# Writing Nuclear Equations

In the early 1900s scientists discovered that various isotopes will undergo nuclear decay. During this process the unstable nucleus of an atom gives off radiation. When scientists studied this radiation they discovered three types of particles: alpha, beta, and gamma. The **alpha particle** is composed of two protons and two neutrons, so it has a mass of 4 amu and a charge of 2+. A **beta particle** is a high energy electron emitted from the nucleus. A **gamma ray** often accompanies the other decay processes. Gamma radiation has no charge and no mass.

| Radiation Type | Symbol | Mass (amu) | Charge |
|---|---|---|---|
| Alpha | $^{4}_{2}He$ or $^{4}_{2}\alpha$ | 4 | 2+ |
| Beta | $^{0}_{-1}e$ or $^{0}_{-1}\beta$ | $\frac{1}{1840}$ | 1– |
| Gamma | $^{0}_{0}\gamma$ | 0 | 0 |

Equations can be written to show how a nucleus changes during a nuclear decay process. With these nuclear equations we track the atomic number and the mass number. For this reason it is important to correctly write the symbols for each particle involved. A nuclear equation is written for an alpha decay and a beta decay below. Notice that the sum of the atomic numbers is equal on both sides of the arrow. The sum of the mass numbers is also the same on both sides.

$$^{206}_{84}Po \rightarrow {}^{202}_{82}Pb + {}^{4}_{2}\alpha$$ **alpha decay**

$$^{124}_{51}Sb \rightarrow {}^{124}_{52}Te + {}^{0}_{-1}\beta$$ **beta decay**

**Rewrite the following equations. Fill in all the missing information.**

1. $^{129}_{53}I \rightarrow {}^{0}_{-1}e$ + _?_
2. $^{216}_{86}Rn \rightarrow {}^{4}_{2}\alpha$ + _?_
3. _?_ $\rightarrow {}^{4}_{2}\alpha + {}^{239}_{97}Bk$
4. _?_ $\rightarrow {}^{0}_{-1}e + {}^{52}_{23}V$
5. $^{255}_{?}Rf \rightarrow {}^{4}_{2}\alpha$ + _?_
6. $^{85}_{?}Br \rightarrow$ _?_ + $^{85}_{?}Kr + {}^{0}_{0}\gamma$
7. _?_ $\rightarrow {}^{0}_{-1}e + {}^{32}_{?}S + {}^{0}_{0}\gamma$
8. $^{257}_{101}Md \rightarrow {}^{4}_{2}\alpha + {}^{4}_{2}\alpha$ + _?_

**Write nuclear equations that describe the following processes.**

9. Uranium-235 undergoes an alpha decay to produce thorium-231.
10. Lanthanum -144 becomes cerium-144 when it undergoes a beta decay.
11. Neptunium-233 is formed when americium-237 undergoes a nuclear decay process.
12. When protactinium-229 goes through two alpha decays, francium-221 is formed.
13. Uranium-238 undergoes an alpha decay and produces two gamma rays.
14. The neon-22 nucleus is formed when an element undergoes a beta decay.
15. Samarium-146 is produced when an element undergoes an alpha decay.
16. The beta decay of dysprosium-165 creates a new element.

**Answer the following questions. Include the mass number when naming isotopes.**

17. What atom produces scandium-47 when it goes through a beta decay?
18. What new element is formed when curium-244 emits two alpha particles and three gamma rays?

# NUCLEAR CHEMISTRY WORKSHEET

__________________________________________ ______________ _____

Most nuclear reactions involve changes in the number of protons and/or neutrons in the nucleus of an atom. These changes are called *transmutations* because an atom of one element is changed into an atom of a different element. During these changes, nuclear particles may be absorbed and/or emitted along with a release of energy.

There are four types of nuclear reactions:

1) *natural radioactive decay*: transmutations occur by *natural radioactivity* (the ability of a nucleus to emit a nuclear particle and energy without external stimulation);
2) *artificial transmutation*: transmutations occur by nuclear disintegration caused by external stimulation as a scientist bombards a nucleus with a particle (the addition of another nuclear particle makes the nucleus unstable);
3) *fission*: certain nuclei having a large mass are bombarded with special particles that cause the nuclei to split into two nuclei each having a smaller mass;
4) *fusion*: nuclei of light elements are combined to form heavier nuclei.

Nuclear reactions are written using symbols in the ${}^{m}_{a}X$ notation. The symbols for the major nuclear particles involved in nuclear reactions are given below.

| | |
|---|---|
| Alpha particle | ${}^{4}_{2}He$ (an alpha particle is a helium nucleus) |
| Proton | ${}^{1}_{1}H$ (the most common hydrogen nucleus is a proton) |
| Neutron | ${}^{1}_{0}n$ |
| Electron | ${}^{0}_{-1}e$ or ${}^{0}_{-1}\beta$ (also called a beta particle) |
| Positron | ${}^{0}_{1}e$ or ${}^{0}_{1}\beta$ |
| Gamma ray | ${}^{0}_{0}\gamma$ |

The table below contains information about nuclear reactions involving the emission of radiation.

