Activity 02-1

Atoms, Isotopes, and Ions

Why?

Atoms are the fundamental building blocks of all substances. To begin to understand the properties of atoms and how they combine to form molecules, you must be familiar with their composition and structure.

Learning Objectives

- Understand the composition and structure of atoms, isotopes, and ions
- Understand how atomic symbols and names identify the number of particles composing an atom, isotope, or ion

Success Criteria

- Use atomic symbols to represent different isotopes and ions
- Given one or more of the following items, determine the others: name, atomic symbol, atomic number, mass number, neutron number, and electron number
- Calculate the percent of the atomic mass that is located in the nucleus of an atom
- Compare the size of an atom to the size of the atomic nucleus

Prerequisites

- Calculation of percent
- **Activity 01-1:** *Units of Measurement*
- **Activity 01-2:** *Unit Analysis*

Information

Matter, which is anything that has mass and occupies space, is composed of substances and mixtures of substances.

A *substance*, or more explicitly, a *pure substance*, is a variety of matter that has uniform and constant composition. For example, pure water is a substance.

Mixtures are composed of two or more substances. For example, salt water is a mixture, even though it is uniform, because the amount of salt in the water (the composition) can vary.

An *element* is a substance that cannot be decomposed into two or more other substances by chemical or physical means. In nuclear reactions, however, one element can be converted into one or more other elements. Only about 118 different elements are known to exist.

An *atom* is the smallest part of an element that can exist either alone or in combination with other atoms.

Isotopes are atoms that have the same number of protons but different numbers of neutrons.

An *ion* is an atom or molecule with a positive or negative charge.

A *cation* is an ion with a positive charge.

An *anion* is an ion with a negative charge.

MODEL: SODIUM

The diagrams below show representations of sodium. Note that the diameter of an atom is about 10,000 times larger than the diameter of the atomic nucleus.

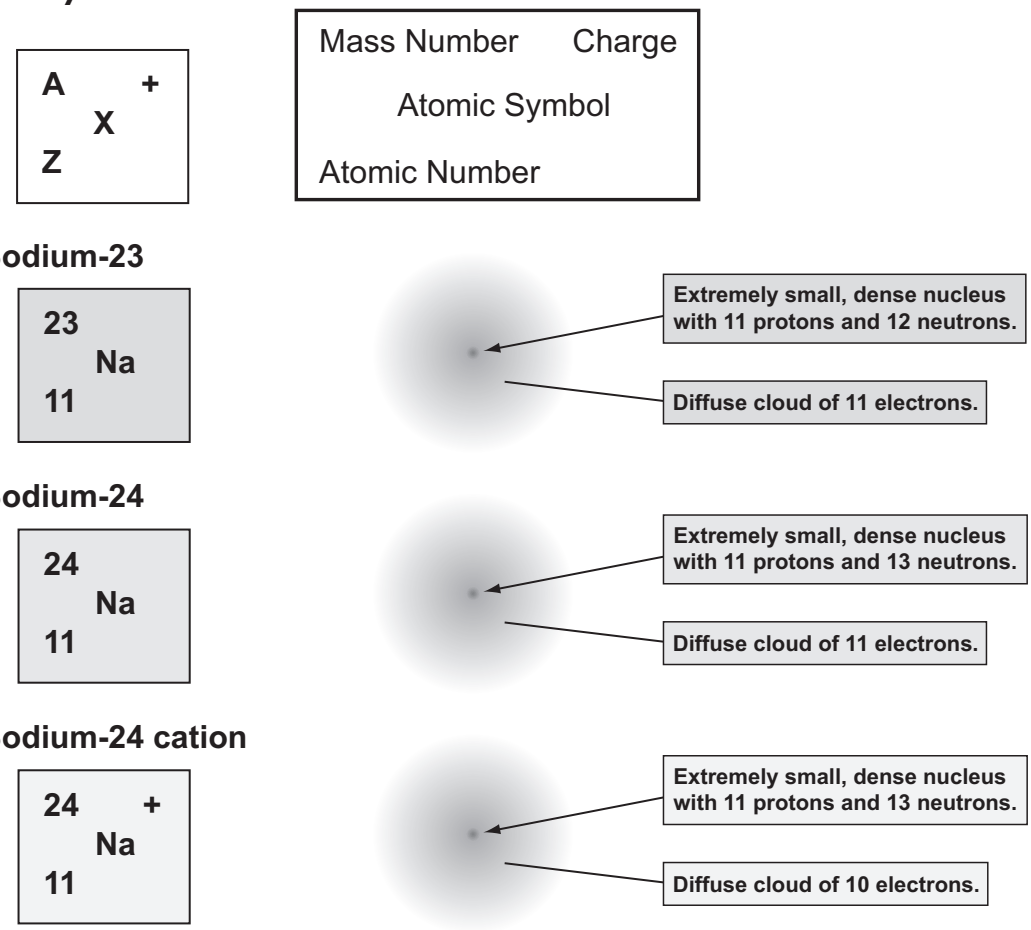
Table 1 Subatomic Particles

Particle	Mass (amu)*	Charge
Proton	1.0073	+1
Neutron	1.0087	0
Electron	0.0005	–1

* *Atomic mass unit* (amu) is a unit of mass equal to 1.66054×10^{-27} kg.

Atomic Symbol Notation

Figure 1



KEY QUESTIONS

1. What are the three particles that comprise a sodium atom?

2. Which particles contribute most of the mass to the atom, and where are these particles located?

3. Which particles contribute most to the volume or size of the atom, and where are these particles located?

4. What information is provided by the atomic number, Z, which is the subscript in the atomic symbol?

5. What information is provided by the mass number, A, which is the superscript in the atomic symbol?

6. What notation is used in the atomic symbol to indicate the charge of an atom or ion?

7. Given the definition of mass number and the information in Table 1 regarding the masses of protons, neutrons, and electrons, why is the mass number approximately, but not exactly equal to, the mass of an atom in amu?

8. How is the charge of the atom or ion determined from the number of protons, neutrons, and electrons present?

9. What do all atoms and ions of sodium have in common?

10. In general, what feature of an atom identifies it as a particular element?

11. In general, how do isotopes of the same element differ?

12. How many isotopes of any particular element could there be? What might prevent all of these isotopes from occurring naturally?

Exercises

1. Insert the missing information in the following table. The first row is completed for you to provide an example.

Table 2

Name	Symbol	Z	A	Number of Neutrons	Number of Electrons
boron-10	$^{10}_{5}B^{+}$	5	10	5	4
	$^{40}_{20}Ca$				18
oxygen-16					8
	U			146	92
		9	19		9
		17		18	18
			39	20	19

2. Show how to calculate the mass of a proton, neutron, and electron in kilograms using the data in Table 1 and the equality statement: $\mathbf{1\ amu = 1.66054 \times 10^{-27}\ kg}$

Problems

1. The mass of a carbon-12 atom is 12 amu. What percent of the mass is located in the nucleus? Why is the value you calculated so close to 100%?

2. The radius of a Cl nucleus is 4.0 fm, and the radius of a Cl atom is 100 pm. If the nucleus of the Cl atom were the size of a dime, which is 17 mm in diameter, determine whether the atom would be approximately a) the size of a quarter, b) the size of a car, c) the size of a football stadium, or d) the size of the earth. Explain how you made your decision.