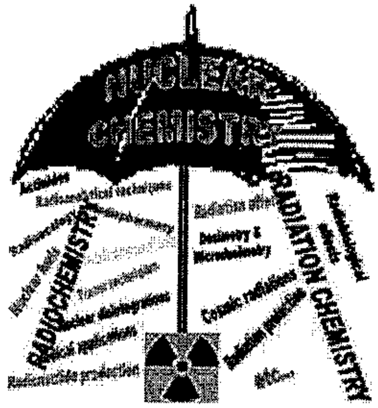
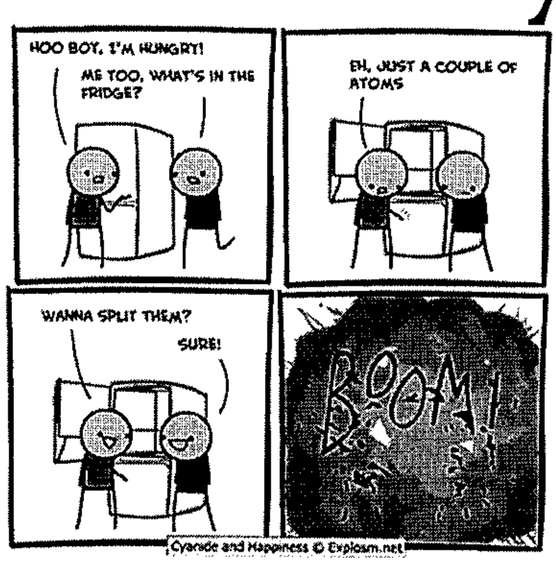
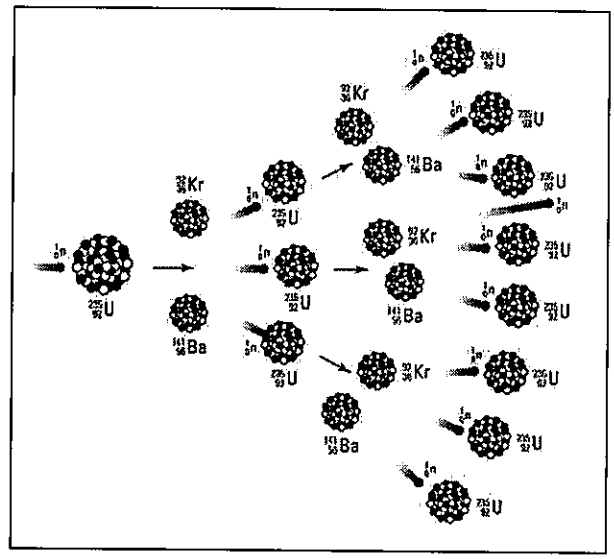
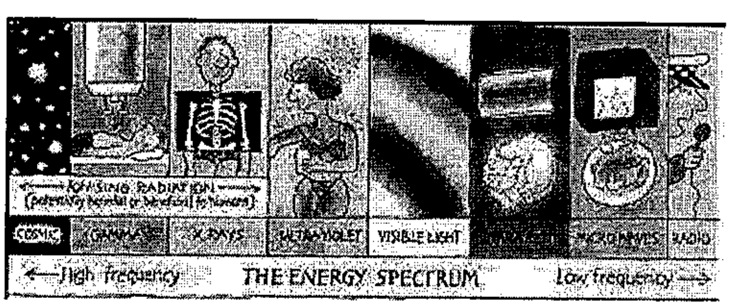
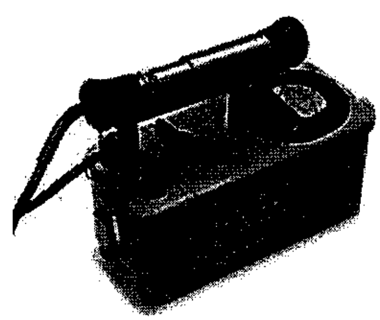
Nuclear Chemistry











Nuclear Stability

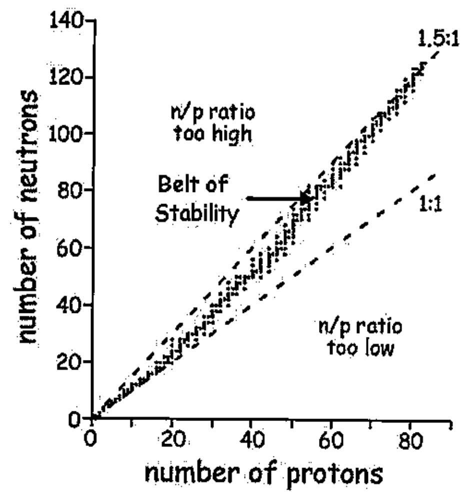
Aim

- to explain why substances are radioactive

Notes

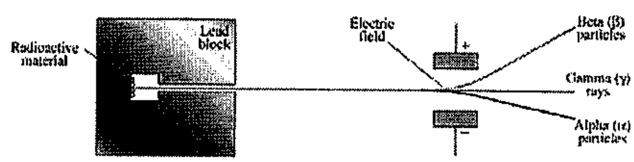
Instability

★ Protons repel each other
  - ☆ the higher the atomic number is, the greater the repulsion among protons is, making the nucleus unstable
    - ✯ atoms with atomic numbers above 82 have no stable isotopes
  - ☆ neutrons help to stabilize the nucleus
    - ✯ hydrogen is the only element that does not 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.



Radioactivity

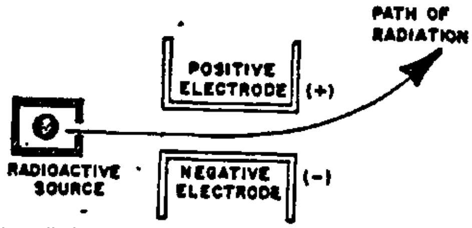
★ Unstable nuclei break apart or decay
  - ☆ decaying nuclei release high speed particles and energy called radioactive emissions
  - ☆ radioactive emissions separate in an electric field into three main types
    - ✯ alpha particle – helium nucleus
    - ✯ beta particle – electron
    - ✯ gamma ray – energy
  - ☆ other important emissions – positrons



COMMON RADIOACTIVE EMISSIONS				
Particle	**Mass**	**Charge**	**Symbol**	**Penetrating Power**
Alpha	4 amu	2+	$^{4}_{2}He$ or α	low
Beta	0 amu	1–	$^{0}_{-1}e$ or β^-	moderate
Positron	0 amu	1+	$^{0}_{+1}e$ or β^+	moderate
Gamma	0 amu	0	γ	high

Answer the questions below by circling the number of the correct response

1. A radioactive source emits radiation which is deflected as shown in the diagram below.



This radiation could be

(1) $^{0}_{-1}e$ (3) $^{1}_{1}H$
(2) $^{4}_{2}He$ (4) $^{1}_{0}n$

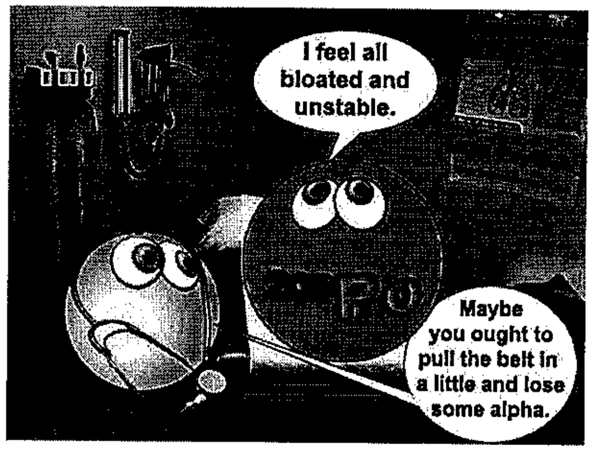
2. Which product of nuclear decay has mass but no charge?
(1) alpha particles (3) gamma rays
(2) neutrons (4) beta positrons

Chemistry: Form WS12.1.1A Name ______________________

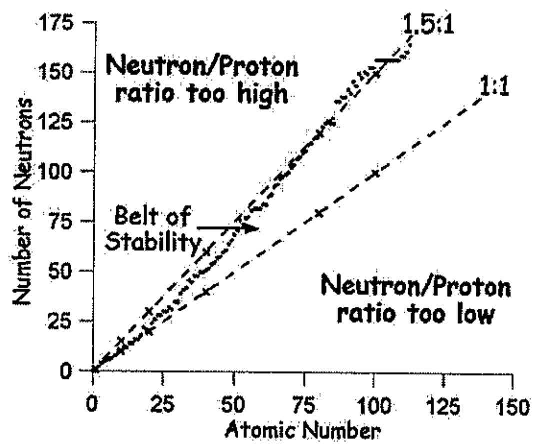
NUCLEAR CHEMISTRY Date ______________ Period _____

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.

