Chemistry:

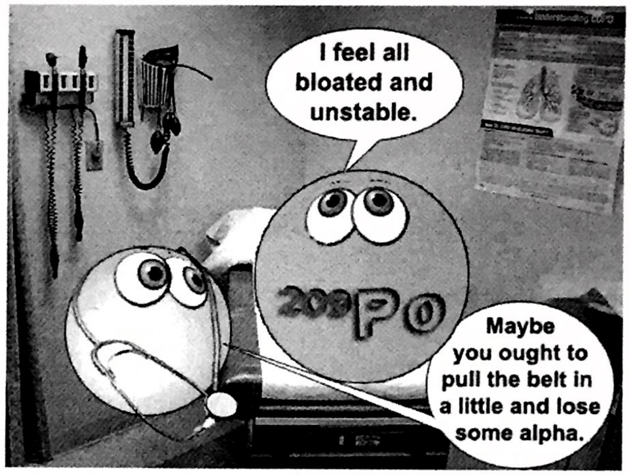
Name ______________________

NUCLEAR CHEMISTRY

Date ______________ Period ______

What is Radioactivity?

Protons repel each other. The higher the atomic number of an atom is, the greater the repulsion among protons is. This makes the nucleus unstable. Atoms with atomic numbers above 82 have no stable isotopes. Neutrons help to stabilize the nucleus by adding forces of attraction, without increasing the repulsion. Hydrogen is the only element that does not always have neutrons. As the number of protons increases, the number of neutrons needed to keep the nucleus stable increases. The ratio of neutrons to protons in stable nuclei is between 1:1 and 1.5:1, the higher ratio being associated with larger nuclei that have larger repulsive forces. Stable atoms have a ratio of neutrons to protons that falls in the belt of stability.



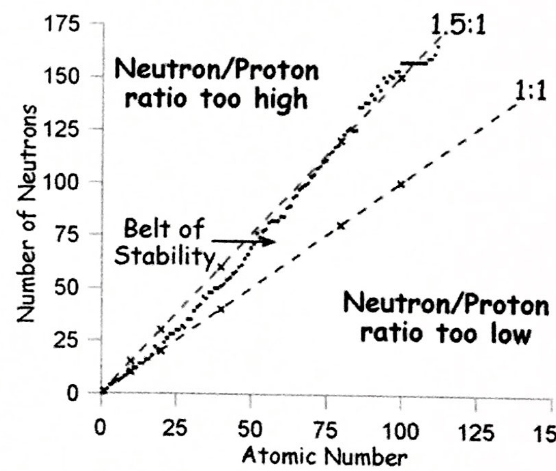
The box below shows a comparison of neutron to proton ratios for lead–206, a stable isotope, and uranium–235, a radioactive isotope. Lead falls in the belt of stability, while uranium does not.

Sample Problems

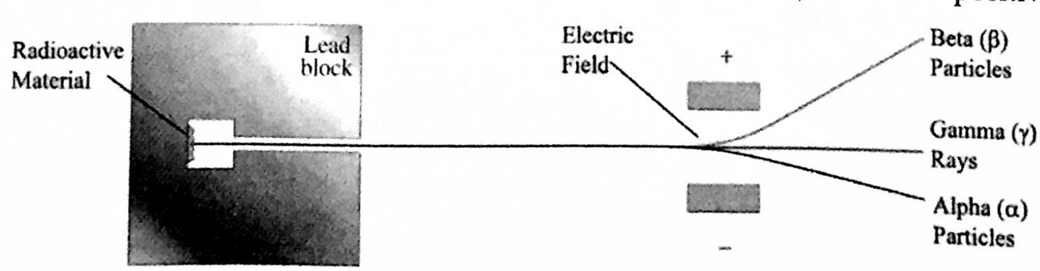
Look up the atomic number (Z) on the *Periodic Table*. Subtract the atomic number from the mass number (A) to get the number of neutrons (N).

