The Nucleus

SECTION 1

OBJECTIVES

- Explain what a nuclide is, and describe the different ways nuclides can be represented.
- Define and relate the terms *mass defect* and *nuclear binding energy*.
- Explain the relationship between number of nucleons and stability of nuclei.
- Explain why nuclear reactions occur, and know how to balance a nuclear equation.

Atomic nuclei are made of *protons and neutrons, which are collectively called* **nucleons.** In nuclear chemistry, *an atom is referred to as a* **nuclide** *and is identified by the number of protons and neutrons in its nucleus*. Nuclides can be represented in two ways. When a symbol such as $^{228}_{88}\text{Ra}$ is used, the superscript is the mass number and the subscript is the atomic number. The same nuclide can also be written as radium-228, where the mass number is written following the element name.

Mass Defect and Nuclear Stability

Because an atom is made of protons, neutrons, and electrons, you might expect the mass of an atom to be the same as the mass of an equal number of isolated protons, neutrons, and electrons. However, this is not the case. Let's consider a $^{4}_{2}\text{He}$ atom as an example. The combined mass of two protons, two neutrons, and two electrons is calculated below.

2 protons: $(2 \times 1.007\,276\text{ amu}) = 2.014\,552\text{ amu}$
2 neutrons: $(2 \times 1.008\,665\text{ amu}) = 2.017\,330\text{ amu}$
2 electrons: $(2 \times 0.000\,548\,6\text{ amu}) = \underline{0.001\,097\text{ amu}}$
total combined mass: $4.032\,979\text{ amu}$

However, the atomic mass of a $^{4}_{2}\text{He}$ atom has been measured to be 4.002 602 amu. The measured mass, 4.002 602 amu, is 0.030 377 amu *less* than the combined mass, 4.032 979 amu, calculated above. *This difference between the mass of an atom and the sum of the masses of its protons, neutrons, and electrons is called the* **mass defect.**

Nuclear Binding Energy

What causes the loss in mass? According to Albert Einstein's equation $E = mc^2$, mass can be converted to energy, and energy to mass. The mass defect is caused by the conversion of mass to energy upon formation of the nucleus. The mass units of the mass defect can be converted to energy units by using Einstein's equation. First, convert 0.030 377 amu to kilograms to match the mass units for energy, $\text{kg}\cdot\text{m}^2/\text{s}^2$.

$$0.030\,377\text{ amu} \times \frac{1.6605 \times 10^{-27}\text{ kg}}{1\text{ amu}} = 5.0441 \times 10^{-29}\text{ kg}$$

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Module 2: Models of the Atom