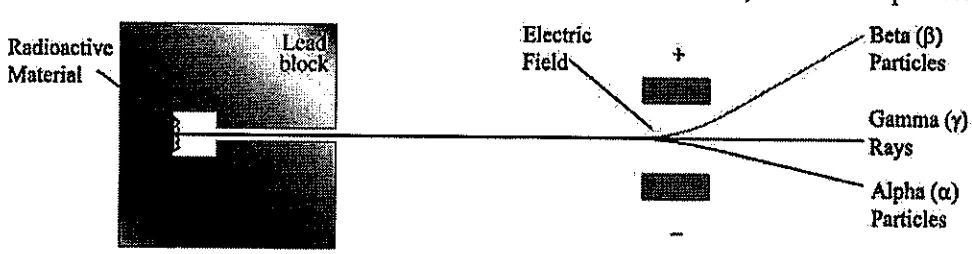


Sample Problems

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 = 84	Z = 92
N = A – Z = 122	N = A – Z = 143
N/Z = 122/84 = 1.45	N/Z = 143/92 = 1.55

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.



(CONTINUED ON THE NEXT PAGE)

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? ______

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

4. What is radioactivity? ______

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

Chemistry: Form Ls12.2A　　Name ____________________

NUCLEAR CHEMISTRY　　Date ______________　Period _____

Natural Radioactivity

Aim

- to describe the types of naturally occurring radioactive decay

Notes

Natural radioactive decomposition - an unstable nucleus emits particles

★ Alpha decay - loss of an alpha particle
- ☆ Alpha particle - helium nucleus
  - ★ Structure
    - ★ 2 protons
    - ★ 2 neutrons
  - ★ Symbol - $^{4}_{2}He$
- ☆ Nuclear equations for alpha decay
  - ★ General format

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

    $^{235}_{92}U \rightarrow {}^{4}_{2}He + {}^{231}_{90}Th$
    - ★ loss of an alpha particle reduces the mass by 4 amu from 235 to 231
    - ★ it also reduces the atomic number by 2 from 92 to 90
    - ★ the element with an atomic number of 90 is Thorium

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

General Format

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

★ Beta decay - loss of a beta particle
- ☆ Beta particle - electron formed from the decay of a neutron into a proton and an electron ($^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}e$)
  - ★ Symbol - $^{0}_{-1}e$
- ☆ Nuclear equations for beta decay
  - ★ General format

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

    $^{234}_{90}Th \rightarrow {}^{234}_{91}Pa + {}^{0}_{-1}e$
    - ★ loss of a beta particle does not effect the mass
    - ★ loss of a beta particle increases the atomic number by 1 from 90 to 91
    - ★ the element with atomic number 91 is protactinium

★ Positron emission - conversion of a proton to a neutron ($^{1}_{1}p \rightarrow {}^{1}_{0}n + {}^{0}_{+1}e$)
- ☆ Positron - particle similar to an electron in mass and size, but with a positive charge
  - ★ Symbol - $^{0}_{+1}e$
- ☆ Nuclear equations for positron emission
  - ★ General format

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

    $^{37}_{19}K \rightarrow {}^{37}_{18}Ar + {}^{0}_{+1}e$
    - ★ loss of a positron does not effect the mass
    - ★ loss of a positron decreases the atomic number by 1 from19 to 18
    - ★ the element with atomic number 18 is argon

Answer the questions below by circling the number of the correct response

1. According to the equation $X \rightarrow {}^{208}_{82}Pb + {}^{4}_{2}He$, the nucleus correctly represented by X is
   (1) ${}^{204}_{80}Hg$ (3) ${}^{204}_{80}Bi$
   (2) ${}^{212}_{84}Po$ (4) ${}^{212}_{84}Pb$

2. In the reaction ${}^{24}_{11}Na \rightarrow {}^{24}_{12}Mg + X$, the particle represented by tile letter X is
   1 a proton 3 an electron
   2 a neutron 4 a positron

3. When an atom emits a beta particle, the total number of nucleons
   1 decreases
   2 increases
   3 remains the same

4. When a beta particle (${}^{0}_{-1}e$) is emitted by the nucleus of an atom the mass number of the atom
   1 decreases
   2 increases
   3 remains the same

5. According to Reference Table F, a product of the radioactive decay of ${}^{226}_{88}\text{Ra}$ is
   (1) ${}^{4}_{2}\text{He}$ (3) ${}^{0}_{-1}e$
   (2) ${}^{226}_{89}\text{U}$ (4) ${}^{230}_{90}\text{U}$

Name ______________________

Date ______________ Period ____

Artificial Transmutation

Aim

- to explain how man made elements are formed

Notes

Artificial Transmutation - human made reactions in which a nucleus is bombarded with a high speed particle which causes the nucleus to emit a proton or neutron

★ particle accelerators give charged particles enough energy to overcome electrostatic forces and penetrate the nucleus of an atom

★ acceleration is accomplished by manipulation of electric and magnetic fields

★ Importance - method by which human made elements are produced

★ Example 1

$${}^{249}_{98}Cf + {}^{15}_{7}N \rightarrow {}^{260}_{105}Db + 4{}^{1}_{0}n$$

- ☆ A nitrogen nucleus is absorbed by californium and 4 neutrons are given off to form the element dubnium
  - ✯ absorption of a nitrogen by californium increases the mass by 15 from 249 to 264 and increases the atomic number by 7 from 98 to 105
  - ✯ loss of 4 neutrons decreases the mass by 4 from 264 to 260 but does not effect the atomic number
    - ✯ The element formed, number 105, is man made

★ Example 2

$${}^{27}_{13}Al + {}^{4}_{2}He \rightarrow {}^{30}_{15}P + {}^{1}_{0}n$$

- ☆ aluminum absorbs an alpha particle and releases a neutron to form phosphorus
  - ✯ absorption of an alpha particle by aluminum increases the mass by 4 from 27 to 31 and increases the atomic number by 2 from 13 to 15
  - ✯ loss of a neutron reduces the mass by 1 from 31 to 30 but does not effect the atomic number

Answer the questions below by circling the number of the correct response

1. Which of the following statements is true with respect to the reaction below:

$${}^{249}_{98}Cf + {}^{15}_{7}N \rightarrow {}^{260}_{105}Db + 4{}^{1}_{0}n$$

(1) The formation of Db is a result of a chemical reaction between Cf and nitrogen in air
(2) The formation of Db is a result of radioactive decay of Cf
(3) The formation of Db is a result of a natural transmutation
(4) The formation of Db is a result of an artificial transmutation

2. With what is aluminum bombarded in the reaction below to produce ^{30}P?

$${}^{27}_{13}Al + ? \rightarrow {}^{30}_{15}P + {}^{1}_{0}n$$

(1) alpha particle
(2) beta particle
(3) positron
(4) ^{15}N

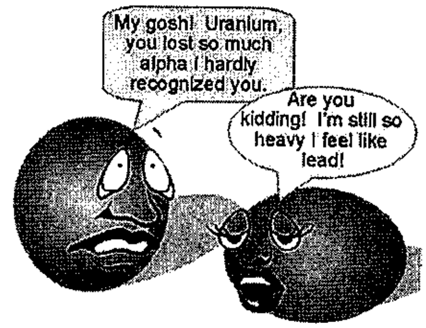
3. The change that is undergone by an atom of an element made radioactive by bombardment with high-energy protons is called
(1) natural transmutation
(2) artificial transmutation
(3) natural decay
(4) radioactive decay

Name ______________________

Date ______________ Period _____

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

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

Continue ☞

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?

