Characteristics of Chemical and Nuclear Reactions	
Chemical Reactions	**Nuclear Reactions**
Occur when chemical bonds are broken and formed.	Occur when nuclei emit particles and/or rays.
Atoms remain unchanged, though they may be rearranged.	Atoms are often converted into atoms of another element.
Involve only valence electrons or the outermost electrons.	May involve protons, neutrons, and electrons.
Associate with small energy changes.	Associated with large energy changes.
Reaction rate is influenced by temperature, pressure, concentration, and catalysts.	Reaction rate is not 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	alpha particle	two p^+ and two n^0 (He nucleus)	$^{4}_{2}He$	2^+	4 amu	paper
Beta decay	beta particle	fast-moving electron	$^{0}_{-1}\beta$	1^-	0 amu	metal foil
Gamma emission	gamma ray	high energy photons	$^{0}_{0}\gamma$	0	0 amu	lead, concrete

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:

   $$^{226}_{88}\text{Ra} \rightarrow \, ^{222}_{86}\text{Rn} + \boxed{^{4}_{2}\text{He}}$$

   radium-226 radon-222 alpha particle

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:

   $$^{14}_{6}\text{C} \rightarrow \, ^{14}_{7}\text{N} + \boxed{^{0}_{-1}\beta}$$

   carbon-14 nitrogen-14 beta particle

3. Gamma emission involves releasing __gamma__ __rays__ but does not create new __atoms__ alone.

   Example: Gamma rays accompany alpha and beta decay processes:

   $$^{241}_{95}\text{Am} \rightarrow \, ^{237}_{93}\text{Np} + \, ^{4}_{2}\text{He} + \boxed{^{0}_{0}\gamma}$$

   americium-241 neptunium-237 alpha particle gamma ray

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.

$$^{238}_{92}\text{U} \rightarrow \, ^{234}_{90}\text{Th} + \, ^{4}_{2}\text{He}$$

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

$$^{43}_{19}\text{K} \rightarrow \, ^{43}_{20}\text{Ca} + \, ^{0}_{-1}\beta$$

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

1. Uranium-233 undergoes alpha decay

$$^{233}_{92}U \rightarrow ^{4}_{2}He + ^{229}_{90}Th$$

2. Copper-63 undergoes beta decay

$$^{63}_{29}Cu \rightarrow ^{0}_{-1}\beta + ^{63}_{30}Zn$$

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

$$^{9}_{4}Be + ^{4}_{2}He \rightarrow ^{13}_{6}C$$

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

$$^{32}_{15}P + ^{1}_{0}n \rightarrow ^{33}_{15}P$$

Practice Set 2. Balance the following nuclear equations.

1. $^{208}_{82}Pb \rightarrow ^{4}_{2}He + \underline{^{204}_{80}Hg}$

2. $^{210}_{82}Pb \rightarrow ^{0}_{-1}\beta + \underline{^{210}_{83}Bi}$

3. $^{226}_{88}Ra \rightarrow ^{4}_{2}He + \underline{^{222}_{90}Th}$

4. $^{60}_{27}Co \rightarrow ^{0}_{-1}\beta + \underline{^{60}_{28}Ni}$

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:

Amt remaining = (initial amt)$(1/2)^n$

where n = number of half-lives passed

Amt remaining = (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 → 58 years → 87 years → 116 years

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

Amt remaining = 6.25 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