

4.4: Protons, Neutrons, and Electrons

Learning Objectives

- Describe the locations, charges, and masses of the three main subatomic particles.
- Determine the number of protons and electrons in an atom.
- Define atomic mass unit (amu).

Dalton's Atomic Theory explained a lot about matter, chemicals, and chemical reactions. Nevertheless, it was not entirely accurate because, contrary to what Dalton believed, atoms can, in fact, be broken apart into smaller subunits or subatomic particles. We have been talking about the electron in great detail, but there are two other particles of interest to us: protons and neutrons. We already learned that J. J. Thomson discovered a negatively charged particle, called the **electron**. Rutherford proposed that these electrons orbit a positive nucleus. In subsequent experiments, he found that there is a smaller positively charged particle in the nucleus, called a **proton**. There is also a third subatomic particle, known as a neutron.

Electrons

Electrons are one of three main types of particles that make up atoms. Electrons are extremely small. The mass of an electron is only about $\frac{1}{2000}$ the mass of a proton or neutron, so electrons contribute virtually nothing to the total mass of an atom. Electrons have an electric charge of $1-$, which is equal but opposite to the charge of a proton, which is $1+$. All atoms have the same number of electrons as protons, so the positive and negative charges "cancel out", making atoms electrically neutral. While protons and neutrons are located inside the nucleus at the center of the atom, electrons are located outside the nucleus in what is often called the electron cloud.



Figure 4.4.1: Electrons are much smaller than protons or neutrons. If an electron was the mass of a penny, a proton or a neutron would have the mass of a large bowling ball!

Protons

A proton is another one of three main particles that make up the atom. Protons are found in the nucleus of the atom – the tiny, extremely dense region at the center of the atom. Protons have a positive electrical charge of one ($1+$) and a mass of about 1 atomic mass unit (1 amu). Together with neutrons, they make up virtually all of the mass of an atom.

Atomic Mass Units

An **atomic mass unit (amu)** is defined as one-twelfth of the mass of a carbon-12 atom, which is about 1.660×10^{-27} kg. Atomic mass units (amu) are useful, since the mass of a proton and the mass of a neutron are almost equal to 1 amu in this unit system.

Neutrons

The last of the three main particles that make up the atom is the neutron. Atoms of all elements (except for most atoms of hydrogen) have neutrons in their nucleus. Unlike protons and electrons, which are electrically charged, neutrons have no charge – they are electrically neutral. That's why the neutrons in the table below are labeled n^0 . The zero stands for "zero charge".

A neutron is slightly more massive than a proton (see below) and has about the same diameter. Neutrons are found in all atoms (except for most atoms of hydrogen) and may be found bound together with other neutrons and protons in the atomic nucleus. Since protons and neutrons are so much more massive than electrons, almost all of the mass of an atom comes from the nucleus, which contains all of the neutrons and protons.

Table 4.4.1 provides a summary of the properties of the three main types of subatomic particles.

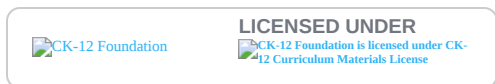
Table 4.4.1: Properties of Subatomic Particles

Particle	Symbol	Mass (kg)	Mass (amu)	Relative Charge	Location
proton	p^+	1.673×10^{-27}	$1.0073 \approx 1$	1+	inside the nucleus
electron	e^-	9.109×10^{-31}	$0.00055 \approx 0$	1–	outside the nucleus
neutron	n^0	1.675×10^{-27}	$1.0087 \approx 1$	0	inside the nucleus

Summary

- Electrons are a type of subatomic particle with a negative charge.
- Protons are a type of subatomic particle with a positive charge. Protons are bound together in an atom's nucleus as a result of the strong nuclear force.
- Neutrons are a type of subatomic particle with no charge (they are neutral). Like protons, neutrons are bound into the atom's nucleus as a result of the strong nuclear force.
- Protons and neutrons have approximately the same mass, but they are both much more massive than electrons (approximately 2,000 times as massive as an electron).
- The positive charge on a proton is equal in magnitude to the negative charge on an electron. As a result, a neutral atom must have an equal number of protons and electrons.
- The atomic mass unit (amu) is a unit of mass equal to one-twelfth the mass of a carbon-12 atom

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