Writing Nuclear Equations

1. Write an equation to describe the alpha decay of a radium-226 nucleus to form a radon nucleus.

2. Write an equation to describe the alpha decay of a radon nucleus to form a polonium-218 nucleus.

3. Write an equation to describe the beta decay of a lead-214 nucleus to form a bismuth-214 nucleus.

4. Write an equation to describe the alpha decay of a uranium-238 nucleus to form a thorium nucleus.

5. Write an equation to describe the beta decay of a thorium-234 nucleus to form a protactinium nucleus.

6. Write the series of equations involving three alpha decays and two beta decays that transmutes a uranium-238 nucleus into a radon-226 nucleus.

Decay Series of Uranium-238

When a radioactive element decays by emitting an alpha (α) or a beta (β) particle, a new element is formed. This process is called transmutation. An alpha particle contains two protons and has an atomic mass of four. During alpha decay, an atom loses two protons and four atomic mass units. Since the atomic number of an element is the number of protons, the atomic number of the atom is decreased by *two*. The mass number is decreased by *four*.

In nuclear science an element is identified in the following way.

$$^{A}_{Z}E \qquad \text{Where } A = \text{atomic mass},\ Z = \text{atomic number},\ E = \text{element}$$

Uranium-238 is $^{238}_{92}U$. Uranium-238 has an atomic mass of 238 and an atomic number of 92. When uranium-238 decays, it emits an alpha particle and becomes element number 90 (92 – 2), which is thorium. The mass of the thorium atom is 234 (238 – 4). This decay can be represented in the following way.

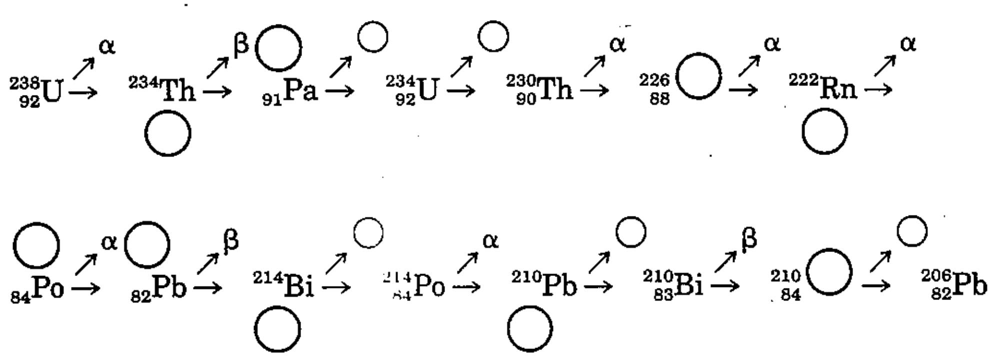
$$^{238}_{92}U \xrightarrow{\alpha} {}^{234}_{90}Th$$

The beta particle is a high-speed electron that is emitted by the nucleus. When a neutron in the nucleus decays, an electron is released and a proton is left behind (1 neutron = 1 proton + 1 electron). The atomic number, therefore, increases by one proton. Since the mass of an electron is so small, the atomic mass remains the same. So beta decay increases the atomic number by one, but does not change the atomic mass. Thorium-234 emits a beta particle and transmutes to element 91, which is protactinium.

$$^{234}_{90}Th \xrightarrow{\beta} {}^{234}_{91}Pa$$

Notice that the atomic mass, 234, does not change.

In the following U-238 decay series, fill in the correct number or element in each of the circles. You will need a periodic table of the elements to identify an element from its atomic number.



Name ____________________ Class______ Date__________

Unit 10 Nuclear Chemistry

Activity 10-1

Natural Radioactivity

Radioactivity

1. What are isotopes? ____________________

2. What is a radioisotope? ____________________

3. Choose words from the word list to complete the following paragraphs relating to radioactivity. The list groups words that have contrasting or related meanings.

Word List

alpha/beta/gamma	number(s)
breakdown	particles
energy	protons/electrons/neutrons
isotope(s)	stable/unstable
nucleus	transmutation(s)

Radioactivity is the spontaneous __________ of the __________ of an atom. This breakdown is accompanied by the emission of __________ and/or radiant __________. This breakdown changes the makeup of the __________. When the number of __________ in the nucleus changes, one element has been changed to another element. If only the number of __________ changes, one isotope of an element has been changed to another __________ of the same element. The first kind of change—one element to another—is called__________.

Some naturally occurring __________ are radioactive. All known __________ of elements with atomic __________ greater than 83 are unstable. These isotopes undergo transmutation such that they are eventually converted to __________ with atomic __________ less than 83. One well-studied series of __________ is that of uranium-238. This unstable radioisotope, $^{238}_{92}U$, undergoes transmutation to $^{206}_{82}Pb$, a __________ isotope. The breakdown products formed during __________ are called nuclear emissions. These include __________ decay, __________ decay, and __________ radiation.

Nuclear emissions

Nuclei of radioisotopes emit energy and subatomic particles. These emissions, or emanations, differ from each other in mass, charge, penetrating power, and ionizing power.

4. Complete the following table to show the properties of some subatomic particles. You may refer to table H in the Appendix.

Name	Symbol used in equations	Other symbol	Mass number	Charge
electron				
positron				
proton				
alpha particle				
neutron				

5. Choose words from the word list below to fill in the blanks in the following paragraphs relating to the properties of nuclear emissions. Words with contrasting meanings have been paired in the list.

Word List

deflected/undeflected
electric
emissions
particles/rays

positive/negative
positively/negatively
zero

Some ________________ are deflected as they pass through an ________________ field. Emissions such as positrons, protons, and alpha particles that are ________________ charged are deflected toward the ________________ electrode. Beta particles, which are ________________ charged, are deflected toward the ________________ electrode. Neutrons and gamma radiation pass ________________ through an electric field since they possess no charge.

Gamma radiation is in the form of ________________, not ________________. Gamma radiation is not included in the list of emissions above because gamma rays have a mass of nearly ________________ and a charge of ________________.

Nuclear equations

6. Complete the following statements:

In balanced nuclear equations, the sum of the superscripts on the left is ________________ (*greater than/equal to/less than*) the sum of the ________________ (*subscripts/superscripts*) on the right. This illustrates the principle of conservation of ________________ (*mass/charge*). Similarly the sum of the subscripts on the left is ________________ (*greater than/equal to/less than*) the sum of the ________________ (*subscripts/superscripts*) on the righ'. This illustrates the principle of conservation of ________________ (*mass/charge*).

Name ______________________________ Class______ Date____________

Nuclear equations show transmutations of one kind of nucleus into another. Complete and balance the equations for the following nuclear transmutations.

