. Watson, Phys. Rev. 87, 621 (1952).

Some Effects of Ionizing Radiation on the Formation of Bubbles in Liquids*

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FOR many problems connected with the study of high energy nuclear events and their products in cosmic-ray interactions, it would be very desirable to have available a cloud-chamber-like detector whose sensitive volume is filled with a hydrogen-rich medium whose density is of the order of 1 g/cc. In investigating possible ways of making such an instrument, it seemed promising to try to make a device which takes advantage of the instability of superheated liquids against bubble formation in the same way that a Wilson cloud chamber utilizes the instability of supercooled vapors against droplet formation.

A macroscopic continuum theory of the stability of small bubbles in a superheated liquid has been developed which predicts that bubbles carrying a single electronic charge will tend to collapse more readily than uncharged bubbles, while bubbles carrying two or more charges will be unstable against rapid growth under some circumstances. On the basis of this picture one can estimate the conditions of temperature and pressure under which a pure liquid in a clean vessel becomes unstable against boiling due to the presence of ions.

An experimental test of the theory for radiation-induced ionization was made by maintaining diethyl ether in a thick-walled glass tube at a temperature near 130°C and under a pressure of about 20 atmospheres. In the presence of a 12.6-Mc Co^{60} source, the liquid in the tube always erupted as soon as the pressure was released, while when the source was removed, time delays between the time of pressure release and eruptive boiling ranged from 0 to 400 seconds with an average time of about 68 seconds. The average time between successive traversals of the tube by a hard cosmic-ray particle is estimated to be 34 seconds.

A second test was made by removing the Co^{60} source from its lead shield at a distance of 30 feet from the ether tube while the latter was sensitive and waiting for a cosmic-ray or local ionizing event. In every case the tube erupted in less than a second after exposure to the source.

A "coincidence telescope" consisting of two parallel tubes was constructed and coincidences apparently resulting from vertical cosmic rays were observed with roughly the expected ratio of single to coincident eruptions. The coincident bubbles occurred near each other in the two neighboring tubes, but other single events occurred at random at different places in the tubes.

According to the proposed explanation of the radiation sensitivity of bubble formation, one expects the threshold conditions of temperature and pressure of the system to be different for the formation of bubbles carrying 2, 3, 4, or more elementary charges. The shapes of the observed delay time curves for different pressures and temperatures are consistent with this expectation.

On the basis of the suggested model for the observed phenomena, it is possible to estimate with the aid of a statistical hole theory of liquids the influence of ionizing radiation and ionic impurities on phenomena such as turbulent and supersonic cavitation, tensile strength and compressibility of liquids, scattering of supersonics in liquids near their boiling points, "bumping" of boiling liquids, maximum attainable superheats in liquids, etc. Further details concerning the experimental and theoretical aspects of the problem will be published elsewhere.

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Effect of Radiation on Elastic Constants

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DIENES[1] has recently published a calculation of the effect of interstitial ions and vacant lattice sites on the elastic constants of copper and sodium. He finds that 1 percent of vacant lattice sites decreases all the elastic constants by about 1 percent, while 1 percent of interstitial ions increases some of the lattice constants of copper by 10 percent. He uses an approximation in which the distorted lattice deforms homogeneously under a homogeneous applied stress; the large increase of energy around interstitial ions which are already abnormally close to their neighbors gives rise to large increases in the elastic constants. The purpose of the present note is to show that this approximation overestimates the difference between the effects of interstitial ions and of vacant lattice sites, because a homogeneous applied stress will produce less distortion near an interstitial ion than it does in the matrix, and, similarly, more distortion near a vacant site. This may most readily be seen by considering the limiting case in which the interstitial ion is rigidly wedged between its neighbors. On Dienes's approximation this rigid wedging would make an infinite contri-