should be evaluated for d-states between 1 and 2 since the predominantly $\cos^2\theta$ angular distribution from the $(p+p\rightarrow\pi^++d)$ interaction shows that the final nucleons are mostly in d-states. In the calculations, s-state wave functions were used for simplicity in view of the crude nature of other approximations.

If one assumes that the deuterium neutron does not influence the production except for the momentum distribution it gives to the deuterium proton[6] and the interactions among the three nucleons in a triton, the cross section $\frac{d\sigma}{d\Omega}(p+d\rightarrow H^3+\pi^+)$ can be estimated in terms of $\frac{d\sigma}{d\Omega}(p+p\rightarrow\pi^++D)$ as

$$\frac{1}{3v_{PD}}\left|\int d\mathbf{x}\frac{\psi_T(0,x)}{\psi_D(0)}\exp\left[i\left(\frac{\mathbf{k}}{2}-\frac{\mathbf{q}}{3}\right)\cdot\mathbf{x}\right]\psi_D(x)\right|^2\frac{E_T}{E_\pi+E_T}\times\left[\frac{d\sigma}{d\Omega}(p+p\rightarrow\pi^++D)\frac{v_{PP}(E_\pi+E_D)}{E_D}\right]. \quad (5)$$

E is the total energy in the center-of-mass system including rest mass; $\mathbf{k}$ is the momentum of the incident proton in the center of mass system; $\mathbf{q}$ is the meson momentum. The quantities in the bracket are evaluated at that energy which gives mesons of momentum $\mathbf{q}$. The factor $1/3$ arises from the various spin sums.

We choose for the spatial part of the wave functions:

$$\psi_D(r)=\frac{e^{-\beta r}-e^{-\gamma r}}{r}\left(\frac{\beta\gamma(\beta+\gamma)}{2\pi(\beta-\gamma)^2}\right)^{\frac{1}{2}} \quad (6)$$

and[7]

$$\psi_T(0,r)=(\alpha^3/8\pi)e^{-\alpha r}, \quad (7)$$

with $\gamma=6\beta$, $\beta=0.32/\lambda$, $\alpha=1.6/\lambda$, $\lambda=1.4\times10^{-13}$ cm.

The differential cross section in the center-of-mass system for 345-Mev incident protons is given in Fig. 1. $\sigma(p+p\rightarrow\pi^++D)$ for 90-Mev center-of-mass mesons was extrapolated from detailed balancing on lower energy π absorption[8] to be about $6.4(0.07+\cos^2\theta)\times10^{-28}$ cm^2 sterad^{-1}, which is 20 times $\sigma(p+p\rightarrow\pi^++D)$ for 345-Mev incident protons. Although this estimate is uncertain the very large increase of this cross section with meson energy, which is certainly present, makes $\sigma(p+d\rightarrow H^3+\pi^+)$ fairly large, approximately 1.3×10^{-29} cm^2.

† This work was performed under the auspices of the AEC.
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[6] The use of an impulse approximation is better here than in the deuterium pick-up calculations [G. F. Chew and M. L. Goldberger, Phys. Rev. **77**, 470 (1950)], where the momentum transfer between the incident and struck nucleon is about equal to the internal momentum that the struck deuteron must have for pick-up to be probable.
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Some Observations on the Gamma-Radiation from Polonium

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THE gamma-radiation from polonium has been the object of a number of recent investigations,[1–5] but the present understanding of the situation is far from satisfactory. This is particularly so with regard to the soft radiation of energy about 80 kev, thought by Zajac *et al.*[2] to be nuclear in origin. Grace *et al.*[3] have recently found evidence that this component seems to be almost entirely the x-radiation of lead following the internal conversion of the well-established hard component at 800 kev, and have estimated the internal conversion coefficient by a study of the internal conversion electrons involved as being 6.7 percent.

