Name: _____ Date: _____ Block: _____1

# Nuclear Chemistry

**Nuclear Reactions:** a nucleus loses or gains protons and neutrons.

**Why do some nuclei undergo radioactive decay?**

1. They are too big (too many protons)!
   - All elements with atomic numbers of 84 or higher are radioactive!
2. There are too many neutrons compared to protons.

**Alpha (α) Decay:** Nucleus releases an alpha particle.

- Alpha particle: helium nucleus (2 protons, 2 neutrons) = $^{4}_{2}He$
  - 2+ charge
  - Lowest energy radiation.
  - Can be stopped by a sheet of paper or skin.
- Reduces mass number by 4 and atomic number by 2.
- A new element is created (transmutation) because the atomic number changed.

Example:

$^{238}_{92}U \rightarrow$

Practice:

1. $^{234}_{90}Th \rightarrow$
2. $^{218}_{84}Po \rightarrow$
3. Write an equation that represents the alpha decay of Rn-222.

**Beta (β) Decay:** A neutron in the nucleus is converted into a proton and an electron. The electron is created INSIDE the nucleus and is emitted as a beta particle.

- Beta particle = a fast moving electron sent shooting out of nucleus
  - Negative charge
  - Can be stopped by aluminum foil or a piece of wood.
- Increases the atomic number by 1 and does not change the mass number.
- A new element is created (transmutation) because the atomic number changed.

Example:

$^{238}_{92}U \rightarrow$

Practice:

1. $^{218}_{84}Po \rightarrow$

2. Write the equation for the beta decay of Pb-214.

Name: _____ Date: _____ Block: _____2

**Gamma (γ) Decay:** A gamma ray (high energy electromagnetic wave) is released from the nucleus.

- Highest energy radiation.
- Most dangerous.
- Can be stopped by several cm of lead or several meters of concrete.

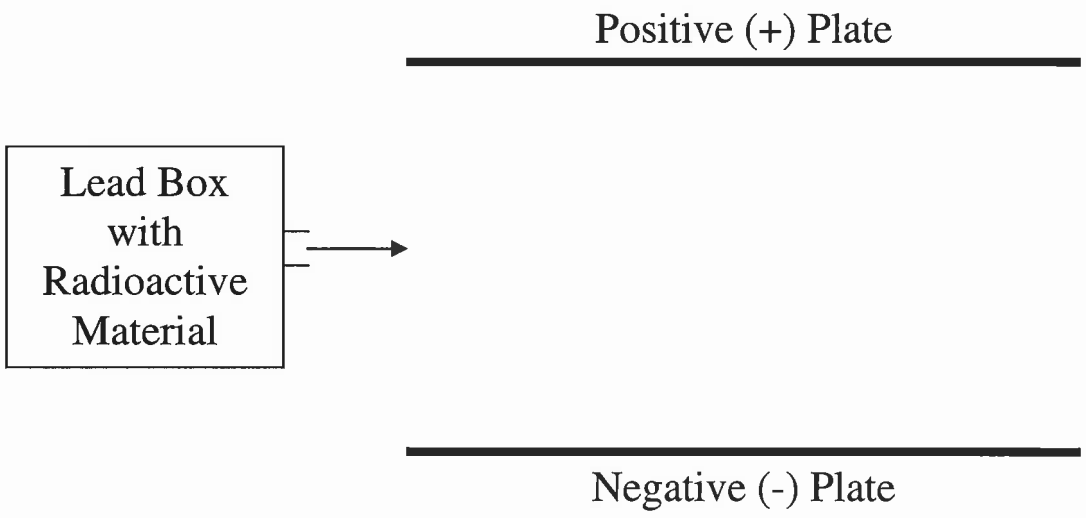
- The nucleus goes from an excited state to a normal (unexcited) state.
- Almost always occurs with alpha or beta decay.
- Does not change mass number or atomic number.
- No new element is created.

$^{238}_{92}U^{*} \rightarrow$

$^{218}_{84}Po^{*} \rightarrow$

* excited state

**How would alpha, beta, and gamma radiation be affected by an electric field?**



Name: _____ Date: _____ Block: _____3

**Nuclear Equations Practice**

Complete each nuclear equation by filling in the blank. Identify the type of nuclear reaction.

