the Bi^{209} line appeared as a well-resolved doublet having a separation given by the splitting of the upper state, 0.828 cm^{-1}. The close components in each member of the doublet due to the much smaller ground-state splitting could not be resolved but produced a noticeable widening.

The Bi^{210} samples were obtained as the RaE (5-day half-life) in equilibrium with 13 millicuries of RaD. The Bi^{210} was isolated by the ion exchange method of Raby and Hyde,[1] which was found to give a 98-percent yield with negligible loss of Pb. A number of separations were made at intervals of several weeks. Considerable difficulty was experienced at first with Bi^{209} contamination, so that an efficient separation process was essential. The amount of RaE isolated in each separation was determined by standard β-counting procedures and was usually about 1.5×10^{-7} gram. For Bi^{210}, λ3067 was found to be a single sharp line. An upper limit to any hfs which might possibly be present is roughly 0.1 the width of the Bi^{209} line. Since such a small splitting would lead to an unreasonably small g_I value, it seems much more probable that no splitting is present and $I=0$. Hence the 127th neutron is almost certainly in a $g_{9/2}$ state.

The isotope shift was measured by superimposing an exposure of Cs λ4593 in the second order of the grating which served as a fiducial mark. The Bi^{210} line was shifted to shorter wavelengths by 0.12 cm^{-1}. Further exposures with an improved light source are planned in order to obtain more accurate and extensive shift measurements.

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Phase-Shift Calculation of High-Energy Electron Scattering by Nuclei*

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EXPERIMENTS on the elastic scattering of high-energy electrons ($E\sim125$ Mev) by several elements have been carried out by Hofstadter, Fechter, and McIntyre.[1] The results have been analyzed by them[1] and by Schiff[2] using the Born approximation to estimate the effects of the finite nuclear size.

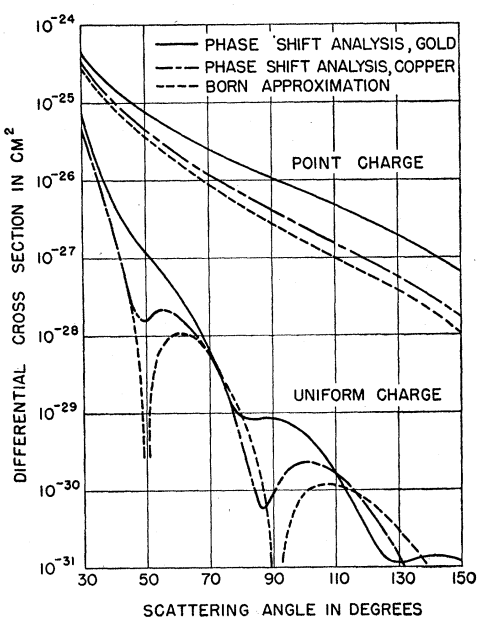

FIG. 1. Scattering from a uniform charge distribution, $kR=5.4$.

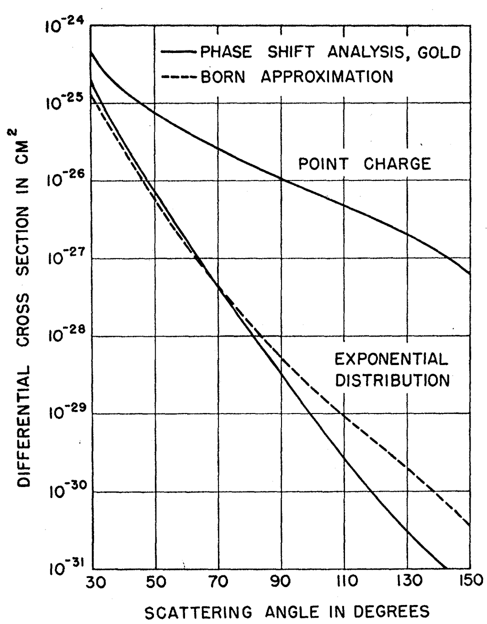

FIG. 2. Scattering from an exponential charge distribution, $ka=0.91$.