7. $^{14}_{6}C \rightarrow ^{14}_{7}N +$ ______

8. $^{218}_{84}Po \rightarrow ^{4}_{2}He +$ ______

9. $^{226}_{88}Ra \rightarrow ^{222}_{86}Rn +$ ______

10. $^{22}_{11}Na \rightarrow ^{22}_{10}Ne +$ ______

11. $^{234}_{90}Th \rightarrow ^{0}_{-1}e +$ ______

12. $^{140}_{59}Pr \rightarrow ^{140}_{58}Ce +$ ______

13. ______ $\rightarrow ^{24}_{12}Mg + ^{0}_{-1}e$

14. $^{230}_{88}Th \rightarrow ^{4}_{2}He +$ ______

15. $^{234}_{91}Pa \rightarrow ^{234}_{92}U +$ ______

16. $^{9}_{5}B \rightarrow ^{1}_{1}H +$ ______

17. $^{8}_{2}He \rightarrow ^{7}_{2}He +$ ______

18. $^{16}_{6}C \rightarrow ^{1}_{0}n +$ ______

19. $^{13}_{8}O \rightarrow ^{13}_{7}N +$ ______

20. $^{3}_{1}H \rightarrow ^{3}_{2}He +$ ______

Half-life

21. What is the definition of half-life for a radioisotope? ______________________
____
____

22. Write the balanced equation for the transmutation of ^{131}I as described in Table F in the Appendix. ____
____

23. a. From a starting mass of 100 g of ^{131}I, what mass will remain after 8 days? __________
After 16 days?____________ After 24 days? ____________

b. Which of the following will be the remaining mass of ^{131}I after 4 days? (See the graph on page 330.) Circle your answer.

greater than 75 g   75 g   less than 75 g

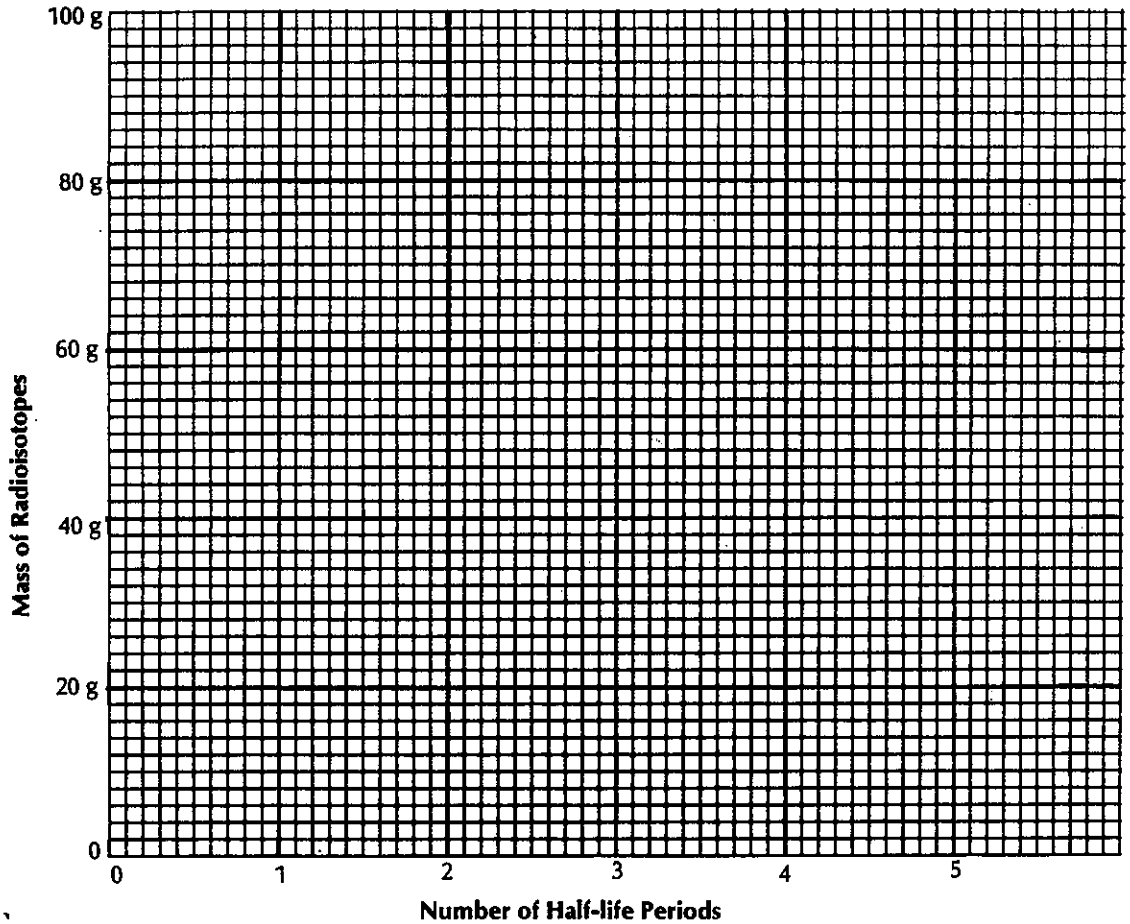
Explain your answer. ____
____

24. Write the balanced equation for the transmutation of ^{220}Fr as described in Table F in the Appendix. ____

25. Starting with a sample of 4.0×10^{-7} mole of Fr atoms, how many Fr atoms will remain After 27.4 sec? ____________ After 54.8 sec? ____________ After 82.2 sec? ____________

In the space below, show your calculations.

26. Using the following grid, make a graph to show the quantity of radioisotope remaining unchanged after the passage of successive half-life periods. The original mass of the radioisotope is 100 grams.



For each of the following, write the equation for the nuclear transformation, the number of half-life periods that has elapsed, and the quantity of radioisotope remaining unchanged after the given period of time. Refer to Table F in the Appendix for information you need.

27. Radioisotope: $^{42}_{19}K$. Original quantity: 100 grams. Time elapsed: 62 hours.

Equation ______________________________

Number of half-life periods ______

Mass of radioisotope remaining unchanged ______ grams

28. Radioisotope: $^{226}_{88}Ra$. Original quantity: 8.0×10^{19} atoms. Time elapsed: 16 000 years.

Equation ______________________________

Number of half-life periods ______

Number of atoms of radioisotope remaining unchanged ______ atoms

6. Complete the following table about different types of radioactive decay.

Type of Radioactive Decay	What happens to the atomic number?	What happens to the mass number?
Beta-particle emission		
electron capture		
positron emission		
alpha particle emission		

Write balanced nuclear equations for the following, and name the type of radioactive emission formed when each occurs.

7. $^{51}_{24}Cr + ^{0}_{-1}e \rightarrow$ ______________ $+ \gamma$ emission: ______________

8. $^{226}_{88}Ra \rightarrow$ ______________ $+ ^{4}_{2}He$ emission: ______________

9. $^{239}_{93}Np \rightarrow$ ______________ $+ ^{0}_{+1}e$ emission: ______________

10. $^{234}_{91}Pa \rightarrow$ ______________ $+ ^{0}_{-1}e$ emission: ______________

11. $^{49}_{24}Cr \rightarrow ^{49}_{23}V +$ ______________ emission: ______________

12. $^{238}_{92}U \rightarrow ^{234}_{90}Th +$ ______________ emission: ______________

13. $^{214}_{83}Bi \rightarrow ^{214}_{84}Po +$ ______________ emission: ______________

Categorize each nuclear equation below by writing the correct term from the following list. Terms may be used more than once.

beta particle emission — electron capture — positron emission
alpha particle emission — annihilation of matter

14. $^{0}_{-1}e + ^{0}_{+1}e \rightarrow 2\gamma$ type: ______________

15. $^{1}_{1}p \rightarrow ^{1}_{0}n + ^{0}_{+1}e$ type: ______________

16. $^{37}_{18}Ar + ^{0}_{-1}e \rightarrow ^{37}_{17}Cl + \gamma$ type: ______________

17. $^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He$ type: ______________

18. $^{1}_{0}n \rightarrow ^{1}_{1}H + ^{0}_{-1}e$ type: ______________

Complete each statement below by writing the correct term in the space provided.

19. Nuclei that have an excess of neutrons can become stable by emitting _______________.

20. Any time a particle collides with an _______________, all of the mass of the two particles is converted into electromagnetic energy.

21. A positron colliding with an electron results in the conversion of all the masses of the two particles into gamma rays; this process is known as the _______________.

22. _______________ emission changes neither the atomic number nor the mass number.

23. In _______________, a proton is changed into a neutron.

24. In beta emission, an electron is emitted by a _______________.

25. None of the elements above atomic number 83 and mass number 126 have stable isotopes, and many stabilize by _______________.

