energy balance and the recombination rate, the discrepancy of a factor of about 3 between the experimental and theoretical electron temperatures[12,13] also is traceable to the neglect of collisional de-excitation. The recombination rate and electron temperature can be obtained by solving Eqs. (5) and (9),[14] and the additional energy equation for the ion gas. It is found that at electron temperatures above 2000°K collisional excitation of the $2\,^3S$ level to the $2\,^1S$ and $2\,^1P$ levels followed by radiation is a more probable path for destruction of metastables than is direct collisional de-excitation. The results of these calculations given in Table II are seen to be in general agreement with experiment.

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[4]E. Hinnov and J. G. Hirschberg, Proceedings of the Fifth International Conference on Ionization Phenomena in Gases, Munich, 1961 (North Holland Publishing Company, Amsterdam, 1962), p. 638; and Phys. Rev. 125, 795 (1962).

[5]This has been found to be the case in references 3 and 4.

[6]Hans A. Bethe and E. E. Salpeter, Quantum Mechanics of One- and Two-Electron Atoms (Academic Press, Inc., New York, 1957), p. 269.

[7]M. Gryzinski, Phys. Rev. 115, 374 (1959). Gryzinski's Eq. (23) has been integrated over the initial electron velocity distribution in the limits of large β_p and small β_p. After use of detailed balance the two asymptotic forms have been joined in a suitable way to obtain our Eq. (4) [note that $C(n, n-1)$ is proportional to n^4 for large n]. Our collisional de-excitation rates differ from those used in reference 4 in two ways. First, the rates as given in Eq. (4) above include contributions from optically forbidden transitions which are not small at these energies. Second, they are independent of T at the low-temperature limit rather than proportional to $T^{1/2}$, the former behavior corresponding to an $E^{1/2}$ threshold dependence of the excitation cross section.

[8]The factor γ accounts for the facts that $N(n^*) < N_{\rm eq}(n^*)$ and $N(n^*-1) \neq 0$. If the minimum is very sharp, as when it occurs at $n^* = 2$–4, γ is near one; when the minimum is less sharp, as it is for larger values of n^*, γ decreases to $\frac{1}{4}$.

[9]$\bar{E} \approx |E(n_{\rm cr})|$ plus the contribution from any metastable states lying below the level $n_{\rm cr}$ which are de-excited by collisions with electrons.

[10]See, for instance, Sanborn C. Brown, Basic Data of Plasma Physics (Technology Press of the Massachusetts Institute of Technology and John Wiley & Sons, Inc., New York, 1959), p. 192 ff.

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[13]R. W. Motley and A. F. Kuckes, reference 4, p. 651.

[14]Direct extension of the hydrogenic cross sections and radiative lifetimes to helium is valid above $n = 3$ where helium energy levels closely approach those of hydrogen.

ELASTIC SCATTERING OF 14.5-MeV POLARIZED PROTONS BY PAIRS OF ISOTOPES AND ISOBARS*

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It is now recognized that the potential which describes nucleon-nucleus elastic scattering must contain a spin-orbit term. In present theories,[1] this spin-orbit term is of the Thomas type and is therefore proportional to the gradient of the central potential. If this be so, polarization measurements should be very sensitive to the shape of this potential and hence to the shape of the nuclear surface. We have, therefore, scattered polarized protons from pairs of isotopes and isobars to determine whether a comparison of the resulting left-right asymmetry, for any given pair, reflects a difference or similarity in nuclear surface structure. The results, thus far obtained, indicate that it does.