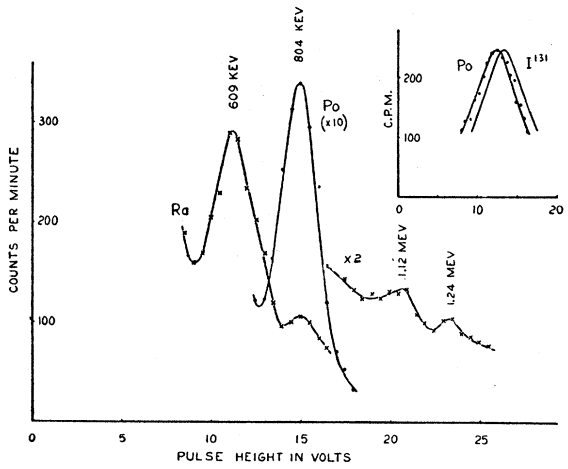

FIG. 1. Pulse-height distribution for the gamma-radiation from polonium 210.

With this interpretation the measurements of Zajac *et al.* would have given a value close to 100 percent. Further information comes from Alburger and Friedlander,[4] who investigated the secondary electrons with a beta-ray spectrometer and concluded that the conversion coefficient must lie in the range 1 to 5 percent. De Benedetti and Minton, as a result of alpha-gamma angular correlation experiments, have shown that the 800-kev component is probably $E2$, and thus imply that the conversion coefficient is less than 1 percent.

In an attempt to clarify this confusing situation certain observations have been made on the radiations involved, using a coincidence scintillation spectrometer and a weak source of polonium in solution from which all traces of Ra and RaD had been removed. Single channel pulse height distribution analysis (Fig. 1) gave a value of 804 ± 5 kev for the energy of the hard component, considerably above the Siegbahn value of 773 kev, but in excellent agreement with the Alburger and Friedlander value of 800 ± 6 kev obtained with a beta-ray spectrometer. Several standard gamma-ray energies were used for purposes of calibration, and the value of 804 kev is a mean for a number of experiments. The calibration source used for the Fig. 1 distribution was a Ra contaminated Po source, so that a residue of the Po line can be seen in the calibration curve. No evidence could be found to suggest the presence of any other component in the gamma-radiation from Po in the range 100 kev to 2 Mev.

Single channel analysis of the soft component failed to reveal any structure because of the limited resolution available at this energy in a scintillation spectrometer, but careful measurements relative to the I^{131} 80.1-kev gamma-ray gave an average energy of 77 ± 2 kev (see Fig. 1). This result is the mean of a number of determinations made with a five-channel kicksorter and also by means of the now conventional photographic storage methods employing a cathode-ray oscillograph. The value is not in disagreement with the observations of Grace *et al.*, for, although the mean energy is significantly above the value of 73 kev given by them for the main component, it agrees well with the conclusions of their critical absorption experiments that one-third of the radiation has an energy higher than 76.5 kev, and most of this is higher in energy than 78.6 kev. On the other hand, the value obtained in this investigation disagrees with the conclusion of Zajac *et al.* that no significant component of the soft radiation lies between 69.4 and 80.7 kev.

An estimate has been made of the intensity of the soft component relative to the hard component from a knowledge of the relative counting rates in the apparatus and the detection efficiencies for the two radiations. On the assumption that the soft component is entirely x-radiation following internal conversion of

the 804-kev gamma-ray, a conversion coefficient is obtained for this radiation of 20 to 30 percent. This value of the conversion coefficient would require the 804-kev gamma-radiation to be $M4$, but considerations of parity and angular momentum[5] in this transition between two even-even nuclei indicate the radiation must be electric.

If, in fact, the internal conversion coefficient for the 804-kev gamma-ray is about 5 percent and the soft component is K-radiation, the above intensity measurements indicate that most of the K-shell ionization is due to processes other than internal conversion, for example, ionization by alpha-particles.[6]

In an attempt to resolve these difficulties a search was made for a possible time association between the two components. A spectrum of coincidences was plotted in the region of 80 kev, with one channel set on the high energy component only. No significant coincidences to the 77-kev component were observed with a resolving time of 0.3 microsecond, and it was concluded that less than 1 percent of the soft radiation is in coincidence with the 804-kev component. This was taken as evidence that, even if part of the soft radiation is nuclear in origin, a prompt cascade de-excitation process does not exist.

