Now $u$ can be expanded in a series the first term of which is $u_0$, as follows

$$u=u_0+\sum_{n=1}^{\infty}k^{-n}\cdot\int_0^r dr_n\cdot\int_0^{r_n}dr_{n-1}\cdots\int_0^{r_2}dr_1 \cdot V(r_1)\cdot V(r_2)\cdots V(r_n) \cdot K(r_n, r)K(r_{n-1}, r_n)\cdots K(r_1, r_2)u_0(kr_1), \quad (4)$$

where $K(r, s)=u_0(kr)\cdot v_0(ks)-u_0(ks)\cdot v_0(kr)$ and $v_0$ is defined by

$$v_0(z)=(-)^l\cdot(\tfrac{1}{2}\pi z)^{\frac{1}{2}}J_{-l-\frac{1}{2}}(z). \quad (5)$$

If all terms but $u_0$ are omitted in the first approximation and we put $f_0(k)=(d/dk)[k\sin\delta(k)]$, we obtain

$$f_0(k)=2\int_0^{\infty}u_0u_0'\cdot r\cdot V(r)\cdot dr. \quad (6)$$

The solution of this equation can be written in the form

$$V(r)=(8/\pi\cdot l!)\int_0^{\infty}k\cdot f_0(k)dk\cdot\int_0^1(ktr)^l \cdot(1-t^2)^l\cdot v_l(2ktr)\cdot dt. \quad (7)$$

Here $v_l$ is identical with $v_0$ defined in (5).

In the case $l=0$ we have $v_l(z)=\cos z$ and thus

$$V(r)=8/\pi\int_0^{\infty}kf_0(k)dk\cdot\int_0^1\cos 2ktrdt =4/\pi\cdot\int_0^{\infty}f_0(k)(\sin 2kr/r)dk, \quad (8)$$

as can be obtained directly from the theory of Fourier integrals.

Formally it will be possible to continue to higher approximations. In doing so we do not change the form of the integral equation, only the function $f_0(k)$ will be modified.

A fuller account of the investigation will be presented in the Arkiv f. Mat., Astr. o. Fys., Stockholm.

I wish to express my gratitude to Professor W. Pauli, Zürich, for suggesting this investigation and for valuable discussions.

## A Coincidence Study of $Ga^{72}$*

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*Bartol Research Foundation of the Franklin Institute, Swarthmore, Pennsylvania*
July 31, 1947

BETA-GAMMA and gamma-gamma coincidences in the disintegration of radioactive $Ga^{72}$ prepared in the Clinton pile have been reinvestigated[1] with the aid of two thin-walled Geiger counters, a coincidence circuit, and a scale of sixty-four. The details of the technique have been described in several publications.[2]

In the case of beta-gamma coincidences, measurements were extended to a beta-ray energy of 1.93 Mev, and all data were corrected for gamma-gamma coincidences, gamma-ray singles in the beta-ray counter, and accidental coincidences. The accidentals were determined by the expression

$$A=N_1N_2(K\tau),$$

where $K\tau$ was four microseconds. The coincidence arrangement was investigated with a strong beta-ray source to ascertain that no genuine coincidences were lost at the resolving time employed. The beta-gamma coincidences per beta-particle recorded in the beta-ray counter are plotted in Fig. 1 as a function of the thickness of aluminum absorber (wall thickness of the beta-ray counter included) between the thin source and the beta-ray counter. The genuine beta-gamma coincidences per beta-particle were observed to decrease from an extrapolated value of $1.63\times10^{-3}$ at zero absorber thickness to $0.58\times10^{-3}$ at a beta-ray energy of 0.72 Mev as determined by Sargent's equation.[3] The soft beta-ray spectrum of $Ga^{72}$, therefore, has a maximum energy of 0.72 Mev.

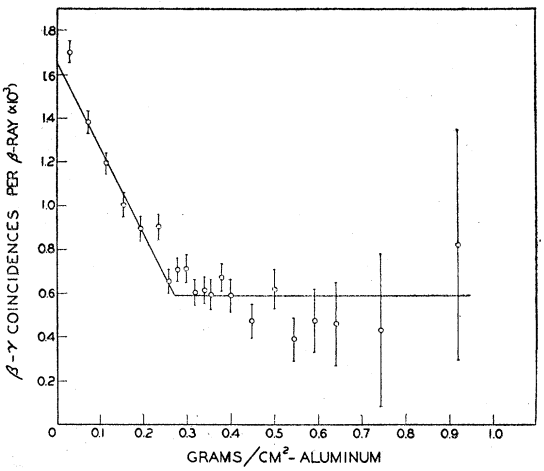


FIG. 1. Beta-gamma coincidences in the disintegration of radioactive gallium.

Gamma-gamma coincidences were observed to be $(0.84\pm0.10)\times10^{-3}$ per quantum recorded in the gamma-ray counter.

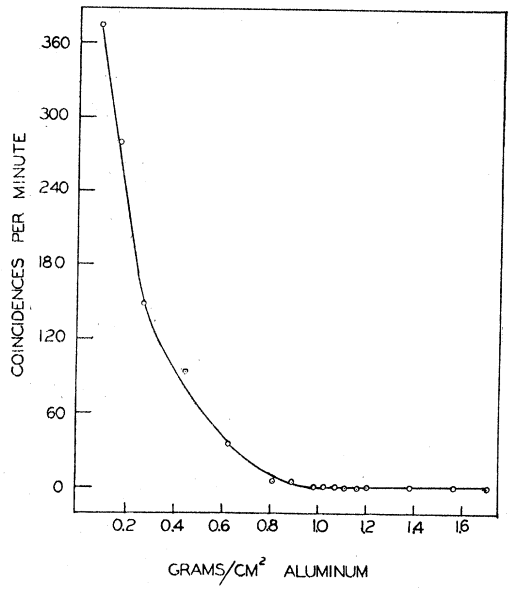


FIG. 2. Coincidence absorption of the Compton recoils of the gamma-rays from $Ga^{72}$.

