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4. Green, A. E. S.: *Phys. Rev.*, **83**, 1248 (1951); **86**, 654 (1952).
5. Green, A. E. S., and N. A. Engler: *Phys. Rev.*, **91**, 40 (1953).
6. Green, A. E. S., and D. F. Edwards: *Phys. Rev.*, **91**, 46 (1953).
7. Flower, B. H.: *Progr. Nuclear Phys.*, **2**, 235 (1952).
8. Coryell, C. D., and H. E. Suess: *Phys. Rev.*, **26**, 609 (1952).
9. Glueckauf, E.: *Proc. Phys. Soc. (London)*, **61**, 21 (1948).
10. Suess, H. E.: *Phys. Rev.*, **81**, 1071 (1951).
11. Coryell, C. D.: *Ann. Rev. Nuclear Sci.*, **2**, 305 (1953).
12. Kohman, T. P.: *Phys. Rev.*, **85**, 530 (1952).
13. Fermi, E.: unpublished.
14. Glasstone, S.: "Sourcebook on Atomic Energy," D. Van Nostrand Company, Inc., New York, 1950.
15. Mayer, M. G.: *Phys. Rev.*, **78**, 22 (1950).
16. Kohman, T. P.: private communication.
17. Condon, E. U., and G. H. Shortley: "The Theory of Atomic Spectra," Cambridge University Press, New York, 1935.
18. "Nuclear Data," *Natl. Bur. Standards (U.S.) NBS Circular* 499 (1950).
19. Mitchell, A. C. G.: *Revs. Mod. Phys.*, **22**, 36 (1950).
20. Alburger, D. E., and E. M. Hafner: *Revs. Mod. Phys.*, **22**, 272 (1950).
21. Ajzenberg, F., and T. Lauritsen: *Revs. Mod. Phys.*, **24**, 321 (1952).
22. Goldhaber, M., and R. D. Hill: *Revs. Mod. Phys.*, **24**, 179 (1952).
23. Wigner, E.: *Am. J. Phys.*, **17**, 99 (1949).
24. Hornyak, W. F., and T. Lauritsen: *Revs. Mod. Phys.*, **20**, 191 (1948).
25. Devons, S.: "Excited States of Nuclei," p. 134, Cambridge University Press, New York, 1949.
26. Pollard, E. C.: *Nucleonics*, **2**(4), 1 (1948).
27. Scharff-Goldhaber, G.: *Phys. Rev.*, **87**, 218 (1952).
28. Pieper, G. F.: *Phys. Rev.*, **86**, 1299 (1952).

CHAPTER 9

LIQUID-DROP MODEL AND FISSION

In the preceding chapter we attempted to systematize the experimental data for ground states of nuclei by using an empirical mass surface which embodies the main regularities of nuclear masses. In the present chapter we shall discuss a theory which leads to a mass surface closely resembling our empirical mass surface. This so-called liquid-drop model has been investigated principally by Weizsäcker,[1] Bethe and Bacher[2] Bohr and Wheeler,[3] and Feenberg.[4] It has been exploited widely in nuclear physics as a basis for the prediction and interpretation of nuclear phenomena.

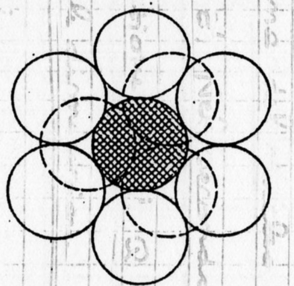

Fig. 9-1. Diagram indicating the 12 neighbors of a sphere (shaded) in closest packing arrangement. Three (dotted) are in contact above, and three (not shown) are in contact below.

The basic premise of the liquid-drop model of complex nuclei is that the number of nucleons in a typical nucleus is sufficiently large that the individuality of nucleons may be disregarded. While the treatment of such a system is most rigorously given by using the methods of quantum statistical mechanics, it is possible to arrive at three components of the expression for the energy of a complex nucleus by simple classical considerations. These components are the volume binding energy, the surface energy, and the coulomb energy. A fourth component known as the symmetry energy cannot be accounted for on classical grounds.

9-1. Volume Binding Energy. The fact that nuclear matter is almost incompressible, as is indicated by the equation $R = bA^{1/3}$, suggests that we treat a complex nucleus as a collection of a large number of rigid spheres held by charge-independent nuclear forces in a spherical closest packing arrangement. In view of the short-range character of the nuclear forces, we may assume that every interior nucleon has 12 bonds, one for each neighbor in contact with it (see Fig. 9-1). If each bonding energy is $-U$, then an energy of $-6U$ is identified with each interior nuclear particle (each bond energy belongs to two particles). Neglect-