On the basis of such an analysis, the results can be fitted well by assuming an exponential distribution of the nuclear charge. Other charge distributions, such as the uniform distribution, are discriminated against because in Born approximation they predict diffraction maxima and minima in the angular distribution. In view of the fact that the Born approximation is not accurate for the heavier elements considered, we have carried out a numerical phase-shift calculation of the process. Our object in the present note is to examine the accuracy of the Born approximation, rather than to attempt to fit the experimental results. Our results are in disagreement with those of Parzen.[3]

The details of the calculation will be published later. Generally the calculation follows the methods given by Parzen[3] and Acheson,[4] with minor modifications. The phase shift relative to the Coulomb phase shift is calculated for the first nine partial waves; the last phase shift used is less than 0.003° in all cases. All the phase shifts are negative and tend monotonically to zero, in disagreement with Elton's assertion[5] that the phase shifts should tend to zero from positive values. We have found it necessary to increase the accuracy of the point scattering amplitudes given by Feshbach,[6] since at large angles this amplitude is largely canceled out by the nuclear size modifications. We estimate that the calculated cross sections given below are accurate to about 5 percent out to 110°; the major errors are contained in the first two phase shifts, which are known to only 0.01°.

The following charge distributions have been used for gold ($Z=79$):

(a) Uniform; $\rho(r)=\rho_0, \quad r<R,$
$\qquad\qquad =0, \quad r>R; \quad kR=5.4;$

(b) Exponential; $\rho(r)=\rho_0 e^{-r/a}; \quad ka=0.91.$

The cross sections given by (a) and (b) are found to decrease in approximately the same ratio between 30° and 90°, and this ratio is roughly that given by Hofstadter's experiment.

For purposes of comparison, we carried through the calculation for copper ($Z=29$) for the uniform charge distribution, with $kR=5.4$. The Born approximation to this cross section is the same, apart from a constant factor $(Z_{\text{copper}}k_{\text{gold}}/Z_{\text{gold}}k_{\text{copper}})^2$, as the Born approximation to (a).

In Fig. 1 are shown the cross sections given by the two uniform charge distributions. If we assume a nuclear radius $r_0A^{\frac{1}{3}}$, with

$r_0=1.22\times10^{-13}$ cm, the curves as shown there correspond to electron energies of 150 and 224 Mev for gold and copper, respectively. (The choice of r_0, and consequently of k, affects the cross sections by a constant factor only. For instance, if $r_0=1.45\times10^{-13}$ cm, the energies are 126 and 188 Mev, respectively.) As is expected, the cross section for copper agrees more closely with the Born approximation than does the cross section for gold. The first minimum predicted by the Born approximation appears in gold as a point of inflection only. The shift of the maxima and minima to smaller angles can be understood qualitatively as due to an increase in wave number as the electron enters the attractive potential of the nucleus. This also makes plausible the increase in slope of the cross section for the exponential distribution compared with the Born approximation, as shown in Fig. 2, and permits the experimental data to be fitted with a smaller a than is required in Born approximation.[1,2]

Further calculations are in progress with charge distributions of intermediate shape.

We wish to thank Professor L. I. Schiff for his advice and suggestions, and Professor W. E. Lamb, Jr. for interesting conversations. Discussions with Professor R. Hofstadter concerning the experiments and his analysis of them have been very stimulating.

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Energy Levels of Be^8

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There is conflicting evidence [1–10] on the spectrum of low states of Be^8, some observations suggesting rather great complexity and other investigations, by failure to observe some of the reported states, suggesting that the array is as simple as seems fitting[2] for so simple a nucleus. It is questionable whether the failure to observe the states in some cases (always with limited resolution and statistical accuracy) may arise from the reaction matrix element being small under these conditions or whether the apparent observation in the other cases arises from statistical illusions. Further observations on a variety of reactions at various angles and bombarding energies will help settle the question. The literature is summarized in Table I, the various states being indicated as (*p*) present in, (*a*) absent from, or (*o*) out of the observed range of, the various observations. The approximate observed width of the ground-state peak is given in Mev, as an indication of resolution. Our present results are also indicated.

