

Characteristics of Chemical and Nuclear Reactions	
Chemical Reactions	Nuclear Reactions
Occur when <u>chemical bonds</u> are broken and formed.	Occur when nuclei emit <u>particles</u> and/or <u>rays</u> .
Atoms remain unchanged, though they may be <u>rearranged</u> .	Atoms are often <u>converted</u> into atoms of another element.
Involve only <u>valence electrons</u> or the outermost electrons.	May involve <u>protons</u> , <u>neutrons</u> , and <u>electrons</u> .
Associate with <u>small</u> energy changes.	Associated with <u>large</u> energy changes.
Reaction <u>rate</u> is influenced by temperature, pressure, concentration, and catalysts.	Reaction rate is <u>not</u> affected by temperature, pressure, or catalysts.

Radioactivity and Radiation

Radiation or radioactive decay is the process by which some substances spontaneously emit radioactive rays and particles. Radioactive isotopes (atomic number > 83) have unstable nuclei and decay spontaneously. Other nuclei are unstable because of too many neutrons. An unstable nucleus decays to become more stable, resulting in:

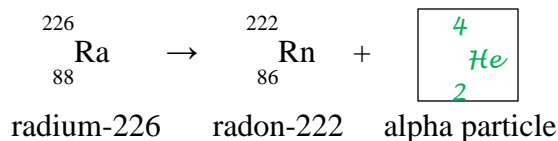
- 1) Release of tremendous amount of energy, and
- 2) Atom forming a new element.

Types of Radiation and Decay

Types of Radiation						
Type	Emission	Composition	Symbol	Charge	Mass	Penetrating Power
Alpha decay	<u>alpha particle</u>	<u>two p⁺ and two n⁰ (He nucleus)</u>	<u>4 He 2</u>	<u>2⁺</u>	<u>4 amu</u>	<u>paper</u>
Beta decay	<u>beta particle</u>	<u>fast-moving electron</u>	<u>0 β -1</u>	<u>1⁻</u>	<u>0 amu</u>	<u>metal foil</u>
Gamma emission	<u>gamma ray</u>	<u>high energy photons</u>	<u>0 γ 0</u>	<u>0</u>	<u>0 amu</u>	<u>lead, concrete</u>

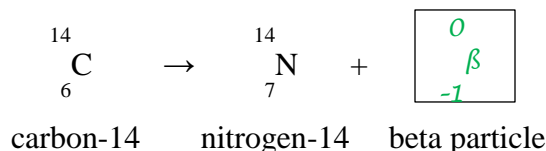
1. Unstable nuclei with more than 83 protons undergo alpha decay, emit an alpha particle, and decrease the number of protons and neutrons.

Example: Nuclear equation for the alpha decay of radioactive radium-226 to radon-222:



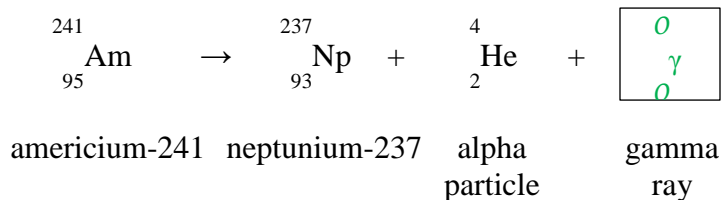
2. Radioisotopes with too many neutrons undergo beta decay, emit an beta particle, and decrease the number of neutrons.

Example: Nuclear equation for the beta decay of carbon-14 into nitrogen-14:



3. Gamma emission involves releasing gamma rays but does not create new atoms alone.

Example: Gamma rays accompany alpha and beta decay processes:

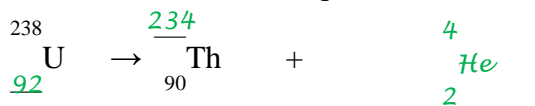


Balancing Nuclear Equations

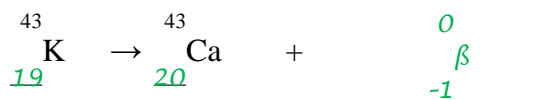
Nuclear equations are written to express nuclear reactions. Isotopic notation is used to show that atomic numbers and mass numbers of the involved particles are conserved.

