The deuteron and the (hypothetical) ^{2}He nucleus

We will mention one further example of the influence of the exclusion principle. We have said earlier that the nuclear forces are the same between the neutron and the neutron, between the proton and the proton, and between the proton and the neutron. Why is it then that a proton and a neutron can stick together to make a deuterium nucleus, whereas there is no nucleus with just two protons or with just two neutrons? The deuteron is, as a matter of fact, bound by an energy of about 2.2 million volts, yet, there is no corresponding binding between a pair of protons to make an isotope of helium with the atomic weight 2. Such nuclei do not exist. The combination of two protons does not make a bound state.

The answer is a result of two effects: first, (A:) ; and second, (B:). The force between a neutron and a proton is attractive and somewhat stronger when the spins are parallel than when they are opposite. It happens that these forces are just different enough so that a deuteron can only be made if the neutron and proton have their spins parallel; when their spins are opposite, the attraction is not quite strong enough to bind them together. Since the spins of the neutron and proton are each one-half and are in the same direction, the deuteron has a spin of one.

We know, however, that two protons are not allowed to sit on top of each other if their spins are parallel. If it were not for the exclusion principle, two protons would be bound, but since they cannot exist at the same place and with the same spin directions, the ^{2}He nucleus does not exist. The protons could come together with their spins opposite, but then there is not enough binding to make a stable nucleus, because the nuclear force for opposite spins is too weak to bind a pair of nucleons.

The attractive force between neutrons and protons of opposite spins can be seen by scattering experiments. Similar scattering experiments with two protons with parallel spins show that there is the corresponding attraction. So it is the exclusion principle that helps explain why deuterium can exist when ^{2}He cannot.

R.P. Feynman, R.B. Leighton, and M.L. Sands: *The Feynman Lectures on Physics* (Addison-Wesley, 1965) Vol. III, Sec. 4-7.