**Type (alpha, beta, gamma)**

1) $^{214}_{84}Po \rightarrow {}^{210}_{82}Pb + $ _____ _____

2) $^{222}_{86}Rn \rightarrow$ _____ $+ {}^{4}_{2}He$ _____

3) $^{230}_{90}Th \rightarrow {}^{226}_{88}Ra +$ _____ _____

4) $^{214}_{82}Pb \rightarrow$ _____ $+ {}^{0}_{-1}e$ _____

5) $^{226}_{88}Ra \rightarrow$ _____ $+ {}^{4}_{2}He$ _____

6) $^{237}_{93}Np \rightarrow$ _____ $+ {}^{0}_{-1}e$ _____

7) _____ $\rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$ _____

8) $^{234}_{92}U \rightarrow {}^{234}_{93}Np +$ _____ _____

9) $^{206}_{82}Pb \rightarrow {}^{4}_{2}He +$ _____ _____

10) $^{254}_{91}Pa \rightarrow$ _____ $+ {}^{0}_{-1}e$ _____

11) $^{228}_{88}Ra \rightarrow$ _____ $+ {}^{4}_{2}He$ + gamma rays _____

12) $^{212}_{82}Pb \rightarrow$ _____ $+ {}^{0}_{-1}e$ + gamma rays _____

13) Write the nuclear decay equation for the alpha decay of Pa-231:

Name: _____ Date: _____ Block: _____4

14) Write the nuclear decay equation for the alpha decay of Francium-223:

15) Write the nuclear decay equation for the beta decay of Xe-152:

16) Write the nuclear decay equation for the beta decay of Cesium-120:

17) Write the nuclear decay equation for the gamma decay of Nd-142

18) Which type of nuclear reaction is NOT a transmutation reaction?

19) An alpha particle can be stopped by _____ or _____
20) A beta particle can be stopped by _____ or _____
21) A gamma ray can be stopped by _____ or _____

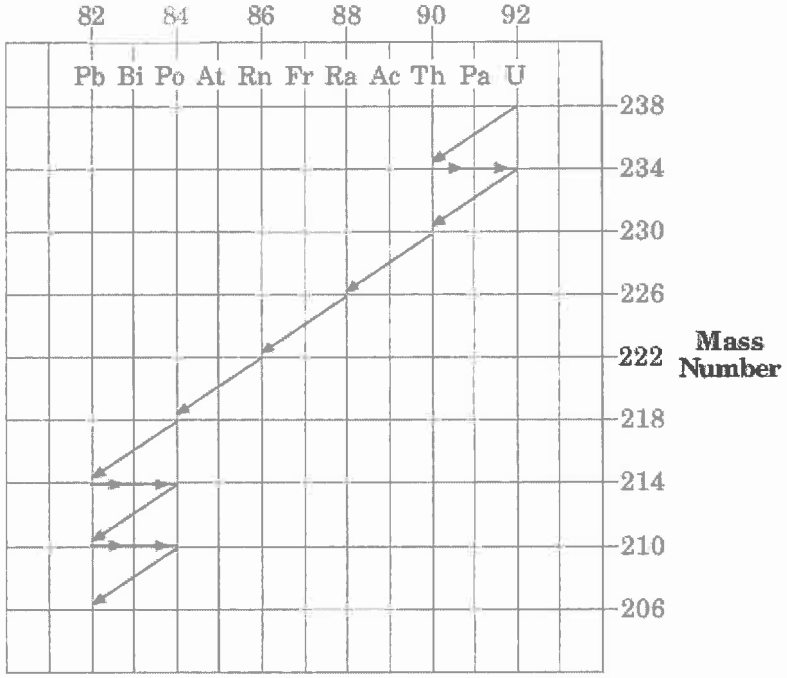
22) Which has the most energy? Alpha particle, beta particle, or gamma ray
23) Which has the least energy? Alpha particle, beta particle, or gamma ray

24) Draw: alpha particle beta particle gamma ray

Name: _____ Date: _____ Block: _____5

**URANIUM DISINTEGRATION SERIES**

**Atomic Number and Chemical Symbol**




1) How many alpha decays are in the Uranium Disintegration Series? _____
2) How many beta decays? _____

3) Use the chart to determine if the following nuclei will undergo an alpha or beta decay.
   a. Uranium-238: _____
   b. U-234: _____
   c. Thorium-234: _____
   d. Lead-214: _____
   e. Pa-234: _____
   f. Po-214: _____

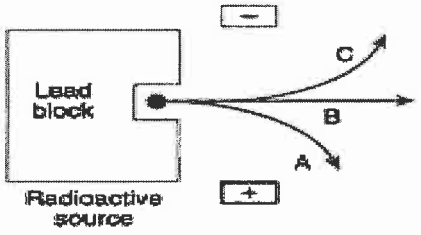
4) How many decays will a sample of Rn-222 undergo before it becomes stable as Pb-206? ___