| | | NUCLEAR CHANGES | |
|---|---|---|---|
| Type of Reaction | Radiation (Particle) | Effect on the Atomic Number | Effect on the Atomic Mass |
| Alpha emission ($\alpha$) | ${}^{4}_{2}He$ | decrease by 2 | decrease by 4 |
| Beta emission ($\beta$) | ${}^{0}_{-1}e$ or ${}^{0}_{-1}\beta$ | increase by 1 | no change |
| Positron emission ($\beta^{+}$) | ${}^{0}_{1}e$ or ${}^{0}_{1}\beta$ | decrease by 1 | no change |
| Gamma emission | ${}^{0}_{0}\gamma$ | no change | no change |
| Electron capture (EC) | ${}^{0}_{-1}e$ or ${}^{0}_{-1}\beta$ | decrease by 1 | no change |

# NUCLEAR CHEMISTRY WORKSHEET

Nuclear reactions that involve bombardment of nuclei vary in their products. For example:

$^{9}_{4}Be + ^{4}_{2}He \rightarrow ^{12}_{6}C + ^{1}_{0}n$

$^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}H$

$^{27}_{13}Al + ^{1}_{1}H \rightarrow ^{26}_{13}Al + ^{2}_{1}H$

$^{45}_{21}Sc + ^{1}_{0}n \rightarrow ^{42}_{19}K + ^{4}_{2}He$

In nuclear equations, the total number of positive charges (represented by the atomic numbers) of the reactants (substances on the left of the reaction arrow) equals the total number of positive charges of the products (substances on the right of the reaction arrow). The total mass of the reactants must also equal the total mass of the products.

For example:
A uranium-238 atom decays by emitting an alpha particle to form a thorium-234 atom.

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

Another example:
Potassium-40 decays to calcium-40 by beta emission.

$^{40}_{19}K \rightarrow ^{40}_{20}Ca + ^{0}_{-1}\beta$

In both examples, the total mass on the left equals the total mass on the right. The total number of positive charges on the left equal the total number of positive charges on the right.

Write out or complete the following nuclear reactions.

Technetium-99 ($^{99}_{43}Tc$) decays by beta emission to form ruthenium-99 ($^{99}_{44}Ru$).

______________________________________________

Phosphorus-32 decays by beta emission to form sulfur-32.

______________________________________________

Francium-212 ($^{212}_{87}Fr$) decays by alpha emission.

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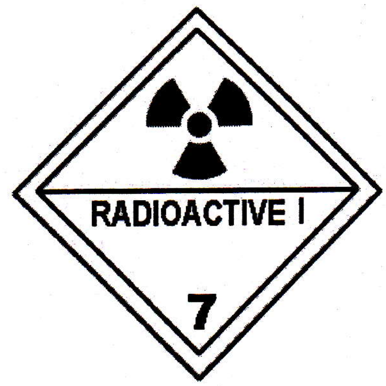
________________________________ ____

# Nuclear decay

Fill in the blanks to complete the following nuclear reactions. Use a periodic table.




1. $^{42}_{19}K \rightarrow {}^{0}_{-1}e$ + ____________

2. $^{239}_{\_}Pu \rightarrow {}^{4}_{2}He$ + ________

3. $^{235}_{92}U \rightarrow$ __________ + $^{231}_{90}Th$

4. $^{1}_{1}H + {}^{3}_{1}H \rightarrow$ __________

5. $^{6}_{3}Li + {}^{1}_{0}n \rightarrow {}^{0}_{-1}e\ {}^{4}_{2}He$ + _________

6. $^{27}_{13}Al + {}^{4}_{2}He \rightarrow {}^{30}_{15}P$ + _________

7. $^{9}_{4}Be + {}^{1}_{1}H \rightarrow$ __________ + $^{4}_{2}He$

8. $^{37}_{\_}K \rightarrow {}^{0}_{+1}e$ + __________

9. ________ + $^{1}_{0}n \rightarrow {}^{142}_{56}Ba + {}^{91}_{36}Kr + 3\,{}^{1}_{0}n$

10. $^{238}_{92}U + {}^{4}_{2}He \rightarrow$ __________ + $^{1}_{0}n$

11. $^{99}_{43}Tc \rightarrow$ _____ + $^{0}_{-1}e$

12. $^{226}_{88}Ra \rightarrow {}^{4}_{2}He$ + _________

13. __________ $\rightarrow {}^{4}_{2}He + {}^{208}_{81}Tl$

14. $^{27}_{13}Al$ + _________ $\rightarrow {}^{24}_{11}Na + {}^{4}_{2}He$

15. $^{235}_{92}U + {}^{1}_{0}n \rightarrow 3\,{}^{1}_{0}n + {}^{139}_{56}Ba$ + _________

16. $^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{139}_{53}I + 2\,{}^{1}_{0}n$ + _________

17. $^{241}_{95}Am + {}^{4}_{2}He \rightarrow 2\,{}^{1}_{0}n$ + _________

18. $^{214}_{84}Po + 2\,{}^{4}_{2}He + 2\,{}^{0}_{-1}e \rightarrow$ __________