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Components of the Atom

Table 2.1 summarizes the basic subatomic particles previously discussed and important information about them.

Table 2.1 Important Information about Subatomic Particles

Particle	Charge	Symbol	Actual Mass	Relative Mass Compared to Proton	Discovery
Electron	– (e^-)	${}^{0}_{-1}e^-$	9.109×10^{-28} g	1/1,837	J. J. Thomson–1897
Proton	+ (p^+)	${}^{1}_{1}p^+$	1.673×10^{-24} g	1	E. Rutherford–1917
Neutron	0 (n^0)	${}^{1}_{0}n^0$	1.675×10^{-24} g	1	J. C. Chadwick–1932

When these components are used in the model, the protons and neutrons are shown in the nucleus. These particles are known as **nucleons**. The electrons are shown outside the nucleus.

The number of protons in the nucleus of an atom determines the **atomic number**, symbolized Z. All atoms of the same element have the same number of protons and therefore the same atomic number; atoms of different elements have different atomic numbers. Thus, the atomic number identifies the element. An English scientist, **Henry Moseley**, first determined the atomic numbers of the elements through the use of X-rays.

The sum of the number of protons and the number of neutrons in the nucleus is called the **mass number**, symbolized by the letter A. A particular atom with a specific number of protons and neutrons is called a **nuclide**. One way to describe a nuclide is by the element name followed by a dash and the mass number, i.e., element-A. A beryllium atom with 4 neutrons is called beryllium-8 because a beryllium atom has to have 4 protons associated with it. The number of neutrons associated with a nuclide can be calculated by subtracting, A – Z. Consequently, a neutral atom of beryllium-9 has 5 neutrons because any beryllium atom has to have 4 protons (or a Z value of 4). A beryllium-9 atom also contains 4 electrons. In any given neutral atom, the number of negative electrons must equal the number of positive protons to have a balance of charge. Another way to represent a nuclide is by the elemental symbol with a left superscript showing the mass number and left subscript showing the atomic number, generically ${}^{A}_{Z}X$. Therefore beryllium-9 could also be written as ${}^{9}_{4}Be$.

As a result of having a different number of neutrons, different nuclides of the same element, called **isotopes**, have different masses. For example, three types of hydrogen atoms are known. The most common and lightest type of hydrogen, sometimes called protium, accounts for 99.985% of the hydrogen atoms found on Earth. The nucleus of a protium atom contains one proton only, and it has one electron moving about it. A heavier and second form of hydrogen, known as deuterium, accounts for 0.015% of Earth's hydrogen atoms. Each deuterium atom has a nucleus containing one proton and one neutron, and it has one electron moving around the nucleus. The third and heaviest form of hydrogen, tritium, is radioactive.

TIP

Isotopes have the same atomic number but different mass numbers. This means they differ in the number of neutrons, not protons.

It exists in very small amounts in nature, but it can be prepared artificially. Each tritium atom contains one proton, two neutrons, and one electron.

Protium, deuterium, and tritium are isotopes of hydrogen. The isotopes of a particular element all have the same number of protons and electrons but different numbers of neutrons. In all three isotopes of hydrogen, the positive charge of the single proton is balanced by the negative charge of the single electron. Most elements are found naturally as a mixtures of isotopes, some stable and others radioactive. Tin, for example, has ten stable isotopes, the most of any element.

The percentage of each isotope for a naturally occurring element on Earth is nearly always the same, no matter where the element is found. The percentage at which each of an element's isotopes occurs in nature is taken into account when calculating the element's **atomic mass**. The atomic mass for an element found on the Periodic Table is the weighted average of the atomic masses of the naturally occurring isotopes of an element. Table 2.2 contains information about the numbers of subatomic particles found in the most abundant atom for the first 21 elements, ranked by atomic number.

Table 2.2 Table of the First 21 Elements*

Element	Atomic No.	Mass No.	Number of Protons	Number of Neutrons	Number of Electrons
Hydrogen	1	1	1	0	1
Helium	2	4	2	2	2
Lithium	3	7	3	4	3
Beryllium	4	9	4	5	4
Boron	5	11	5	6	5
Carbon	6	12	6	6	6
Nitrogen	7	14	7	7	7
Oxygen	8	16	8	8	8
Fluorine	9	19	9	10	9
Neon	10	20	10	10	10
Sodium	11	23	11	12	11
Magnesium	12	24	12	12	12
Aluminum	13	27	13	14	13
Silicon	14	28	14	14	14
Phosphorus	15	31	15	16	15
Sulfur	16	32	16	16	16
Chlorine	17	35	17	18	17
Argon	18	40	18	22	18
Potassium	19	39	19	20	19
Calcium	20	40	20	20	20
Scandium	21	45	21	24	21

**The particular atom shown is the most abundant in the group of isotopes for that element.*

Calculating Average Atomic Mass

The average atomic mass of an element depends on both the mass and the relative abundance of each of the element's isotopes. For example, naturally occurring copper consists of 69.17% copper-63, which has an atomic mass of 62.919598 amu, and 30.83% copper-65, which has an atomic mass of 64.927793 amu. The average atomic mass of copper can be calculated by multiplying the atomic mass of each isotope by its relative abundance (expressed in decimal form) and adding the results:

$$(0.6917 \times 62.919598 \text{ amu}) + (0.3083 \times 64.927793 \text{ amu}) = 63.55 \text{ amu}$$

Therefore, the calculated average atomic mass of naturally occurring copper is 63.55 amu. Average atomic masses of the elements are, more often than not, listed under the symbol for the element in a Periodic Table as a decimal number. These atomic masses are typically rounded to one decimal place when doing chemical calculations. The whole number, usually above the elemental symbol, is the atomic number, Z. Mass numbers, A, are not shown as information on the Periodic Table because the symbol represents an average atom in the set of isotopes for that element and not any particular isotope.

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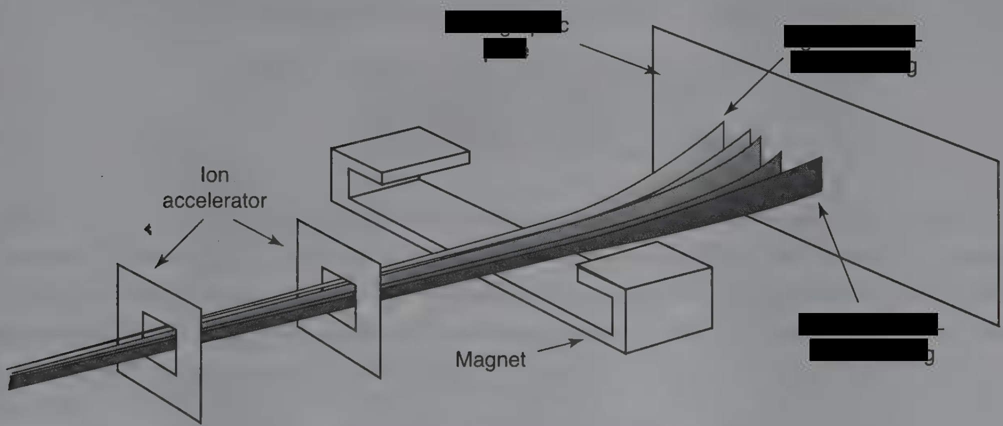

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TIP

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