26. A few sheets of paper can stop _______________.

27. In an alpha emission, the atomic number of the nucleus decreases by _______________ while the mass number decreases by _______________.

Complete each statement below by choosing a term from the following list. Use each term only once.

fission	fusion	sustains	chain reaction	fuse
neutrons	binding energy	spontaneous	critical mass	

28. Nuclear _______________ refers to a nuclear reaction in which a very heavy nucleus splits into two smaller nuclei, each having a higher _______________ per nucleon than the original nucleus. A very small fraction of naturally occurring uranium atoms undergoes _______________ fission. Most fission reactions are artificially induced by bombarding nuclei with _______________. A _______________ is a fission reaction which, once initiated, _______________ itself. The smallest mass of radioactive material needed to sustain a chain reaction is known as the _______________ of the material.

29. Nuclear ____________ occurs when two small nuclei combine, or ____________, to form a larger, more stable nucleus with a higher binding energy.

Categorize each nuclear equation below as *fission* or *fusion*.

30. ${}^{3}_{1}H + {}^{2}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n$ type: ____________

31. ${}^{239}_{94}Pu + {}^{1}_{0}n \rightarrow {}^{90}_{38}Sr + {}^{147}_{56}Ba + 3{}^{1}_{0}n$ type: ____________

32. ${}^{235}_{92}U \rightarrow {}^{90}_{38}Sr + {}^{144}_{58}Ce + {}^{1}_{0}n + 4{}^{0}_{-1}e$ type: ____________

33. $2{}^{3}_{2}He \rightarrow {}^{4}_{2}He + 2{}^{1}_{1}H$ type: ____________

Answer the following items in the space provided.

34. Describe potential benefits and hazards of nuclear fission.

____

____

____

____

____

____

____

____

NAME:________________________________ DATE:______SECTION______LAB______

Where did the mass go?

Background:

The first hints concerning nuclear structure came with the discovery of radioactivity, 15 years before the existence of the atomic nucleus was demonstrated. One question that naturally arose at once in connection with radioactivity was where all of that energy might be coming from. Uranium seemed to ceaselessly emit alpha rays and beta rays. All of these particles traveled at very high speeds. It takes considerable energy to make them move quickly from a standing start. Then, too, there were gamma rays, which were far more energetic.

Uranium's radiation isn't just a brief spurt of energy. A sample of uranium metal will continue to radiate indefinitely at an apparently constant rate, and this was a serious problem. By the law of conservation of energy, it would seem that energy could not be created out of nothing, and yet energy seemed to be created out of nothing in connection with radioactivity.

In 1903, Rutherford suggested that all atoms possessed large volumes of energy within their structure. Ordinarily, this energy was never tapped, so that people remained unaware of its existence. Radioactivity was, however, a spontaneous outpouring of a little of this energy.

And yet Rutherford's suggestion might have seemed to be a case of pulling a rabbit out of a hat. Just saying that the atom contained energy explained nothing. But then in 1905, Einstein showed, convincingly, that mass a very concentrated form of energy. If radioactive substances were to turn even a small fraction of their mass to energy, then all of the energy liberated in radioactivity could easily be accounted for.

Mass Defect

Careful measurements have shown that the mass of a particular atomic nuclei is always slightly less than the sum of the masses of the individual neutrons and protons. The difference between the mass of the nucleus and the sum of the masses of its parts is called the *mass defect.* So, the mass of any nucleus is less than the sum of the separate masses of its protons and neutrons. In other words, sticking protons and neutrons together somehow causes some of their mass to vanish into thin air. The "vanishing" mass of the protons and neutrons is simply converted to energy. This energy is called the binding energy.

Procedure:

1) For the following examples calculate the mass defect in terms of "u" the atomic mass unit.

Mass of a Proton: 1.0073 u Mass of a Neutron: 1.0087 u

A) $^{6}Li_{3}$ Mass = 6.0151u, 3 protons and 3 neutrons.

B) $^{14}C_6$ Mass = 13.0034 u, 6 protons and 8 neutrons.

C) $^{56}Fe_{26}$ Mass = 55.9349 u, 26 protons and 30 neutrons.

D) $^{238}U_{92}$ = 238.0508 u, 92 protons and 146 neutrons.

2) During a decay process energy is released from the decaying nuclei. This energy comes from the mass of the starting parent nuclei which is lost as it transmutes into a daughter nuclei, an emitted particle and radiation. Calculate the difference between the mass of the reactants and the products and reactants. This missing mass is converted to energy via $E=mc^2$.

A) $^{222}Rn_{86} \rightarrow {}^{4}He_2 + {}^{218}Po_{84}$ + Energy

Mass of particles
Rn-222 = 222.0175 u
He-4 = 4.0026 u
Po-218 = 218.0090 u

B) $^{19}Ne_{10} \rightarrow {}^{0}e_{+1} + {}^{19}F_9$ + Energy

Mass of particles
Ne-19 = 19.0019 u
Positron = 0.0005 u
F-19 = 18.9984 u

C) $^{42}K_{19} \rightarrow {}^{0}e_{-1} + {}^{42}Ca_{20}$ + Energy

Mass of particles
K-42 = 41.9624 u
Beta = 0.0005 u
Ca-42 = 41.9586 u

Reflection:

Describe where the energy released during radioactive decay comes from.

Questions:

1) What is the name of the force which holds the nucleus of an atom together?

2) Why do a positron and a beta particle have the same mass?

3) If 1 u = 1.6605×10^{-27} kg determine the amount of kilograms found in the energy from question *2A*. The missing mass from the alpha decay of Rn-222.

4) Convert the mass from energy of the alpha decay of Rn-222 in to energy by using $E=mc^2$. Where $c = 3.00 \times 10^8$ m/s.

Name ______________________

Date ________________ Period ______

Half-Life

Aim

- to explain half-life and solve half-life problems

Notes

Half life

★ Definition - the amount of time it takes for half of a radioactive sample to decay

★ Explanation
- ☆ During radioactive decay, high speed particles are emitted that bang into other atoms and cause them to decay
- ☆ As a sample decays the amount of radioactive material decreases
- ☆ As the size of the radioactive sample decreases, the number of particles emitted decreases
- ☆ As the number of particles emitted decreases, the number of collisions decreases and radioactive decay slows down
- ☆ Radioactive decay slows down over time in such a way that the amount of time it takes for half a sample to decay is constant regardless of the size of the sample

★ Radioactive dating
- ☆ Carbon dating
  - Carbon-14 is radioactive and has a half life of 5,700 years
  - Carbon dioxide in the air contains carbon-14
  - Plants take in carbon dioxide and make carbohydrates as long as they are alive
  - Animals eat plants as long as they are alive
  - As soon as an organism dies, it stops taking in carbon, so its amount of c-14 begins to decrease
- ☆ Uranium dating
  - Uranium-238 is radioactive and has a half life of 10^9 years
  - Uranium-238 is found in igneous rock
  - Uranium-238 decays into lead
  - After the rock cools, the amount of uranium-238 in the rock begins to decrease and the amount of lead begins to increase
  - the fraction of uranium left can be determined by comparing its mass to the mass of the lead
- ☆ number of half lives and time elapsed

  T_e = Time elapsed

  $t_{½}$ = ½ life

  n = number of ½ lives

  f = fraction left

  $f = (½)^n$ $T_e = n(t_{½})$

  - Half Life Problems
    - Half life problems of all types are best solved by setting up a table that shows the *number of half lives*, the *mass*, the *time elapsed*, and the *fraction left.* (any of these 4 variables can be the unknown)
    - Half lives of many elements are listed in *Table N*

Sample Problem

An ore that once contained 320 g of ^{60}Co now contains only twenty grams of the radio active material. How long has it been decaying?

