4.7: Isotopes and Mass Numbers

Learning Objectives

- Explain what isotopes are and how an isotope affects an element's atomic mass.
- Determine the number of protons, electrons, and neutrons of an element with a given mass number.

As discussed in the the previous section, atoms of the same element always have the same number of protons. However, atoms of the same element may have differing numbers of neutrons. While all carbon atoms have six protons and most have six neutrons, some carbon atoms have seven neutrons, while others have eight. Atoms of the same element that differ in their numbers of neutrons are called **isotopes**. Many isotopes occur naturally. Quite often, there are one or two isotopes of an element that are the most stable and common. Different isotopes of an element generally have the same physical and chemical properties due to the fact they have the same numbers of protons and electrons.

Mass Number

The **mass number** (A) of an atom represents the sum of protons and neutrons in the nucleus of that atom and provides a very close approximation to the mass of the atom in atomic mass units. This is because the mass of the proton and neutron are each about 1 amu, while the mass of the electron is very small in comparison.

$$\text{mass number } (A) = \text{number of protons} + \text{number of neutrons} \tag{4.7.1}$$

Consider oxygen, which has an atomic number (Z) of 8. This means that oxygen atoms have 8 protons. Most atoms of oxygen also have 8 neutrons. Oxygen atoms with 8 neutrons would have a mass number of 16 (8 p^+ + 8 n^0), meaning they would have a mass of about 16 amu.

Some oxygen atoms have 9 neutrons, while others have 10 neutrons. Oxygen atoms with 9 neutrons would have a mass number of 17 (8 p^+ + 9 n^0), meaning they would have a mass of about 17 amu. Oxygen atoms with 10 neutrons would have a mass number of 18 (8 p^+ + 10 n^0), meaning they would have a mass of about 18 amu.

Isotope Notation

The three types of oxygen atoms described above are the three naturally-occurring isotopes of oxygen. While there are several other known isotopes of oxygen, they are not found anywhere in nature and may only be synthesized in the laboratory, which is not necessarily an "easy" thing to do.

Isotopes of elements are designated by their mass number. Oxygen atoms with a mass number of 16 are called oxygen-16, or O-16, while oxygen atoms with a mass number of 17 are called oxygen-17, or O-17, and oxygen atoms with a mass number of 18 are called oxygen-18, or O-18.

Another type of **isotope notation** or **isotope symbol** uses the mass number (A) written as a superscript to the left of the chemical symbol with the atomic number (Z) written below the mass number as a subscript to the left of the chemical symbol.

$$^{\mathrm{A}}_{\mathrm{Z}}\mathrm{X}$$

Sometimes, the atomic number is left off the isotope notation, since the atomic number and the number of protons for a given element never changes.

$$^{\mathrm{A}}\mathrm{X}$$

Assuming the atoms are neutral, the number of protons, electrons, and neutrons in one atom of each of the three naturally-occurring isotopes of oxygen are shown in Table 4.7.1 below.

Table 4.7.1: The Three Naturally-Occurring Isotopes of Oxygen

Isotope	Abbreviation	Isotope Symbol	Isotope Symbol	p^+	e^-	n^0
oxygen-16	O-16	^{16}O	$^{16}_{8}O$	8	8	8
oxygen-17	O-17	^{17}O	$^{17}_{8}O$	8	8	9
oxygen-18	O-18	^{18}O	$^{18}_{8}O$	8	8	10

It is important to note that the mass number is *not* shown on the Periodic Table. You may find all of the known isotopes of a given element by clicking on the chemical symbol of the desired element on the Periodic Table located at https://www.webelements.com/isotopes.html.

✅ Example 4.7.1

A. What is the mass number of an atom of chromium (Cr) that has 30 neutrons?
B. Write the different isotope notations or isotope symbols for this isotope.

Solution

A. Cr has an atomic number (*Z*) of 24, so it has 24 p^+. With 24 p^+ and 30 n^0, the mass number of this atom is 54.

B. The isotope notations include:

- chromium-54
- Cr-54
- ^{54}Cr
- $^{54}_{24}Cr$

✅ Example 4.7.2

How many protons, electrons, and neutrons are in a neutral atom of $^{204}_{80}Hg$?

Solution

- The atomic number is 80, so there are 80 p^+.
- Since the atom is neutral, there are also 80 e^-.
- Starting with $\text{mass number } (A) = \text{number of protons} + \text{number of neutrons}$, rearrange the equation to solve for the number of neutrons.
  $\text{number of neutrons} = \text{mass number } (A) - \text{number of protons}$ = 204 – 80 = 124 n^0

✏️ Exercise 4.7.1

How many protons, electrons, and neutrons are in each neutral atom?

A. $^{60}_{27}Co$
B. Na-24
C. $^{45}_{20}Ca$
D. Sr-90

Answer A

27 p^+, 27 e^-, 33 n^0

Answer B

11 p^+, 11 e^-, 13 n^0

Answer C

20 p^+, 20 e^-, 25 n^0

Answer D

38 p^+, 38 e^-, 52 n^0

Exercise 4.7.2

Write the different isotope notations or isotope symbols for an atom with 42 p^+, 42 e^-, and 52 n^0.

Answer

The isotope notations include:

- molybdenum-94
- Mo-94
- ^{94}Mo
- $^{94}_{42}$Mo

Summary

- The number of protons is always the same in atoms of the same element.
- The number of neutrons can be different, even in atoms of the same element.
- Atoms of the same element that contain the same number of protons, but different numbers of neutrons, are known as **isotopes**.
- Isotopes of any given element all contain the same number of protons, so they have the same atomic number.
- Isotopes of a given element contain different numbers of neutrons, therefore, different isotopes have different mass numbers.

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