**Identify the path of each type of radiation:**

Gamma ray: _____

Alpha particle: _____

Beta particle: _____



Name: _____ Date: _____ Block: _____6

**Nuclear Fission:** A large nucleus is split into two or more nuclei.

- A neutron is sent into a uranium nucleus. The U nucleus splits into two smaller nuclei and three neutrons are released to hit other U nuclei.
- Nuclear chain reaction: continuous series of fission reactions
- Lots of energy released.
- Atom bomb = uncontrolled fission reaction.
- Nuclear power plants use controlled fission reactions to make electricity.

Example:

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}n \rightarrow {}^{140}_{56}\mathrm{Ba} + {}^{93}_{36}\mathrm{Kr} + 3{}^{1}_{0}n$$

**Nuclear Fusion:** Two or more small nuclei combine to form a larger nucleus.

- Occurs on the sun and other stars (not on Earth!).
- Produces enormous amounts of energy
- To start a fusion reaction, temperature must be 200 million Kelvin.
- Difficult to initiate and contain this reaction due to high temperature required.

Example:

$$^{2}_{1}\mathrm{H} \quad + \quad {}^{3}_{1}\mathrm{H} \quad \rightarrow \quad {}^{4}_{2}\mathrm{He} \quad + {}^{1}_{0}n$$

Deuterium Tritium

***[Isotopes of Hydrogen]***

1) Complete the following reaction:

$$^{2}_{1}\mathrm{H} + \_\_\_\_\_ \rightarrow \quad {}^{4}_{2}\mathrm{He}$$

This reaction would be considered {fission or fusion?}.

2) The reaction below is a {fission or fusion?} reaction.

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}n \rightarrow {}^{140}_{56}\mathrm{Ba} + {}^{93}_{36}\mathrm{Kr} + 3{}^{1}_{0}n$$

3) A fission reaction is started when a neutron collides with a large uranium nucleus. The nucleus splits and 3 more neutrons are released. These neutrons collide with other uranium nucleus causing a _____ _____, like dominoes.

Name: _____ Date: _____ Block: _____7

**Radioactive Half-Life ($t_{1/2}$):** the amount of time it takes for half of the atoms to undergo decay.

- Use: dating fossils (carbon-14 dating), geological formations and human artifacts
- *Example Half Lives:*
  - *Potassium-40: Half-life = 1.25 years*
  - *Carbon-14: Half-life = 5739 years*
  - *Uranium-238: Half-life = 4.5 billion years*
  - *Rubidium-87: Half-life = 48 billion years*

Examples:

1. The half-life of carbon-14 is 5739 years. You start with a sample of 16 grams of C-14.
   a. How much will you have after 5739 years? _____
   b. How much will you have after 11,478 years? _____
   c. What fraction of the original amount will be left after 4 half-life periods? _____
   d. After 7 half-life periods? _____
2. A radioactive substance with a half-life of 8 years is allowed to decay. If the sample started out with 80 grams and ended with 10 grams, how many years have passed?

3. You started with a sample of 70 grams of a radioactive material. After 30 years, you only had 8.75 grams left. What is the half-life of this substance?

4. You have 60 grams of Potassium-40 (half-life = 1.25 years). If this sample has been decaying for 10 years, how much did you start with?

## Radioactive Half-Life Problems

1) If the half-life of iodine-131 is 8.10 days, how long will it take a 500 g sample to decay to 62.5 g?

2) Chromium-48 has a short half-life of 21.6 hours. How long will it take 360 g of chromium-48 to decay to 11.25 g?

Name: _____ Date: _____ Block: _____8

3) A 208 g sample of sodium-24 decays to 13 g of sodium-24 within 60 hours. What is the half-life of this radioactive isotope?

4) What is the half-life of a 100 g sample of nitrogen-16 that decays to 12.5 g of nitrogen-16 in 21.6 seconds?

5) Cobalt-60 has a half-life of 5.3 years. If a pellet that has been in storage for 26.5 years contains 14.5 g of cobalt-60, how much of this radioisotope was present when the pellet was originally put into storage?

6) A radioactive sample is allowed to decay. What fraction will be left after:
   a. 1 half-life? _____
   b. 2 half-lives? _____
   c. 3 half-lives? _____
   d. 4 half-lives? _____

7) Nitrogen-16 has a half-life of approximately 7.13 minutes. How much of a 25 g sample is left after 21.39 minutes?

