Nuclear Reactions

SECTION 3

SECTION OBJECTIVES

- Distinguish between nuclear fission and nuclear fusion.
- Explain how a chain reaction is utilized by nuclear reactors.
- Compare fission and fusion reactors.

FISSION AND FUSION

Any process that involves a change in the nucleus of an atom is called a *nuclear reaction.* Nuclear reactions include *fission,* in which a nucleus splits into two or more nuclei, and *fusion,* in which two or more nuclei combine.

Stable nuclei can be converted to unstable nuclei

When a nucleus is bombarded with energetic particles, it may capture a particle, such as a neutron. As a result, the nucleus will no longer be stable and will disintegrate. For example, protons can be released when alpha particles collide with nitrogen atoms, as follows:

$$^4_2\text{He} + {}^{14}_7\text{N} \rightarrow \text{X} + {}^1_1\text{H}$$

According to this expression, an alpha particle ($^4_2$He) strikes a nitrogen nucleus ($^{14}_7$N) and produces an unknown product nucleus (X) and a proton ($^1_1$H). By balancing atomic numbers and mass numbers, we can conclude that the unknown product has a mass number of 17 and an atomic number of 8. Because the element with an atomic number of 8 is oxygen, the product can be written symbolically as $^{17}_8$O, and the reaction can be written as follows:

$$^4_2\text{He} + {}^{14}_7\text{N} \rightarrow {}^{18}_9\text{F} \rightarrow {}^{17}_8\text{O} + {}^1_1\text{H}$$

This nuclear reaction starts with two stable isotopes—helium and nitrogen—that form an unstable intermediate nucleus, fluorine. The intermediate nucleus then disintegrates into two different stable isotopes, hydrogen and oxygen. This reaction, which was the first nuclear reaction to be observed, was detected by Rutherford in 1919.

Heavy nuclei can undergo nuclear fission

Nuclear fission occurs when a heavy nucleus splits into two lighter nuclei. For fission to occur naturally, the nucleus must release energy. This means that the nucleons in the daughter nuclei must be more tightly bound and therefore have less mass than the nucleons in the parent nucleus. This decrease in mass per nucleon appears as released energy when fission occurs, often in forms such as photons or kinetic energy of the fission products. Because fission produces lighter nuclei, the binding energy per nucleon must *increase* with decreasing atomic number. **Figure 8** shows that this is possible only for atoms in which $A > 58$. Thus, *fission occurs naturally only for heavy atoms.*

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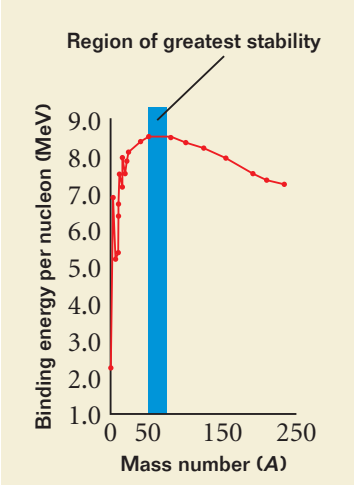

Figure 8
Light nuclei are very loosely bound. The binding energy of heavy nuclei is roughly the same for all nuclei.