material from the sap will cause similar material to leave the cells of the stem and to diffuse into the sap. If this purely chemical reasoning is sound it would follow that the larger the mass of the stem the greater the mass of chemical substances available for the growth of shoots per unit of time. On this basis we should expect that the mass of shoots formed on the node of an isolated piece of stem would be in proportion with the mass of the piece of stem. That this is correct can be shown by cutting a defoliated stem of *Bryophyllum* into as many pieces as it possesses nodes. In this case, each node will produce shoots but their mass will be unequal in the different pieces, and will be greatest where the mass of stem is greatest.

If it is true that in a long defoliated piece of stem only the two shoots of the apical node grow out because practically all the material available in the stem flows to the apex; and that the shoots in the nodes below do not grow out because practically none of the material reaches them, then we should expect that the mass of the two shoots formed at the apex of a long piece of stem should approximately equal the mass of all the shoots which would have been formed if the stem had been cut into as many pieces as it contained nodes. A large number of experiments have been made which have shown that this is correct. The following example may suffice: Four large stems of *Bryophyllum* were defoliated and a piece containing 9 nodes was cut from each defoliated stem. From each piece of stem the three uppermost nodes were cut off and cut into three pieces containing one node each. These 12 one-node pieces produced 23 shoots. The 4 stems, with 6 nodes each, produced all together 8 shoots. After 20 days the dry weight of the shoots and of stems was determined. It was found that the 12 small pieces of 1 node each had produced 23.2 mg. dry weight of shoots per gram of dry weight of stems, while the 4 large pieces with 6 nodes each had produced 26.3 mg. dry weight of shoots per gram of dry weight of stems.

This shows that the mass of the two shoots produced at the apex of a long piece of stem equals approximately the mass of shoots which would have been produced in the same stem in the same time under the same conditions if the shoots could have grown out in all the nodes. This leaves no doubt that the polar character of the regeneration of shoots is due to the fact that all the material available for growth reaches the apical and none of the other nodes of a long piece of stem. The average growth of shoots in small pieces is slightly less than in large pieces in the experiment mentioned (23.2 mg. instead of 26.3 mg.), probably because the extreme ends of each piece die or cease to participate in the supply of material for growth. As a consequence the mass of a stem which supplies material for growth is less when the stem is cut into smaller pieces than when it is left intact.

It had been shown in previous papers that the mass of shoots and roots produced by a leaf of *Bryophyllum* is also in proportion to the mass of the leaf.[1]

A fuller description of the results will be given in the *Journal of General Physiology.*

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THE SCATTERING OF ELECTRONS BY NICKEL

A study of the electron emission from a nickel target under electron bombardment has revealed certain features of this emission which appear to be of considerable interest on account of their probable bearing on the structure of the nickel atom.

Besides the emission of slow-moving secondary electrons characteristic of all metals the emission from nickel contains an appreciable fraction of electrons of higher speed which appear to be scattered directly from the incident beam of primaries by the atoms of the target. The fastest of these scattered electrons have speeds almost if not quite equal to the speed of the primaries. It would appear that the sharp deflections experienced by these scattered electrons must result from their penetrating into the atom structure and being

1 Loeb, J., *J. Gen. Physiol.,* 1918–19, I., 81; 1919–20, II., 297, 651.

swung about by the strong field there encountered. For an electron to thus enter and emerge from an atom without appreciable loss of energy would seem to require that it do so without having a near encounter with any of the electrons of the atom structure. On the other hand the structural electrons may be so anchored in position that no energy is transferred to them in any except very close encounters. The fraction of the primary electrons scattered from a nickel target without appreciable loss of energy is small, not more than one in a thousand being turned back with a loss not to exceed one per cent. of its initial energy.

The distribution of these high-speed scattered electrons in the region in front of the target is particularly interesting. Our observations suggest that it is entirely symmetrical with respect to the incident beam and independent of the inclination of the target to the incident beam except as this affects the region into which the scattered electrons are free to emerge. With a target inclined at an angle of 45 degrees to the incident beam the intensity of scattering as a function of angle has been studied in the plane including the incident beam and the normal to the target. The range of 135 degrees on one side of the incident beam has been explored with the exception of 25 degrees adjacent to the beam. The Faraday box collector used for picking up the scattered electrons can not be brought nearer the primary beam in our present apparatus. The principal features of the angular distribution are two maxima of emission, one back along the path of the bombarding electrons ($\Psi = 0$) and another lateral to the primary beam whose position depends upon the bombarding voltage. The relative importance of these two maxima also depends upon the speed of the primaries.