A beam of 14.5-MeV polarized protons was generated by α-p scattering in essentially the manner previously described.[2] However, the precision and resolution attained in the present experiments were facilitated by two modifications to our apparatus, as follows: (a) The polarized beam is now collected by a 4-inch aperture quadrupole magnet and focussed on a target seven feet away from the first scattering volume, and (b) the H_2 target is maintained at the temperature of liquid nitrogen in order to increase the density of H nuclei and

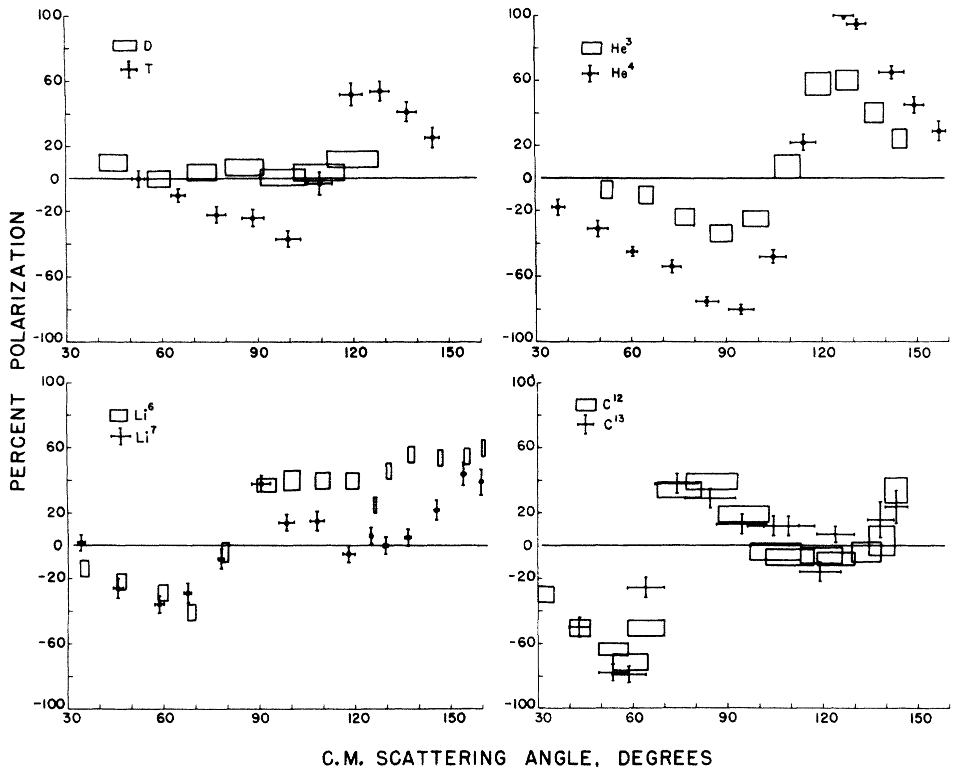

FIG. 1. Angular dependence of the polarization in the elastic scattering of 14.5-MeV protons by isotopes of H, He, Li, and C.