Lead–206	*Uranium–235*
A = 206	A = 235
Z = 82	Z = 92
N = A – Z = 124	N = A – Z = 143
N/Z = 124/82 = 1.48 inside	N/Z = 143/92 = 1.55 outside

RATIO: 1.48 : 1.00   RATIO 1.55 : 1.00



Radioactivity. Unstable nuclei break apart or decay. Decaying nuclei release high speed particles and energy called radioactive emissions. Radioactive emissions separate in an electric field into three main types: alpha particles which are the same as a helium nucleus and have a positive charge; beta particles which are the same as a negatively charged electron except that they erupt from the nucleus; and gamma rays which are massless, chargeless energy. Sometimes atoms also give off positrons which are the same mass and size as an electron, but have a positive charge.



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Answer the questions below based on your reading and your knowledge of chemistry.

1. Determine whether each of the isotopes below is stable or unstable by first determining the N/Z ratio..

	N/Z	Stable/Unstable
a. ^{3}H	____________	____________
b. ^{14}N	____________	____________
c. ^{14}O	____________	____________
d. ^{97}Kr	____________	____________
e. ^{206}Pb	____________	____________

2. Calculate the N/Z ratio for elements with atomic numbers 104 through 109. Are they in the belt of stability? Are they stable? How do you know? What does this show about the belt of stability? ____

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3. Why are all elements with atomic numbers above 82 unstable? ____

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4. What is radioactivity? ____

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5. What are three common types of radioactivity given off by unstable atoms? How are they similar? How are they different? ____

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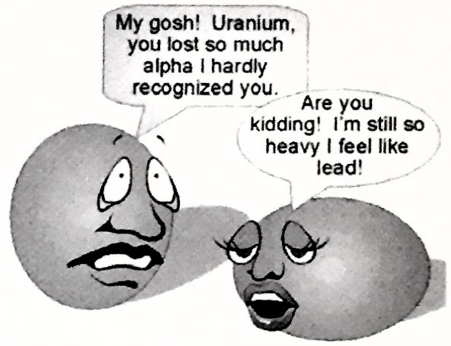
Writing Nuclear Equations

When elements undergo radioactive decay, they change from one element to another. This happens by losing high energy alpha or beta particles, or by emitting positrons. The process is called transmutation. Nuclear equations are written to track the changes that occur during transmutation. When writing nuclear equations, it is important to make sure that mass and charge are conserved.



Rules for writing nuclear equations

1. the masses on each side of the equation must be equal
2. the charges on each side of the equation must be equal
3. the nuclear charge is the atomic number, and can be used to identify any new elements that form

General Format

$${}^{A}_{Z}X \rightarrow {}^{a}_{z}x + {}^{A-a}_{Z-z}Y$$

A *or* a = mass number

Z *or* z = charge; atomic number

X = original element

x = radioactive emission

Y = new element

Following are general equations for alpha decay, beta decay, and positron emission. An example is also given of each.

Nuclear equations for alpha decay:

★ General format: ${}^{A}_{Z}X \rightarrow {}^{4}_{2}He + {}^{A-4}_{Z-2}Y$

★ Example: ${}^{235}_{92}U \rightarrow {}^{4}_{2}He + {}^{231}_{90}Th$

Nuclear equations for beta decay:

★ General format: ${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e$

★ Example: ${}^{234}_{90}Th \rightarrow {}^{234}_{91}Pa + {}^{0}_{-1}e$

Nuclear equations for positron emission:

★ General format: ${}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + {}^{0}_{+1}e$

★ Example ${}^{37}_{19}K \rightarrow {}^{37}_{18}Ar + {}^{0}_{+1}e$

The type of emission given off by a radioactive element is listed on *Table N* of the Reference Tables. Once the type of emission an element gives off is known, it is possible to determine what the final product is, or if the new element is known, it is possible to figure out what type of emission was responsible for the transmutation.

Sample Problem

Write a nuclear equation showing what forms when radon 222 decays?

Step 1: Determine the type of emission by looking on *Table N*
the emission is an α–particle

Step 2: Look up the atomic number of the known element and write an equation showing the known information

$${}^{222}_{86}Rn \rightarrow {}^{4}_{2}He + {}^{222-4}_{86-2}Y$$

Step 3: Subtract the weight and charge of the emission from the weight and charge of the original element to determine the weight and charge of the new element

$${}^{222}_{86}Rn \rightarrow {}^{4}_{2}He + {}^{218}_{84}Y$$

Step 4: Identify the new element based on the nuclear charge or atomic number

$${}^{222}_{86}Rn \rightarrow {}^{4}_{2}He + {}^{218}_{84}Po$$

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Answer the questions below based on your reading above and on your knowledge of chemistry. Write a complete nuclear equation showing the transmutation that occurs. Use *Table N* for reference.