8) Cobalt-60 is used in various medical procedures and has a half-life of about 5 years. How much should a hospital order if they want 20 grams to remain after 15 years?

9) Potassium has a half-life of 12.4 hours. How much of an 848 g sample of potassium-42 will be left after 62 hours?

10) A sample of iodine-131 was originally ordered as 100 g. When the shipment arrived 24 days later, only 12.5 g remained. How long is the half-life of iodine-131?

# NUCLEAR DECAY

Name _____

Predict the products of the following nuclear reactions.

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

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

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

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

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

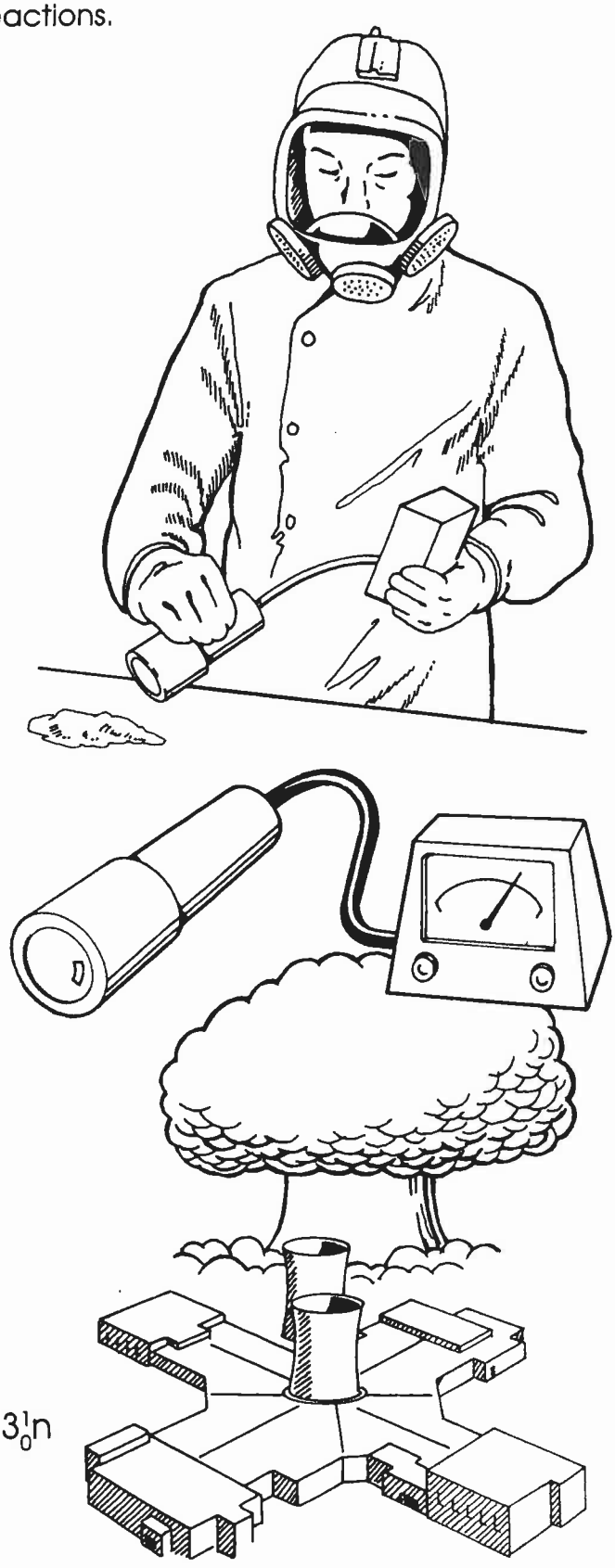
6. $^{27}_{13}Al + {}^{4}_{2}He \rightarrow {}^{30}_{15}P +$ _____

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



## Redox Reactions (Oxidation-Reduction Reactions)

Reactions in which electrons are lost by one element and gained by another element.
Examples of Redox Reactions – apples turning brown after cutting, formation of rust (corrosion of metals), combustion of fuels, photography, bleaching (removing stains from clothing), removing silver tarnish, chemiluminescence (cool light, like in light sticks). Redox reactions also occur during respiration and photosynthesis.

**LEO GER**
**Loses Electrons – Oxidation**
**Gains Electrons – Reduction**

Oxidation and Reduction always occur together.

