Coulomb's Law

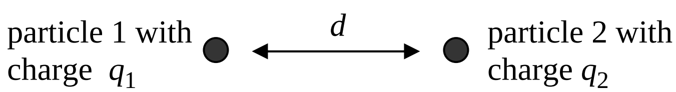
Consider two stationary particles with charges q_1 and q_2 separated by a distance d. According to Coulomb's law, the force of attraction between the particles, F, is

$$F = \frac{kq_1q_2}{d^2}$$

where k is a constant. The potential energy, V, of this attractive force is the product of the force of attraction and distance; thus

$$V = \frac{kq_1q_2}{d}$$

Pictorially, we have this model



Questions to Consider

What happens to the potential energy if we increase the distance between the particles? Explain your reasoning.

The energy must decrease because there is an inverse relationship between energy, V, and distance, d.

What happens to the potential energy if the particles are infinitely far apart? Explain your reasoning.

If the distance, d, becomes infinitely large, then the denominator becomes infinitely large and the energy approaches zero. The energy of a "free" electron, therefore, is zero. This is an important point to remember.

Assuming that d has a finite value (that is, it isn't infinity), what must be true if the potential energy is negative? Explain your reasoning.

The charges q_1 and q_2 must have different signs since the distance cannot be negative. This is the only way to make the potential energy negative.

If q for an electron is –1, what are the values of q for a proton and a neutron? What is q for the nucleus of an atom of ^{14}N?

The proton's charge is same magnitude of that for an electron, but of opposite sign; thus, it is +1. A neutron has no charge, so its value is 0.

The nucleus of an atom of ^{14}N contains 7 neutrons so it has a charge of +7.

An atom of ^{1}H has a nucleus with a single proton and a single electron a distance d from the nucleus. Is the potential energy between the nucleus and the electron positive or negative? If you move the electron further from the nucleus, what happens to the potential energy? Can you extend this conclusion to other atoms? For each question, explain your reasoning.

The electron's potential energy must be negative since q_1 is -1 and q_2 is +1.

Increasing the distance between the electron and the proton makes the potential energy less negative, approaching a limit of a potential energy of zero when the electron and neutron are sufficiently far apart.

We can easily extend this generalization to the electrons in any atom.