

Particle Adventure

1.
 - a) An atom is approximately 10^{-10} m in diameter. It consists of a nucleus and electron cloud. Each chemical element consists of atoms that possess a characteristic number of protons.
 - b) When two or more atoms are joined by covalent bonding they form a molecule, for example a carbon dioxide molecule CO_2 and water molecule H_2O .
 - c) An atom or molecule that has lost or gained electrons and thus carries an electric charge, for example the alpha particle He^{2+} (helium nucleus) and hydroxide ion OH^- .
2.
 - a) An atom consists of a tiny, dense, positively charged nucleus made of neutrons and protons and a negatively charged electron cloud around the nucleus.
 - b) A nucleus is made of positively charged protons and electrically neutral neutrons. A typical nucleus is very dense, approximately 10^{-14} m in diameter, that is 1/10000 of the diameter of a typical atom. Almost all of the atom's mass is concentrated in the nucleus.
 - c) A proton is made of two up quarks and one down quark.
 - d) A neutron is made of two down quarks and one up quark.
 - e) An electron is a fundamental particle. According to current knowledge, it doesn't have any internal structure.
3. The fundamental interactions are (in the order of relative strength): strong interaction, electromagnetic interaction, weak interaction and gravitational interaction. They are mediated by the carrier particles.
4.
 - a) Since the nucleus is positively charged and electrons negatively charged there is an attractive electromagnetic force between the nucleus and electrons that holds the atom together.

- b) Since the protons inside the nucleus are positively charged and extremely close to each other, there is a very strong repulsive force between them. Since the protons and neutrons are extremely tightly bound to the nucleus there has to be an additional interaction that prevents a nucleus from falling apart. This interaction is the strong interaction. Like the name suggest, it is the strongest of the fundamental interactions. When the protons and neutrons move away from each other, the strong interaction attracts the nucleons, and pull them together. It is so strong, that it overcomes the electric repulsion between the protons. As nucleons approach each other, the strong interaction becomes repulsive and prevent them from touching each other.
- 5. Quarks are fundamental particles. The types of quarks are: up (u), down (d), charm (c), strange (s), top (t) and bottom (b).
 - 6. The ordinary matter is made of up and down quarks and electrons.
 - 7. The fundamental interactions are mediated by carrier particles.
 - a) The carrier particle of electromagnetic interaction is a photon. It travels by the speed of light and it doesn't have mass.
 - b) The carrier particle of gravitational interaction is a supposedly graviton. However, up to date we haven't been able to detect any gravitons. Whether they exist or not is still a question to be answered in physics.
 - 8. Antiparticles are just like their counterparts expect that they have opposite charge. If the particle doesn't have electric charge, the antiparticle is the particle itself, for example the antiparticle of a photon is just photon. Examples are positron and electron, and neutrino and antineutrino.

9. They annihilate to electromagnetic radiation. As a result two gamma photons are produced. This is important for example in Positron Emission Tomography, when we construct images from the human brain.