$2Zn\ (s) + O_2\ (g) \rightarrow 2ZnO\ (s)$

Zinc is oxidized. Oxygen is reduced.
Zinc is the reducing agent (Substance that loses electrons).
Oxygen is the oxidizing agent. (Substance that gains electrons).

**Half Reactions:**

$O_2 + 4e^- \rightarrow 2O^{2-}$

$2Zn \rightarrow 2Zn^{2+} + 4e^-$

**To determine which element is being reduced and which is being oxidized, compare oxidation numbers of each atom before and after the reaction takes place.**

### Rules for Determining Oxidation Numbers

1. All elements in their free form (not chemically combined with other elements) have an oxidation number of zero.
2. Diatomic elements have an oxidation number of zero.
3. For elements in ionic compounds, the oxidation number equals the charge on the ion.
4. The sum of the oxidation numbers of elements in neutral ionic compounds is zero.
   - e.g. $Li_2O$: $2(+1) + (-2) = 0$
5. The sum of oxidation numbers of elements in polyatomic ions equals the charge on the ion.
6. H is usually 1+ except in hydrides of Group 1 and 2 metals ($CaH_2$) where it is 1-.
7. O is usually 2- except in peroxides (such has $H_2O_2$) when it is 1- and in compounds with F when it is 2+.
8. The oxidation number of the more electronegative atom in a molecule or complex ion is the same as the charge it would have if it were an ion.
9. Fluorine (the most electronegative element) always has an oxidation number of 1- when bonded to another element.

**Are these Redox Reactions?**

$NaOH + HCl \rightarrow NaCl + H_2O$

$2Na + Cl_2 \rightarrow 2NaCl$

**PRACTICE**

Identify what is oxidized and what is reduced in the following processes.

1. $2Br^- + Cl_2 \rightarrow Br_2 + 2Cl^-$
2. $2Ce + 3Cu^{2+} \rightarrow 3Cu + 2Ce^{3+}$
3. $Ca + Cl_2 \rightarrow CaCl_2$
4. $C + 2H_2O \rightarrow CO_2 + 2H_2$

Identify the oxidizing agent and the reducing agent in each of the following reactions.

1. $Mg + I_2 \rightarrow MgI_2$
2. $2Na + 2H^+ \rightarrow 2Na^+ + H_2$
3. $H_2S + Cl_2 \rightarrow S + 2HCl$

Determine the oxidation number of the boldface element in the following formulas for compounds and ions.

1. $Na\mathbf{Cl}O_4$
2. $Al\mathbf{P}O_4$
3. $H\mathbf{N}O_2$
4. $\mathbf{N}H_4^+$
5. $\mathbf{As}O_4^{3-}$
6. $\mathbf{Cr}O_4^{2-}$

# REDOX REACTIONS

Name _____

For the equations below, identify the substance oxidized, the substance reduced, the oxidizing agent, the reducing agent, and write the oxidation and reduction half reactions.

**Example:** $\overset{\text{oxidized}}{Mg} + \overset{\text{reduced}}{Br_2} \rightarrow MgBr_2$

($Mg$: reducing agent; $Br_2$: oxidizing agent)

oxidation half reaction: $Mg^{\circ} \rightarrow Mg^{+2} + 2e^-$

reduction half reaction: $2e^- + Br_2^{\circ} \rightarrow 2Br^-$

1. $2H_2 + O_2 \rightarrow 2H_2O$

2. $Fe + Zn^{2+} \rightarrow Fe^{2+} + Zn$

3. $2Al + 3Fe^{+2} \rightarrow 2Al^{+3} + 3Fe$

4. $Cu + 2AgNO_3 \rightarrow Cu(NO_3)_2 + 2Ag$

# ASSIGNING OXIDATION NUMBERS

Name _____

Assign oxidation numbers to all of the elements in each of the compounds or ions below.

| | |
|---|---|
| 1. $HCl$ | 11. $H_2SO_3$ |
| 2. $KNO_3$ | 12. $H_2SO_4$ |
| 3. $OH^-$ | 13. $BaO_2$ |
| 4. $Mg_3N_2$ | 14. $KMnO_4$ |
| 5. $KClO_3$ | 15. $LiH$ |
| 6. $Al(NO_3)_3$ | 16. $MnO_2$ |
| 7. $S_8$ | 17. $OF_2$ |
| 8. $H_2O_2$ | 18. $SO_3$ |
| 9. $PbO_2$ | 19. $NH_3$ |
| 10. $NaHSO_4$ | 20. $Na$ |