Fig. 1 shows such a distribution curve for a bombarding potential of 150 volts. The intensity is measured as the ratio of the current entering the Faraday box collector to the total current reaching the target. The opening in the Faraday box subtends about .03 of unit solid angle to the spot under bombardment. The retarding potential between box and target for the curve, Fig. 1, is 135 volts, so that only electrons that have lost not more than 10 per cent. of their initial energy are caught. The effect of bringing the retarding voltage nearer the bombarding volt-

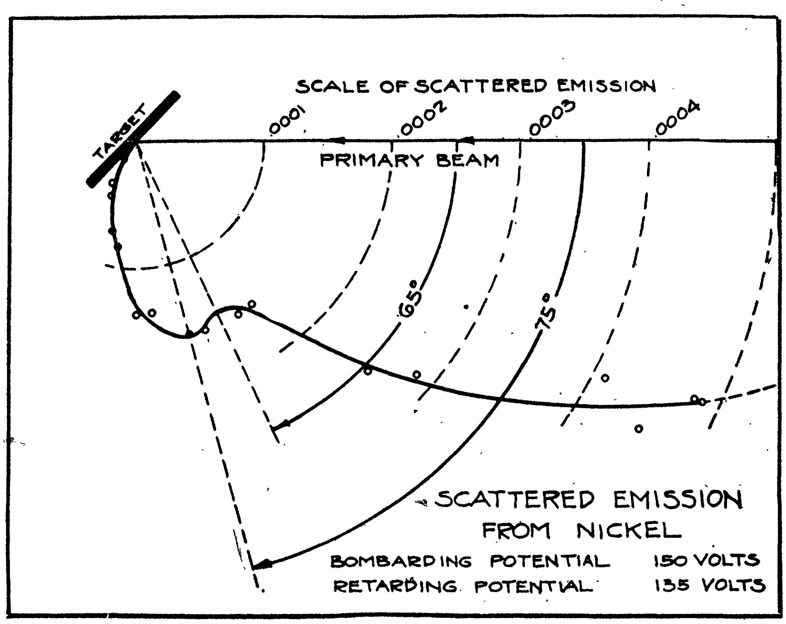

FIG. 1.

age is to reduce the number of electrons caught and to increase the sharpness of the pattern. On decreasing the bombarding potential without altering the ratio of retarding to bombarding potential the lateral maximum moves away from the primary beam toward the plane of the target, and the ratio of the intensity of this maximum to that of the other becomes greater.

In attempting to interpret these results we have been led to consider the scattering of electrons by a positive nucleus of limited field, one for which the central force on an electron is Ee/r^2 for values of r less than ρ, and zero for all values of r greater than ρ. Such a field would exist for a concentrated positive charge E surrounded by a spherical shell of uniformly distributed charge $-E$ and of radius ρ. The field of a system comprising a central positive nucleus of n electronic charges surrounded by n electrons uniformly distributed over the surface of a sphere of radius ρ will also be roughly of this nature, provided n is not too small. Neglecting the change of mass of the bombarding electrons while traversing the field within the shell it turns out that when such a system is under random bombardment by electrons approaching on parallel lines, the number of these emerging per unit solid angle in a direction making an angle Ψ with the path of the incident beam is given by

$$I_\Psi = K\left(\frac{2\beta - 1}{(2\beta - 1)^2(1+\cos\Psi) + (1 - \cos\Psi)}\right)^2,$$

where

$$\beta = \frac{V\rho}{E},$$

V being the potential drop through which the bombarding electrons have acquired their speed.

An examination of this expression shows that when β is very large the intensity of scattering will be small in all directions except in and near the direction $\Psi = \pi$, that is, in the direction of motion of the incident electrons. As β decreases the emerging electrons are less concentrated in this direction. For $\beta = 1$ the distribution becomes entirely independent of angle. As β decreases from unity to the value one half the scattered electrons become more and more concentrated in and near the direction $\Psi = 0$, the intensity in this direction being infinite for $\beta = 1/2$. For values of β less than 1/2 the distribution curves for the range $1 > \beta > 1/2$ are identically repeated, the distribution approaching uniformity in all directions as β approaches zero.

For a neutral system of two or more concentric shells the distribution will be broken up into various beams or lobes corresponding to groups of electrons whose trajectories pass through one, two or more of the shells. In particular a system comprising two shells will give, in an appropriate range of bombarding potentials, distribution curves similar to that shown in Fig. 1.

All of the main features of the distribution curves so far observed for the scattering from nickel seem reasonably accounted for on the supposition that a small fraction of the bombarding electrons actually do penetrate one or more of the shells of electrons which are supposed to constitute the outer structure of the nickel atom and, after executing simple orbits in a discontinuous field, emerge without appreciable loss of energy.

If the theory of the scattering here proposed proves to be the correct one, there seems no reason why the careful study of such distribution curves as shown in Fig. 1 may not reveal much of interest concerning the disposition of electrons within the atom. It is hoped to report more extensively on this work in the near future.

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THE ATOMIC WEIGHT OF BORON

THE application of positive-ray analysis by Aston[1] has yielded the evidence of existence of two isotopes of boron with atomic weights 10 and 11, in accordance with the prediction of Harkins.[2] Although the result of Smith

[1] *Phil. Mag.*, *40*, 628 (1920).

[2] *Jour. Amer. Chem. Soc.*, *42*, 1988 (1920).