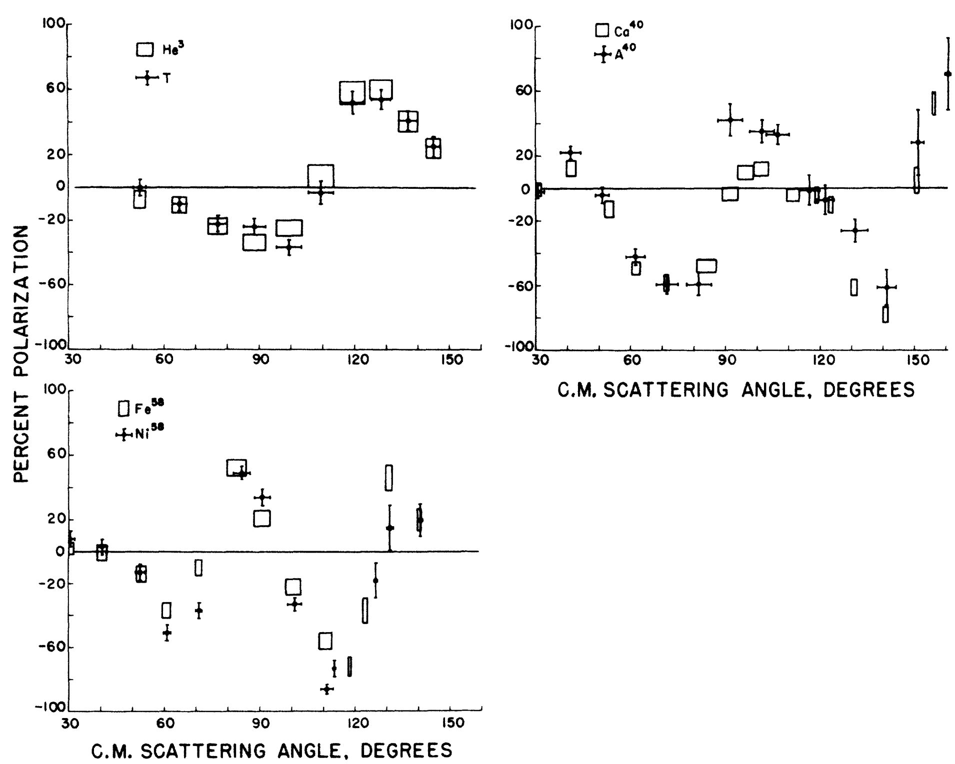

FIG. 2. Angular dependence of the polarization in the elastic scattering of 14.5-MeV protons by isobars of mass 3, 40, and 58.

the tensile strength of the target windows.

The polarized protons were elastically scattered from twelve nuclides comprising four pairs of isotopes and three pairs of isobars. The scattered protons were detected by nuclear emulsions and the angular dependence of the left-right asymmetry was determined for each nuclide. From these measurements was deduced the angular dependence of the polarization that would obtain in the scattering of unpolarized protons under identical conditions. The results are displayed in Figs. 1 and 2.

It is observed (Fig. 1) that the largest differences in polarization occur for the isotopes of H, He, and Li, where we know that the addition of a neutron to the lighter isotope produces a large change in the surface structure. On the other hand, we observe no detectable difference between the mirror nuclei H^3 and He^3 (Fig. 2), although the elastic scattering cross sections for these nuclides differ by a factor of almost two at some angles (implying a very significant difference in the central potentials), and the variation in the symmetry parameter $(N-Z)/A$ is a maximum for this pair of isobars.

C^{12} and C^{13} show very similar polarization patterns, in keeping with the hypothesis that C^{13} consists of a neutron outside a core of C^{12}, which is not much perturbed by the extra neutron. The isobaric pairs Ar^{40}, Ca^{40} and Fe^{58}, Ni^{58} also show very small polarization differences, with $Ar^{40}-Ca^{40}$ indicating the greater difference. This is presumably related to the fact that Ca^{40} is a doubly magic nucleus and that substitution of two neutrons for two protons produces a significant perturbation in the nuclear surface.

It is concluded that polarization measurements may provide a sensitive probe for investigating the surface structure of nuclei.

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[1]See, for example, H. Feshbach, Ann. Rev. Nuclear Sci. 8, 49 (1958).

[2]L. Rosen, J. E. Brolley, and L. Stewart, Phys. Rev. 121, 1423 (1961).

NEUTRON FORM FACTORS AND NUCLEON STRUCTURE*

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Last year new information on the Dirac and Pauli form factors of the neutron was reported.[1-3] A theoretical model based on the existence of two resonances involving pions was proposed by Bergia, Stanghellini, Fubini, and Villi[4]; which was consistent with the Clementel-Villi expressions for the form factors. From a different point of view, an attempt to fit the experimental neutron and proton form factor material in terms of Yukawa clouds with different ranges and delta functions was made by Hofstadter and Herman.[2] As is well known, the Clementel-Villi model is equivalent to the latter interpretation. Therefore the two models are identical in all practical aspects. An important feature of each model was that it gave a neutron rms electric radius of zero and values of the proton rms radii and neutron magnetic radius in agreement with experiment. The Cornell group[5] has confirmed the form factor data and the model of nucleon structure as given in references 1 and 2.

We now wish to present a concise version of our recent results. In summary we find that while the idea of the nucleon models proposed above[1,2,4] appears to be quite satisfactory, the numerical values of the parameters involved require certain changes. Thus the numerical values of the parameters we are now reporting differ from those of the previous Stanford results, and noting the above-mentioned agreement of