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Wall Energy of Ferroelectric Domains

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THE present paper will give a simple tentative explanation of the behavior of small ferroelectric particles reported in a previous letter.[1]

The stable domain configuration of an isolated and nonconducting ferroelectric crystal corresponds to a minimum of the sum of wall energy and volume energy. The arrangement of the domains which has to be expected for a KH_2PO_4-crystal is shown in Fig. 1.[2] Assuming a cube-shaped crystal with edges D, consisting of n domains and imbedded in a medium with the dielectric constant ϵ, the depolarization energy is[3]

$$W_{\text{dep}} = 1.7 P^2 D^3/n\epsilon. \tag{1}$$

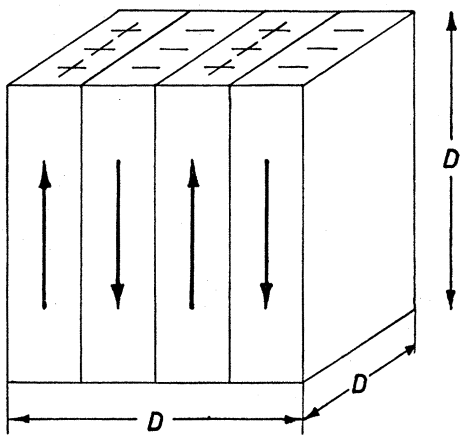

FIG. 1. Expected arrangement of the domains for a KH_2PO_4 crystal.

For the surface energy density of the domain walls, we may put $\sigma = \alpha P^2$. Hence,

$$W_{\text{wall}} = (n-1)\alpha P^2 D^2. \tag{2}$$

These energies are now introduced into the well-known Mueller interaction theory.[4] According to Mueller the free energy density of the shorted (single domain) crystal is

$$A = (T - T_C)P^2/2C + \tfrac{1}{4}\xi' P^4 + \cdots, \tag{3}$$

where T_C is the Curie temperature ($=123°\text{K}$), C is the constant of the Curie-Weiss law ($=260°\text{C}$),[2] and the coefficients ξ', $\cdots$ are assumed to be independent of temperature.

Introducing W_{dep} and W_{wall} into Eq. (3), the total free energy of the free energy of the crystal described above turns out to be

$$Aa^3 = a^3[P^2\{T - T_C + 3.4C/n\epsilon + 2(n-1)\alpha C/D\}/2C + \xi' P^4/4 + \cdots]. \tag{4}$$

Comparing this expression with (3), we find that the Curie temperature is lowered by

$$\Delta T_C = -\{3.4C/n\epsilon + 2(n-1)\alpha C/D\}. \tag{5}$$

The stable domain number n corresponds to a minimum of $|\Delta T_C|$. Hence, for given ϵ and D, the relation between ΔT_C and α is unique.

For small particles the second term in (5) becomes important. The measurement of the Curie temperature of small isolated particles allows, therefore, the evaluation of the wall energy coefficient α. The previously reported investigations on colloidal KH_2PO_4 have now been completed by dielectric measurements with an improved sample technique.[5] A lowering of the Curie temperature with decreasing ϵ and decreasing D has been observed.

For $\epsilon \sim 5$ and $D \geq 4000$A the Curie point was found to be above the temperature of liquid nitrogen (i.e., $|\Delta T_C| < 46°\text{C}$). From this an upper limit for α can be deduced:

$$\alpha < 26 \times 10^{-8} \text{ cm}.$$

On the other hand, for $\epsilon \sim 5$ and $D \leq 1500$A the Curie point is below the temperature of liquid nitrogen (i.e., $|\Delta T_C| > 46°\text{C}$), indicating a lower limit

$$\alpha > 9 \times 10^{-8} \text{ cm}.$$

These limits are consistent with the assumption of classical dipole-dipole interaction together with a domain wall thickness of a few lattice constants.[6]

The value of the spontaneous polarization being[2] 5×10^{-6} coulomb/cm^2, the limits for the surface energy density of a domain wall are

$$20 < \sigma < 58 \text{ erg/cm}^2.$$

The author is indebted to Professor P. Scherrer for illuminating discussions.

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Anomalous Magnetic Resonance Absorption of Cu^{++}

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IN magnetic resonance absorption of salts containing Cu^{++}, no structure is observed in the resonance lines except for hyperfine structure. The reason is that the ion is in a ^2D state and