Cu^{63}, which is in fairly good agreement with the measurements of Price[3] on natural Cu. However, the high-energy group in such a composite model would comprise only 0.3 percent of the total neutron yield, much less than the measured value of 10 percent.[4] Hence, even when considered as only a partial picture, the independent particle model falls short.

Probably the reason low-energy transitions predominate in the calculated photon-capture cross section is that all neutron momenta in the square-well nucleus are relatively small. Higher momentum components in the ground-state wave function, such as those which would be produced by stronger interactions of near-neighbor nucleons, would raise the energy of maximum absorption and thus produce better agreement with experiment. At any rate, these calculations show that the independent particle model is definitely inadequate for treatment of photoneutron production in the dipole resonance region.

The author is greatly indebted to Professor V. F. Weisskopf, Professor P. Morrison, Professor H. Feshbach, and to Dr. I. Halpern for valuable discussions and encouragement.

---

* National Science Foundation Predoctoral Fellow.

[1] P. F. A. Klinkenberg, Revs. Modern Phys. **24**, 63 (1952).

[2] See E. D. Courant, Phys. Rev. **82**, 703 (1951).

[3] Glenn A. Price, Ph.D. Thesis, University of Illinois, 1952 (unpublished).

[4] P. R. Byerly, Jr., and W. E. Stephens, Phys. Rev. **83**, 54 (1951).

A "Magnetic Scanning" Method for Investigating Hyperfine Structure and Isotope Shift*

F. Bitter, H. Plotkin, B. Richter,† A. Teviotdale, and J. E. R. Young
Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Massachusetts

(Received May 27, 1953)

THIS note describes a new technique[1] for observing hyperfine structure and isotope shift in absorption lines. Preliminary application has been to the resonance lines of the natural isotopes of mercury and to the radioactive isotope Hg^{197}

The 2537A radiation emitted axially from a Hg^{198} lamp in a magnetic field is passed through a quarter-wave plate and Nicol prism adjusted so as to pass only one of the two σ-components of the normal Zeeman triplet. Since the frequency displacement of this component depends linearly on the field, this arrangement provides us with a monochromatic light source of variable frequency. This light is used to excite selectively the hyperfine components of the resonance radiation of the isotopes in the mercury vapor being investigated. Fields up to 10 000 gauss vary the frequency over a range sufficient to cover the entire hyperfine structure pattern of the resonance line of natural mercury. The intensity of the resonance radiation is observed with a photomultiplier. The effective resolving power of this arrangement is limited only by the width of the radiated and absorbed lines.

Good agreement was obtained between the frequency of the lines as computed from the magnetic field and results obtained by Schüler and Keystone,[2] but anomalous results were found for the intensities. Separate experiments have shown that the intensity of the resonance is not a linear function of the partial pressure, but rather reaches a maximum at total vapor pressures corresponding to temperatures of about 0°C, the position of the maximum being different for different isotopes. The effect is thought to be due to the influence of collisions of the second kind leading to radiationless transitions to the ground state or to the metastable $^3P_0$ state. Further experiments for investigating these effects are in progress.

Since the sample in this experiment is in the form of a vapor in a sealed tube, it is particularly suitable for experiments on radio isotopes which are produced in small quantities. Hg^{197}, produced by bombarding gold with 15-Mev deuterons in the M.I.T. cyclotron, has been made, and the position of the lines in the hyperfine structure pattern observed. In addition to the normal five components of the natural mercury spectrum, presumably due to contamination, several new components were found, whose intensity changed with time. It was not possible to identify these lines in our preliminary experiments, but the results seem at present to be compatible with the spin assignments of the shell model, and of experiments on γ-emission,[3] namely 13/2 for the isomeric state and $\frac{1}{2}$ for the ground state. Further experiments attempting to identify the various newly discovered lines are also in progress.

---

* This work has been supported in part by the Signal Corps, the Air Materiel Command, and the U. S. Office of Naval Research.

† Fellow of the National Science Foundation.

[1] Attention is called to related experiments by O. Buhl, Z. Physik **109**, 180 (1938); **110**, 395 (1938).

[2] H. Schüler and J. E. Keystone, Z. Physik **72**, 423 (1931).

[3] de-Shalit, Huber, and Schneider, Helv. Phys. Acta **25**, 279 (1952).

Mass-Renormalization with the Tamm-Dancoff Method

F. J. Dyson
Laboratory of Nuclear Studies, Cornell University, Ithaca, New York

(Received May 22, 1953)

IN an earlier letter[1] a modified form of the Tamm-Dancoff method was proposed. Let us call the original form of the method[2] "old TD method" and the modified form "new TD method." It was shown that certain divergence problems connected with the self-energy of the vacuum, which are troublesome with the old TD method, are absent with the new TD method.

In this letter we discuss the quite separate divergence problem connected with the self-energy of a single particle. Consider for example the scattering of a pseudoscalar meson by a nucleon, with the symmetric interaction

$$H=iG\int\bar{\psi}(r)\gamma_5\tau_\alpha\psi(r)\phi_\alpha(r)d_3r. \tag{1}$$

Let $a(pu,k\alpha)$ be the Tamm-Dancoff amplitude (old or new) for finding one nucleon with momentum p and spin u, and one meson with momentum k and charge α, in a state of total energy E. Let

$$E_p=(M^2+p^2)^{\frac{1}{2}},\quad \omega_k=(\mu^2+k^2)^{\frac{1}{2}},\quad E_1=E_p+\omega_k,\quad \Delta=E-E_1. \tag{2}$$

To order G^2, the Tamm-Dancoff equation for $a(pu,k\alpha)$ is

$$a(pu,k\alpha)=[S/\Delta]a(pu,k\alpha)+\text{other terms}. \tag{3}$$

Here S is the second-order nucleon self-energy, and the "other terms" describe meson self-energy and meson-nucleon scattering processes. Since S is divergent, we must use mass-renormalization to obtain from Eq. (3) a usable finite equation.

With the old TD method,

$$S=\Sigma_I[|H_{I1}|^2/(E-E_I)]-\Sigma_J[|H_{J1}|^2/(E-E_J)]. \tag{4}$$

Here H_{I1} is the matrix element of H for the transition from the state $(pu,k\alpha)$ to an intermediate state I of energy E_I. The states I are states of one nucleon and two mesons, and

$$E_I=E_q+\omega_{p-q}+\omega_k. \tag{5}$$

The states J are states of two nucleons, one antinucleon, and two mesons, and

$$E_J=2E_p+E_q+\omega_{p-q}+\omega_k. \tag{6}$$

The states J are excluded by the Pauli principle, since they contain two identical nucleons, and this results in the minus sign in Eq. (4). With the new TD method the first sum in S remains unchanged. The second sum is changed (a) by counting the whole sum plus instead of minus, and (b) by using instead of Eq. (6)

$$E_J=-E_q-\omega_{p-q}+\omega_k. \tag{7}$$

With both old and new TD methods, the self-energy of a free nucleon of momentum p is obtained by putting $E=E_1$ in Eq. (4). A plausible nonrelativistic method of mass-renormalization is to subtract the free-particle self-energy from S. Thus we replace