1. Balance the number of nucleons (protons and neutrons) using mass number.
2. Balance the charge using atomic number.
3. Determine the decay product (alpha or beta particles) and write the balanced equation.

Example 1. Write a balanced equation for the decay of uranium-238 to thorium-234.

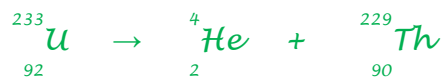


Example 2. Write a balanced equation for the decay of potassium-43 to calcium-43.

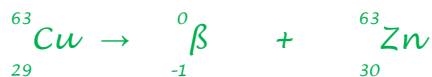


Practice Set 1. Write the balanced equation for the following nuclear reactions.

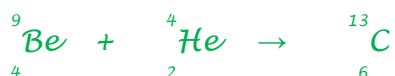
1. Uranium-233 undergoes alpha decay



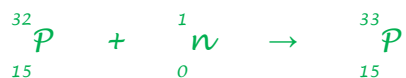
2. Copper-63 undergoes beta decay



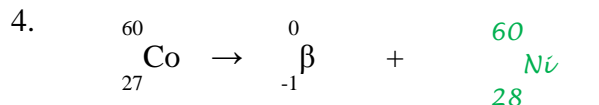
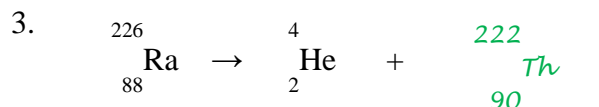
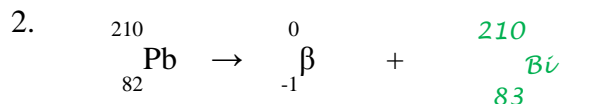
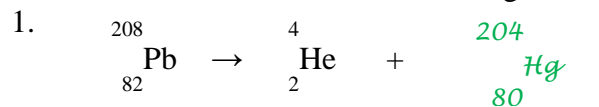
3. Beryllium-9 and an alpha particle combine to form carbon-13



4. Phosphorus-32 and a neutron combine to form phosphorous-33



Practice Set 2. Balance the following nuclear equations.



Nuclear Fission

In nuclear fission, the heavy nucleus of an atom is bombarded by a neutron and splits into two smaller nuclei. The new isotopes formed emit a neutron, which can be used to split other nuclei. This process continues forming a chain reaction. The explosion from an atomic bomb results from an uncontrolled chain reaction.

Nuclear Fusion

The process by which two small nuclei combine to form a larger, more stable nucleus is nuclear fusion. Nuclear fusion releases more energy than nuclear fission, but extremely high energies and temperatures are required to initiate and sustain fusion reactions. The sun and stars are powered by fusion reactions. All elements heavier than He are formed through nuclear fusion.

Half-Life

Radiochemical dating is the process of determining the age of an object by measuring the amount of a certain radioisotope that remains. This process is possible because the decay rates of radioactive nuclei are constant and are referred to as the half-life of the radioisotope.

Half-life defined: *the average time required for one-half of a radioactive isotope to decay into more stable isotopes*
Carbon-14 is used in radioactive dating for specimens that are less than 20,000 years old and were once living. Potassium-40 has been used to date ancient rocks and minerals.

Half-Life Problems

Half-life problems may be solved using a mathematical formula or a step-by-step table.

Two formulas:

$$\text{Amt remaining} = (\text{initial amt})(1/2)^n$$

where $n =$ *number of half-lives passed*

$$\text{Amt remaining} = (\text{initial amt})(1/2)^{t/T}$$

where $t =$ *elapsed time*
and $T =$ *duration of half-life*

Example: The half-life of strontium-90 is 29 years. If you had 100. g today, how much Sr-90 would remain in 116 years? ($t =$ 116 years and $T =$ 29 years)

How many half-lives (n) will have passed in 116 years? *4 half-lives*

29 years \rightarrow 58 years \rightarrow 87 years \rightarrow 116 years

$$\text{Amt remaining} = (100. \text{ g})(1/2)^{116/29} = (100. \text{ g})(1/2)^4$$

$$\text{Amt remaining} = 6.25 \text{ g}$$

# of Half-lives	Time Passed	Amount Remaining
0	0 years	100. g
1	29 years	50.0 g
2	58 years	25.0 g
3	87 years	12.5 g
4	116 years	6.25 g