The energy of the hard quanta emitted by $Ga^{72}$ has been measured by semicircular focusing of Compton recoils,[4] photoelectric lines in a magnetic lens spectrometer,[5] photoneutron scattering cross section,[6] and coincidence absorption.[1] The values obtained were 2.65, 2.25, 2.50, and 2.4 Mev. The data for coincidence absorption of Compton recoils of the gamma-rays from radioactive gallium are given in Fig. 2. The end point taken from the curve is 1.00 g/cm². This corresponds to a quantum energy of 2.29 Mev.

* Supported by the Office of Naval Research.

[1] A. C. G. Mitchell, E. T. Jurney, and Margaret Ramsey, Phys. Rev. **71**, 324 (1947).
[2] L. M. Langer, A. C. G. Mitchell, and P. W. McDaniel, Phys. Rev. **56**, 422 (1939); J. V. Dunworth, Rev. Sci. Inst. **11**, 167 (1940); F. Norling, Arkiv. f. Mat. Astr. och Fysik **B27(3)**, 9 (1941).
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[4] C. E. Mandeville, Phys. Rev. **64**, 147 (1943).
[5] L. C. Miller and L. F. Curtiss, Phys. Rev. **70**, 983 (1946).
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# Proceedings of the American Physical Society

## Minutes of the Meeting of the New England Section at Amherst, Massachusetts

May 31, 1947

THE twenty-eighth meeting of the New England Section of the American Physical Society was held at Fayerweather Laboratory of Physics of Amherst College in Amherst, Massachusetts, on Saturday, May 31, 1947. Ninety-seven members of the Section registered. The programme included a symposium of five invited papers on the subject of nuclear physics. There follow the titles of the invited papers and the abstracts of the ten-minute papers relating to research. Abstracts of ten-minute papers relating to the teaching of physics will appear in the American Journal of Physics.

GORDON F. HULL, JR.
*Secretary-Treasurer*

## Symposium on Nuclear Physics

### Invited Papers

**Plans for Brookhaven National Laboratory,** P. M. MORSE, *Brookhaven National Laboratory.*

**Recent Results in Nuclear Magnetic Resonance Absorption,** E. M. PURCELL, *Harvard University.*

**Inelastic Scattering of Protons,** C. B. COLLINS, *University of Rochester.*

**Beta- and Gamma-Ray Level Schemes,** M. D. DEUTSCH, *Massachusetts Institute of Technology.*

**Proton Groups in Transmutations,** E. POLLARD, *Yale University.*

### Contributed Papers

**1. The Calculation of Thermodynamic First Derivatives by use of Jacobians.** F. H. CRAWFORD, *Williams College.*—Starting with the generalized Clausius equation for $dU$ for a system of $n$ degrees of freedom, it is possible to determine any desired first derivative directly in terms of a standard set of first derivatives. The procedure is essentially a generalization of results obtainable from a treatment given by Shaw[1] for the case of $n=2$. Maxwell's equations, $n(n-1)/2$ in number, are written in a concise Jacobian form. Then the desired derivative is expressed directly as a ratio of two $n$th-order Jacobians which involve partial derivatives of the dependent variables concerned with respect to a selected set of independent variables. Provided this set contains no conjugate pairs (i.e., such as $T$ and $S$ or $p$ and $V$, etc.) the Jacobians involve only symmetric or anti-symmetric terms and are particularly simple to handle. It is shown that the number of independent first derivatives in the standard set for the general case is always $n(n+1)/2$. Thus for $n=2$ we have the well-known result that 3 first derivatives must be measured while for a single crystal of the least symmetric type under homogeneous strain, with $n=7$, the set contains 28 first derivatives.

[1] Shaw, Phil. Proc. Roy. Soc. (London) **A234** (1935).

**2. Binding Energy of the Quadrielectron.** AADNE ORE, *Yale University.*—An attempt has been made to determine the energy of a compound consisting of two electrons and two positrons with greater accuracy than in previous calculations. For this purpose a variational function has been used which is similar to the linear combination of "atomic" and "ionic" functions with adjustable screening constants taken by Weinbaum[1] to approximate the hydrogen molecule. Our function may be written $\Psi=\Psi_\beta+c\Psi_\alpha$ where $\Psi_\beta$ is the generalized "atomic" function used previously,[2] whereas

$$2\Psi_\alpha=\exp-\tfrac{1}{2}[(1+\alpha)(r_{1a}+r_{2a})+(1-\alpha)(r_{1b}+r_{2b})]+\exp-\tfrac{1}{2}[(1-\alpha)(r_{1a}+r_{2a})+(1+\alpha)(r_{1b}+r_{2b})]+\exp-\tfrac{1}{2}[(1+\alpha)(r_{1a}+r_{1b})+(1-\alpha)(r_{2a}+r_{2b})]+\exp-\tfrac{1}{2}[(1-\alpha)(r_{1a}+r_{1b})+(1+\alpha)(r_{2a}+r_{2b})].$$

While $\Psi_\beta$ alone yielded the value 0.11 ev for the binding