Other models which may make this process more important will be reported on later.

* Now at Department of Physics, University of Illinois, Urbana, Illinois.
[1] The emission of fast electrons in disintegrations of nuclei by cosmic radiation has been observed by W. B. Fretter, Phys. Rev. **71**, 462 (1947); and Bridge, Hazen, and Rossi, Phys. Rev. **73**, 179 (1948). They have alternately been explained by J. R. Oppenheimer, Richtmeyer Lecture, Annual Meeting of the American Physical Society, January, 1947, as being produced by photons arising from the decay of a hypothetical short-lived neutral meson.
[2] Depending on the charges of the meson and nucleon, steps (1) and (2) may be reversed.

Inappreciable Effect of Compton Shifted Scattering, within a Gamma-Ray Source, on Precision Wave-Length Determinations with the Focusing Crystal Spectrometer

JESSE W. M. DUMOND
California Institute of Technology, Pasadena, California
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THE instrumental line widths obtained with the present 2-meter focusing curved crystal spectrometer[1] are substantially constant and of order $\Delta\lambda = 0.17$ x.u. full width at half maximum Compton shifted scattering in the source material will yield a continuous spectral distribution extending, in the case of single scattering, some 48 x.u. to the long wave side of the primary line. Figure 1 shows how a *step* in

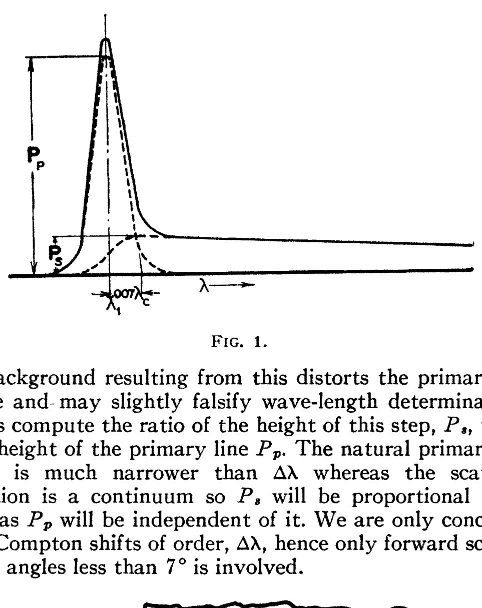

FIG. 1.

the background resulting from this distorts the primary line profile and may slightly falsify wave-length determinations. Let us compute the ratio of the height of this step, P_s, to the peak height of the primary line P_p. The natural primary line width is much narrower than $\Delta\lambda$ whereas the scattered radiation is a continuum so P_s will be proportional to $\Delta\lambda$ whereas P_p will be independent of it. We are only concerned with Compton shifts of order, $\Delta\lambda$, hence only forward scattering at angles less than 7° is involved.

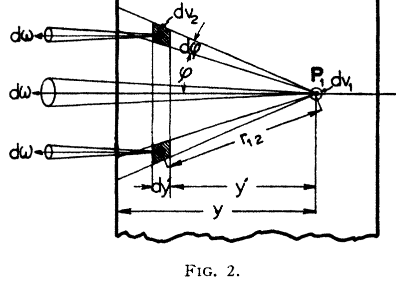

FIG. 2.

In Fig. 2, Y is the thickness of the source in the direction of observation. At P_1 a volume element, dv_1, sends radiation to the spectrometer, (1) by the direct path, (2) by scattering (under scattering angle φ) in other elements of volume such as dv_2. The acceptance solid angle utilized by the spectrometer is $d\omega$ in both cases. We assume the source indefinitely extended laterally to avoid boundary complications. This overestimates the ratio P_s/P_p for many thin sources. Because φ is small the total paths in matter (1) for direct transmission and (2) for single scattering are essentially equal and hence the attenuations (from absorption and scattering) by these two routes cancel out in computing the ratio P_s/P_p. This overestimates P_s/P_p as does also the assumption here made that r_{12} equals y'. Applying the Klein-Nishina scattering formula[2] for unpolarized radiation, integrating over y' and averaging over all depths y one readily obtained the ratio of singly scattered to direct power