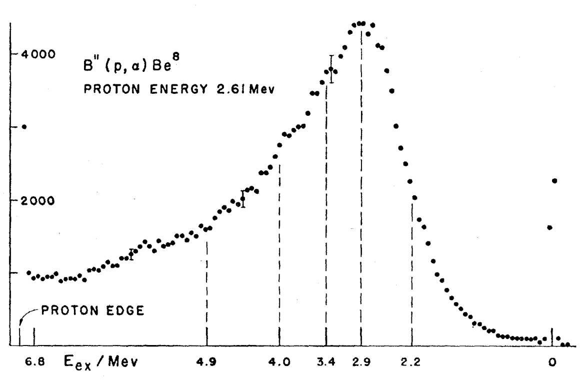

Fig. 1. Alpha spectrum, linear in the magnetic field of the spectrometer.

Table I. Presence (*p*) or absence (*a*) of peaks corresponding to the states of Be^8. The symbol *o* signifies "out of the observed range."

E_{ex}/Mev	0 (width)	2.2	2.9 (broad)	3.4	4.05	4.9	7.5 (broad)
Cambridge[a] (1939)	0.6	*a*	*p*	*a*	*a*	(*p*)	*p*
Rice[b] (1941)	0.6	(?)	*p*	(?)	(?)	*p*	*p*
Cambridge[c] (1949)	0.7	(?)	*p*	(?)	*p*	(*p*)	(*p*)
Zürich[d] (1953)	0.5	*p*	*p*	*p*	*p*	*p*	(6.8)
Hopkins[e] (1953)	0.10	*a*	*p*	(?)	*o*	*o*	*o*
Canberra[f] (1953)	0.3	*a*	*p*	*a*	*a*	*a*	(*a*)
Oak Ridge[g] (1953)	0.6	*a*	*p*	*a*	*a*	*a*	*a*
Copenhagen[h] (1953)	0.1	*a*	*p*	*a*	*a*	*o*	*o*
Present work	0.06	*a*	*p*	*a*	*a*	*a*	*o*

[a] See reference 3. [b] See reference 4. [c] See reference 5. [d] See reference 6. [e] See reference 7. [f] See reference 8. [g] See reference 9. [h] See reference 10.

We have observed the alpha groups from the $B^{11}(p,\alpha)Be^8$ reaction in a 16-inch, two-dimensional focusing magnetic spectrometer at 90° using a proportional counter for detection. The excitation function for the ground-state alphas is found to show resonances for proton energies of 1.98 and 2.61 Mev, corresponding to excited states of the C^{12} nucleus at 17.94 and 18.56 Mev. For each of these proton energies, the region of excitation energy E_{ex} of Be^8 from 0 to 7 Mev has been investigated and only the sharp ground-state peak and the broad 2.9-Mev state peak appear, as shown for the higher resonance in Fig. 1. In spite of the limited statistical accuracy, it is believed that any groups having a peak height greater than about 10 percent of the ground-state group would have been observed.

The statistical basis for the published observations[5,6] of the levels at 2.2, 3.4, and 4.05 Mev is not so good, but it appears at present rather likely that these states do not exist though surely more evidence on this point is desired. Evidence for the 4.9-Mev state rests mainly on an early report[4] of the gamma ray (which may be open to some doubt) and on the (n,γ) coincidence more recently reported[11] too briefly to permit critical judgement, leaving the existence of this state in sufficient doubt that it appears desirable to improve on those data and on our resolution and statistics at least in this region.

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The Mechanism of Stripping Reactions

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The cross section for the reaction[1] $\mathfrak{N}_1(d,p)\mathfrak{N}_2$ is given rigorously by

$$\sigma(d\rightarrow p)=2\pi|\langle p|V+P|\Phi\rangle|^2\rho_E, \qquad (1)$$

where V is the $n-p$ potential in the deuteron, P the interaction $p-\mathfrak{N}_1$, ρ_E the statistical factor, $\langle p|$ the product of a proton plane-wave function by the wave function $\psi_2(\mathbf{r}_n,\rho)$ of the residual nucleus, $|\Phi\rangle$ the wave function describing the whole stationary state of collision initiated by the incident deuteron; we take $\hbar=1$ and denote by ρ, $\mathbf{r}_n$, $\mathbf{r}_p$ the dynamical variables of the nucleons in $\mathfrak{N}_1$ and the neutron and proton coordinates, respectively.

The Born approximation, in the sense of Daitch and French,[2,3] consists in neglecting P throughout and replacing Φ by Φ_d,