1. What forms when carbon–14 decays?

2. What forms when radium–226 decays?

3. What forms when iron–53 decays?

4. What kind of decay causes neptunium–238 to form from uranium–238?

5. From what radioactive element does fluorine–19 form by positron emission?

6. What forms from the decay of francium–220?

7. What forms from the decay of potassium–42?

8. What forms from the decay of potassium–37?

9. What forms from the decay of iodine–131?

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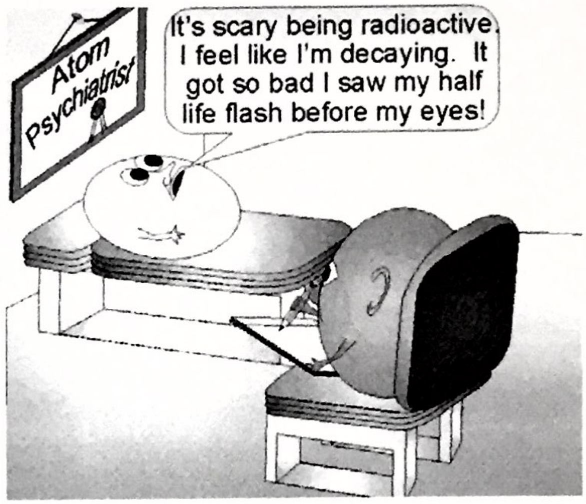
Working with Half-Life



When radioactive materials decay they release high speed particles that bang into other unstable radioactive atoms, hastening their decay. As the process proceeds, the amount of radioactive material decreases. This causes the number of high speed emissions to decrease. The fewer emissions there are, the slower the decay process becomes. As a result, large samples of radioactive material decay at a faster rate than small samples. In fact, as the sample size decreases, the rate of decay slows in such a way that the amount of time it takes for half the sample to decay is constant regardless of the sample size. In other words, it takes 500 g of uranium the same amount of time to decay into 250 g of uranium as it does for 2 g of uranium to decay into 1 g of uranium. The amount of time it takes for a radioactive sample to decay to half its original mass is called the half-life.

The easiest way to solve half life problems is to set up a table.

Sample Problem

How much ^{42}K will be left in a 320 g sample after 62 h?

Step 1: Look up the half life in *Table N*, the table of Selected Radioisotopes 12.4 h

Step 2: Set up a table showing the mass, time elapsed, the fraction remaining, and number of half lives starting with the initial conditions and ending when the full time has elapsed. For each half life elapsed, cut the mass in half, increase the time by an amount equal to the half life, cut the fraction in half, and add one to the number of half lives.

Mass	Time	Fraction	Half lives
320	0	1	0
160	12.4	½	1
80	24.8	$^1/_4$	2
40	37.2	$^1/_8$	3
20	49.6	$^1/_{16}$	4
10	62	$^1/_{32}$	5

Following this procedure it is possible to determine the final mass, the time elapsed, the fraction of the original sample, or the number of half lives elapsed.

Answer the questions below using data from *Table N*, the table of *Selected Radioisotopes*.

1. How long will it take for 30 g of ^{222}Rn to decay to 7.5 g?

2. How many grams of ^{16}N will be left from a 16 g sample after 21.6 s?

Continue ☞

3. How many half lives will it take for 50 g of ^{99}Tc to decay to 6.25 g?

4. What fraction of a sample of ^{32}P will be left after 42.9 d?

5. How long will it take for a 28 g sample of ^{226}Ra to decay to 3.5 g?

6. How long will it take for 50% of a sample of ^{131}I to decay?

7. After 9.8×10^{10} y, how many grams will be left from a 256 g sample of ^{232}Th?

8. How long will it take for 500 g of ^{90}Sr to decay to 125 g?

9. What fraction of a sample of ^{3}H will be left after 36.78 y?