Step 1: divide the mass in half repeatedly until it is reduced from 320 g to 20 g

Step 2: look up the half life and fill in the rest of the table

number of half lives	mass	time elapsed	fraction left
0	320 g	0	1 (100 %)
1	160 g	5.26 y	1/2
2	80 g	10.52 y	1/4
3	40 g	15.78 y	1/8
4	20 g	21.04 y	1/16

Answer the questions below by circling the number of the correct response

1. How much of an 8 gram sample of $^{226}_{38}Ra$ will remain unchanged at the end of 3 half-life periods?
(1) 1 g (3) 3 g
(2) 2 g (4) 4 g

2. What is the total mass of a 10. gram sample of ^{42}K that will remain unchanged after 12.4 hours?
(1) 2.5 g (3) 7.5 g
(2) 5. 0 g (4) 10. g

3. As the temperature of a radioactive sample increases, the rate of nuclear decay
1 decreases
2 increases
3 remains the same

4. A sample contains 100 milligrams of iodine-131. At the end of 32 days, the number of milligrams of iodine-131 that will remain will be
(1) 25.00 (3) 6.250
(2) 12.50 (4) 3.125

5. Approximately how many grams of a 40-gram sample of $^{131}_{53}I$ will remain unchanged after 24 days?
(1) 5 (3) 13
(2) 10 (4) 20

6. How much of an 8 gram sample of $^{226}_{38}Ra$ will remain unchanged at the end of 3 half-life periods?
(1) 1 g (3) 3 g
(2) 2 g (4) 4 g

7. What is the number of half-life periods required for a sample of a radioactive material to decay to $^1/_{16}$ of its original mass?
(1) 8 (3) 3
(2) 16 (4) 4

8. As a sample of the radioactive isotope ^{131}I decays, its half–life
(1) decreases
(2) increases
(3) remains the same

9. Exactly how much time must elapse before 16 grams of potassium–42 decays, leaving 2 grams of the original isotope?
(1) 8 × 12.4 hours (3) 3 × 12.4 hours
(2) 2 × 12.4 hours (4) 4 × 12.4 hours

Chemistry: Form WS12.6.1A

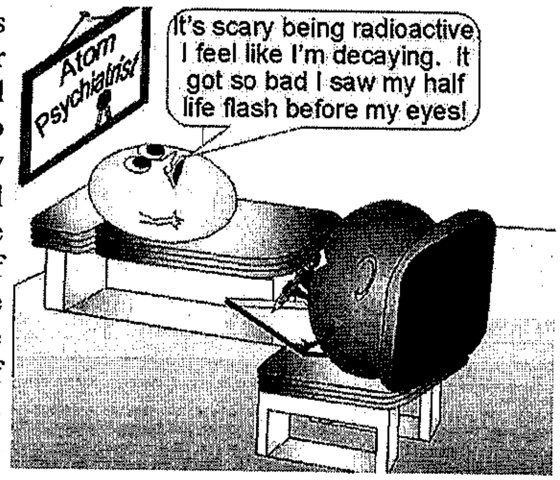
NUCLEAR CHEMISTRY

Name ______________________

Date ______________ Period _____

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?

Fission and Fusion

Aim

- to compare and contrast nuclear fission and nuclear fusion

Notes

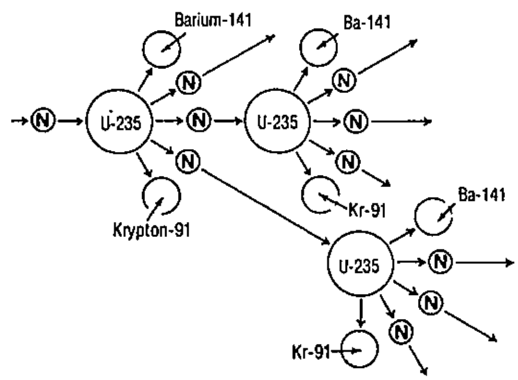
Fission

★ Definition - a nuclear reaction in which a heavy nucleus splits into two lighter nuclei releasing neutrons and a tremendous amount of energy
  - ☆ Cause - initiated by capture of a neutron fired at the nucleus of an atom
  - ☆ the lighter elements that form from fission are more stable than the parent element due to greater binding energy per nucleon

★ Chain Reaction
  - ☆ A reaction in which the neutrons released by fission of one nucleus trigger fission in other nuclei nearby
    - ✯ Uranium-235 is unstable and splits into two smaller nuclei plus neutrons and energy.
    - ✯ The rate of fission can be increased by firing a neutron at the uranium atom

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3^{1}_{0}n + Energy$$

    - ✯ the neutrons released in the reaction can cause additional reactions



  - ☆ Importance
    - ✯ an uncontrolled chain reaction results in a nuclear explosion (atomic bomb)
    - ✯ a controlled chain reaction can be used as a source of energy (nuclear reactor)

Fusion

★ Definition - nuclear reaction in which the nuclei of two different isotopes of hydrogen combine
- ☆ D-T reaction - in fusion reactors

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

  - ✯ deuterium is obtained from heavy water extracted from water
  - ✯ tritium is manufactured by a nuclear reaction

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

- ☆ Proton-proton chain - in stars

$${}^{1}_{1}H + {}^{1}_{1}H \rightarrow {}^{2}_{1}H + {}^{0}_{+1}e$$

$${}^{1}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He$$

$${}^{3}_{2}He + {}^{3}_{2}He \rightarrow {}^{4}_{2}He + 2{}^{1}_{1}H$$

★ Importance
- ☆ energy released in fusion is greater than the energy released in fission
  - ✯ mass of new nucleus is less than the sum of the light nuclei
  - ✯ the difference in mass is the amount of mass that was converted to energy (**$E = mc^2$**)
  - ✯ the energy provides for the greater binding energy per nucleon and the greater stability of the heavier nucleus formed
- ☆ principle behind the hydrogen bomb and source of energy for stars

★ High energy requirements - in order for nuclei to combine they need enough energy to overcome the forces of repulsion between like charges
- ☆ the magnitude of the repulsion increases with the charge
- ☆ only small nuclei with small charges can be used in fusion reactions
- ☆ temperatures of 10^{9}°C are needed to provide the high activation energy needed for fusion

Answer the questions below by circling the number of the correct response

1. Which type of reaction occurs in a nuclear power plant and in an atomic bomb?
   (1) fusion (3) oxidation
   (2) fission (4) combustion

2. Which type of reaction occurs in stars such as the sun?
   (1) fusion (3) oxidation
   (2) fission (4) combustion

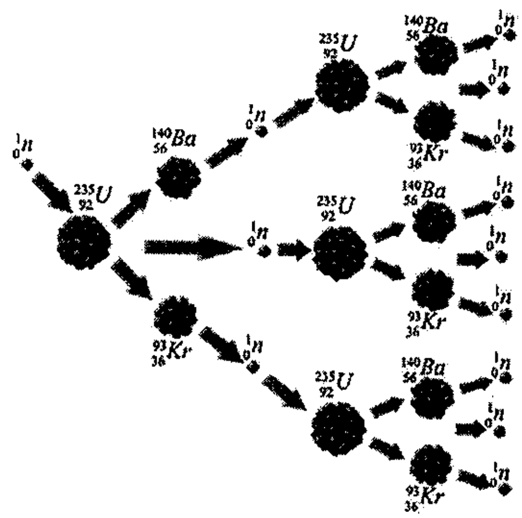
Chemistry: Form WS12.7.1A Name ______________________

NUCLEAR CHEMISTRY Date ______________ Period ____

Fission and Fusion

Fission and fusion are opposites, but they both involve nuclear reactions and have the potential to provide tremendous amounts of energy. Fission is a nuclear reaction in which a heavy nucleus splits into two lighter nuclei releasing neutrons and a tremendous amount of energy. It is initiated by capture of a neutron fired at the nucleus of an atom. The lighter elements that form from fission are more stable than the parent element due to greater binding energy per nucleon. Very few elements can undergo fission. Uranium–235 is one of the few that can. Below is a possible fission reaction.