$$P_s/P_p = [\pi n e^4/(2m_0^2c^4)](1+\cos^2\varphi)(1+\alpha\,\mathrm{vers}\varphi)^{-3} \times[1+\alpha^2(1-\cos\varphi)^2(1+\cos^2\varphi)^{-1}(1+\alpha\,\mathrm{vers}\varphi)^{-1}Y\sin\varphi d\varphi \quad (1)$$

wherein $\alpha=\lambda_1/\lambda_c$ measures the quantum energy of the primary line ($\lambda_c = h/(m_0c) = 24.2$ x.u., the Compton wave-length) and n is the effective number of electrons per cm^3 of source material. Since $1-\cos\varphi$ is of order 0.007, we may substitute for the second bracket and the two preceding parentheses, for radiation up to say 12 Mev,[3] the numerical value 2. Expressing the wave-length shift in units λ_c as $l=(\lambda_2-\lambda_1)/\lambda_c = 1-\cos\varphi$, $dl = \sin\varphi d\varphi$ and with the approximations just indicated (1) becomes

$$P_s/P_p = [\pi n e^4/(m_0^2c^4)]Ydl. \quad (2)$$

Here P_s is the shifted intensity included *in a shift range dl* so we must substitute for dl the instrumental line width in l-units or 0.007. For the case of our recent precision determination[4] of the annihilation wave-length λ_c from recombination of β^+ and β^- in a neutron activated block of copper 1-cm thick (Cu^{64}), $n=2.5\times10^{24}$ cm^{-3}; $e^4/(m_0^2c^4) = 7.8\times10^{-24}$ cm^2; $Y=1$ cm; $dl=0.007$ and $P_s/P_p = 4\times10^{-3}$, a distortion in the line shape too small for detection.

The author is grateful to Professor C. C. Lauritsen for suggesting this possible source of error and to Professor R. F. Christy for most helpful discussions of it.

[1] J. W. M. DuMond, Rev. Sci. Inst. **18**, 626 (1947); J. W. M. DuMond, D. A. Lind, and B. B. Watson, Phys. Rev. **73**, 1392 (1948); Watson, West, Lind, and DuMond, Phys. Rev. **75**, 505 (1949).
[2] See for example A. H. Compton and S. K. Allison, *X-rays in Theory and Experiment* (D. Van Nostrand Company, Inc., New York, 1935), p. 237, formula (3.139) and p. 119, formula (3.05).
[3] Since P_s/P_p turns out to be so minute only a rough order of magnitude estimate is required and formula (2) would be reliable far above 12 Mev for this.
[4] J. W. M. DuMond, D. A. Lind, and B. B. Watson, Phys. Rev. **75**, 1226 (1949).

On Problems Involving Permutation Degeneracy

E. M. CORSON
Armour Research Foundation, Chicago, Illinois
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THE calculation of energies for many electron problems often resolves itself essentially into the determination of appropriate irreducible representations (n, k) of the symmetric group π_n. Of course, any procedure for this purpose becomes involved for large n, and the usual procedure of constructing the appropriate spin functions offers no simple insight (in routine application) into the structure and relation of the representations for varying n and $k(=n/2-S)$. Primarily for this reason, it seems worth while to consider an alternative inductive, or symbolic, method which yields all physically significant representations by elementary algebra and matrix multiplication.

If we assume all irreducible representations known for π_{n-2}, and that for (n, k) of π_n chosen in reduced form for the elements contained in π_{n-2}, then it follows that we need only find the representative matrix of $P_{n-2,n-1}$; since that of $P_{n-1,n}$ is diagonal with known elements, by virtue of the fact that we are effectively compounding spin vectors by pairs. We