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



Since uranium releases neutrons when it splits, these neutrons can be captured by other uranium atoms causing them to split. This results in a chain reaction. A chain reaction is a reaction in which the neutrons released by fission of one nucleus trigger fission in other nuclei nearby. An uncontrolled chain reaction results in a nuclear explosion (atomic bomb). A controlled chain reaction can be used as a source of energy (nuclear reactor).

Fusion is a nuclear reaction in which the nuclei of two different isotopes of hydrogen combine. There are two types: [1] the D-T reaction in fusion reactors; and [2] the proton-proton chain in stars. In the D-T reaction, deuterium combines with tritium.

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

Deuterium is obtained from heavy water extracted from water and tritium is manufactured by a nuclear reaction.

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

The proton-proton chain in stars consists of a series of three nuclear reactions. This is the reaction that makes stars shine. It is an extremely important reaction, because the energy released in fusion is greater than the energy released in fission. The mass of the new nucleus formed by fusion is less than the sum of the light nuclei that fused. The difference in mass is the amount of mass that was converted to energy (**E = mc²**). Unfortunately, in order for nuclei to combine they need enough energy to overcome the forces of repulsion between like charges. The magnitude of the repulsion increases with the charge, so only small nuclei with small charges can be used in fusion reactions. Temperatures of 10^9°C are needed to provide the high activation energy needed for fusion, so the reaction basically occurs only in stars.

$$^{1}_{1}H + ^{1}_{1}H \rightarrow ^{2}_{1}H + ^{0}_{+1}e$$

$$^{1}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{2}He$$

$$^{3}_{2}He + ^{3}_{2}He \rightarrow ^{4}_{2}He + 2^{1}_{1}H$$

(*Continue on the Next Page*)

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

1. Which type of reaction occurs in a nuclear power plant and in an atomic bomb? ____________

2. Which type of reaction occurs in stars such as the sun? ____________

3. How is fission different than alpha or beta decay? ____________

4. What characteristic of fission makes a chain reaction possible? ____________

5. If fusion releases more energy than fission, why isn't fission used as a source of energy on earth? ____________

6. What is the fuel that runs fusion in stars? ____________

7. Why is fusion only possible with small nuclei? ____________

8. What is the net loss of hydrogen for each full cycle of the proton-proton chain? Explain. ____________

Name ______________________________ Class______ Date____________

Activity 10-2

Artificial Radioactivity

Induced radioactivity

1. Choose words from the word list to fill in the blanks in the following paragraph relating to artificial radioactivity. Words that have contrasting or related meanings have been paired.

Word List

artificial/natural	neutrons/protons
bombarded	stable/unstable
existing/new	transmutation

Stable nuclei can be converted to ______________, hence radioactive, nuclei. Bombardment of stable nuclei with particles such as ______________, ______________, and alpha particles produces unstable nuclei. For instance, when beryllium-9 is bombarded by ______________ the following transmutation takes place:

$$^{9}_{4}Be + ^{1}_{1}H \rightarrow ^{6}_{3}Li + ^{4}_{2}He$$

Such bombardment can produce ______________ elements as well as various isotopes of ______________ elements. All transuranium elements have been produced by the bombardment of existing natural or artificial isotopes. For example, when uranium-238 is ______________ by an alpha particle the ______________ element plutonium-240 is produced:

$$^{238}_{92}U + ^{4}_{2}He \rightarrow ^{240}_{94}Pu + 2^{1}_{0}n$$

Uses of radioisotopes

2. What is a radioactive tracer? ______________

3. Give an example of the use of a radioactive tracer in:
   a. Medicine ______________
   b. Research ______________
   c. Industry ______________

4. How is radioactive cobalt (Co-60) used for cancer therapy? ______________

5. How are radioisotopes used for food preservation? ______________

6. How is radioactive carbon (C-14) used to date archeological findings? ____________

____

____

____

Nuclear reactors

7. Name three fissionable isotopes used as fuels in nuclear reactors. ____________, ____________, ____________

8. What is a breeder reactor? ____________

____

For each of the following components of a nuclear reactor, describe its use and then list one or more substances that are used in the component.

9. Moderators. Use: ____________

____

Substance(s): ____________

10. Control rods. Use: ____________

____

Substance(s): ____________

11. Coolants. Use: ____________

____

Substance(s): ____________

12. Shielding. Use: ____________

____

Substance(s): ____________

Particle accelerators

13. Choose words from the word list to fill in the blanks in the following paragraph related to particle accelerators.

Word List

beams	linear accelerator
bombarded	energy
cyclotron	synchrotron

Artificial transmutations result when target nuclei are ____________ by high ____________ particles. Particle accelerators are used to produce ____________ of such high ____________ particles. The ____________ and ____________ accelerate charged particles in circular paths by use of electromagnetic fields. The ____________ ____________ uses synchronized fields of electric force to accelerate positively charged particles.

Name ______________________________ Class______ Date__________

Nuclear energy—fission

14. Choose words from the word list to fill in the blanks in the following paragraphs relating to nuclear fission. Words with contrasting or related meanings have been paired in the list.

Word List

chain	neutrons
controlled/uncontrolled	stable/unstable
energy	

Fission occurs when nuclei with high atomic numbers capture ______________. This process produces fission fragments and ______________ while releasing two or more neutrons. The energy produced is the result of conversion of mass into ______________ according to the Einstein formula:

$$E = mc^2$$

The release of additional ______________ causes the buildup of a chain reaction. The elements formed as fission fragments are more ______________ than the original heavier nucleus because they have greater binding energy per nucleon. The energy produced in an atomic bomb blast results from an uncontrolled chain reaction. This same ______________ reaction is carried out under ______________ conditions in a nuclear reactor.

15. Why is the disposal of radioactive wastes a special problem? ______________

Learn about and describe one or more methods used or suggested for their disposal. ______________

Nuclear fusion

16. Define nuclear fusion. ______________

17. The energy produced by nuclear fusion is ______________ (*greater/less*) than the energy produced by a fission reaction.

18. What is the source of energy in a nuclear fusion reaction? ______________

19. What fusion reaction is probably the source of solar energy? ______________

20. What is the purpose of the fission reaction in a thermonuclear device? ______________

21. What isotopes of hydrogen are used as fuels in fusion reactions in thermonuclear devices?

Chemistry: Form WS12.8.1A

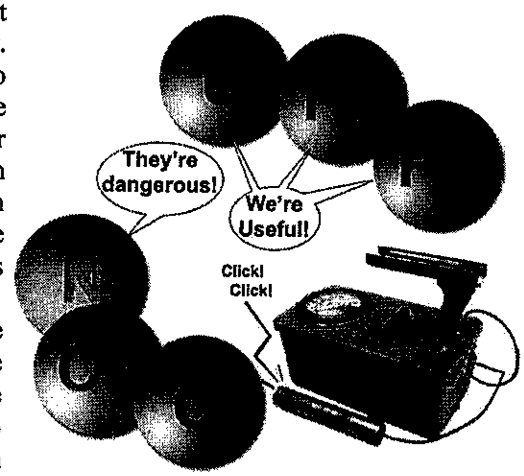
NUCLEAR CHEMISTRY

Name ______________________

Date ______________ Period _____

Uses of Radiation

Radiation is both useful and dangerous. The danger is caused by the fact that radioactive emissions are high energy and can ionize atoms they contact. Ionizing radiation damages cells causing burns, rashes, or cancer. Damage to reproductive cells can cause genetic defects. As a result it is important to be able to detect radiation. The tool used for detecting radiation is a Geiger counter. A Geiger counter is a hollow negatively charged cylinder filled with argon gas. It has a positive wire in the center and a thin window through which radiation passes. The radiation ionizes the argon gas. The ions are attracted to the electrodes where they create an electric pulse which is amplified to an audible click.

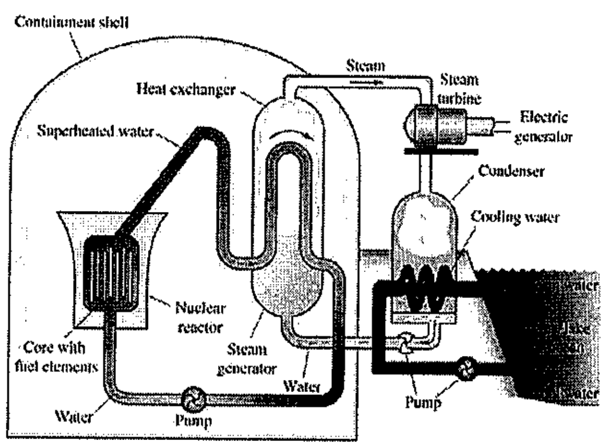


Xenophobia among atoms.

Radioactive isotopes, or radioisotopes, of different elements have a wide variety of uses depending on their chemical activity, their radioactive properties, and their half-lives. Radioisotopes can be used as tracers because radioactivity has no effect on chemical behavior. P-31 in fertilizer is used to trace uptake of phosphorus by plants. C-14 is used to map the path of carbon in metabolic processes. Radioisotopes with short half lives that concentrate in certain organs are administered as tracers. Tc-99 is used for location of tumors. I-131 is used for detection and treatment of thyroid disturbances because the thyroid gland uses iodine. Some cancer therapies depend on radiation because malignant cells are more sensitive to radioactivity than normal cells. Gamma radiation from cobalt 60 can be aimed at cancerous tumors. Gamma radiation can also destroy bacteria, yeasts, molds, and insect eggs, so it is used in food preservation. Radiation intensity decreases as radiation passes through matter, so it can be used to measure the thickness of industrial products.

Radioactive dating depends on the characteristic of radioactive substances known as half-life. Carbon dating is used to measure the age of fossils of living things fro the not too distant past. Carbon-14 is radioactive and has a half life of 5,730 years. Carbon dioxide in the air contains carbon-14. Plants take in carbon dioxide and make carbohydrates as long as they are alive. Animals eat plants as long as they are alive. Each gram of carbon in a living organism emits about 15 disintegrations per minute (dpm). As soon as an organism dies, it stops taking in carbon, so its amount of C-14 begins to decrease as does the number of dpm. A reading of 7 dpm/g of carbon indicates an age of about 5700 y. Uranium dating is useful for measuring the age of very old rocks. Uranium-238 is radioactive and has a half life of 10^9 years. Uranium-238 is found in igneous rock and decays into lead-206. After the rock cools, the amount of uranium-238 in the rock begins to decrease and the amount of lead begins to increase. The fraction of uranium left can be determined by comparing its mass to the mass of the lead. Then the number of half lives elapsed and the age can be determined.

One of the more important uses of radioactivity is nuclear energy. A **Nuclear reactor (fission reactor)** converts nuclear energy into heat energy which can then be used to generate electricity. The fuel for a nuclear reactor is usually U-235. It is found in the core. A nuclear reactor needs a moderator, a substance that slows neutrons down without absorbing them, in order to increase the chance of collision between the neutrons and the U-235 nuclei. Hydrogen, deuterium, water, heavy water, beryllium and graphite are used as moderators. The coolant keeps the system from overheating. Control rods made of boron or cadmium steel absorb neutrons controlling the rate of fission. Shielding provides protection from radiation damage.



(*Continue on the Next Page*)

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

1. Why is radiation dangerous? ______________________________

____

2. How is it possible to tell if dangerous radiation is leaking into the environment from a radioactive source? ______

____

3. Phosphorous is used by living things to make DNA, RNA, and ATP:

   a. Does radioactive phosphorous influence the functioning of these compounds? Explain. ______

   ____

   b. Explain how scientists showed that viruses hijacked cells with their DNA or RNA and not with their protein. ____

   ____

   ____

4. Radiation is more readily absorbed by actively growing cells. How is this both useful and dangerous? ______

____

____

5. Why is uranium better for radioactive dating of older things than carbon–14? If living things don't absorb uranium, how might uranium be used to find the age of very old fossils? ______________________________

____

____

____

6. How do nuclear power plants provide energy? ______________________________

____

____

____

7. Based on your understanding of radioactivity, what are some pontential problems associated with nuclear energy? ____

____

____

____

PERSONAL RADIATION DOSE

We live in a radioactive world—always have. Radiation is all around us as a part of our natural environment. It is measured in terms of millirems (mrems). The annual average dose per person from all sources is about 360 mrems, but it is not uncommon for any of us to receive far more than that in a given year (largely due to medical procedures we may have done). As an example, international standards allow up to 5,000 mrems a year exposure for those who work with and around radioactive material.

	Common Sources of Radiation	Your Average Annual Dose (mrems)*
Where you live	Cosmic radiation at sea level (from outer space)................	26
	For your elevation (in feet) - add this number of millirems:	___
	up to 1000 ft.= 2; 1-2000 ft = 5; 2-3000 ft = 9; 3-4000 ft = 15; 4-5000 ft.= 21; 5-6000 ft.= 29; 6-7000 ft.= 40; 7-8000 ft.= 53; 8-9000 ft.= 70	
	Elevation of some U.S. cities (in feet). Atlanta 1050; Chicago 595; Dallas 435; Denver 5280; Las Vegas 2000; Minneapolis 815, Pittsburgh 1200; St. Louis 455; Salt Lake City 4400, Spokane 1890.	
	Terrestrial (from the ground)	
	If you live in states that border the Gulf or Atlantic Coasts (from Texas east, and then north) add 23	___
	If you live in the Colorado Plateau Area (around Denver)................add 90............	___
	If you live in Middle America (rest of the U.S.)................add 46............	___
	House construction	
	If you live in a stone, brick or concrete building................add 7	___
What you eat and drink	Internal radiation (in your body).	
	From food and water - U.S. average	40
	From air (radon) - U.S. average	200
How you live	Weapons test fallout (less than 1)**	1
	Jet plane travel.	
	For each 1000 miles you travel................add 1............	___
	If you have porcelain crowns or false teeth* ....add 0.07............	___
	If you use gas lantern mantles when camping................add 0.003............	___
	If you wear a luminous wristwatch (LCD)................add 0.06............	___
	If you use luggage inspection at airport (using typical X-ray machines)................add 0.002............	___
	If you watch TV (value is less than 1)................add 1............**	___
	If you use a video display terminal (less than 0.1)................add 1............**	___
	If you have a smoke detector................add 0.008............	___
	If you wear a plutonium-powered cardiac pacemaker................add 100............	___
	If you have had medical exposures:* **	
	Diagnostic X-rays (e.g., upper and lower gastrointestinal, chest X-rays) - U.S. average....add 40......	___
	If you have had nuclear medical procedures (e.g., thyroid scans) - U.S.average................add 14......	___
	If you live within 50 miles of a nuclear power plant (pressurized water reactor) - U.S. average add 0.009	___
	If you live within 50 miles of a coal-fired electrical utility plant................add 0.03............	___
	My total annual mrems dose	___

*Some of the radiation sources listed in this chart result in an exposure to only part of the body. For example, false teeth result in a radiation dose to the mouth. The annual dose numbers given here represent the "effective dose" to the whole body.

**The value is less than 1, but adding a value of 1 would be conservative.

***These are yearly average doses. If you have had many such procedures, your dose would be much greater

Primary sources for this information are National Council on Radiation Protection and Measurements Reports, #92 Public Radiation Exposure from Nuclear Power Generation in the United States (1987); #93 Ionizing Radiation Exposure of the Population of the United States (1987); #94 Exposure of the Population in the United States and Canada from Natural Background Radiation (1987), #95 Radiation Exposure of the U.S. Population from Consumer Products and Miscellaneous Sources (1987); and #100 Exposure of the U.S. Population from Diagnostic Medical Radiation (1989).

Note: **Boldface items are man-made radiation; others are naturally occurring.**

Movie: Radiation Naturally

Calculate Your Own Annual Dose

SOURCE	ANNUAL DOSE (mSv)*
Cosmic radiation at sea level (add 0.01 mSv/100 ft. above sea level)	0.27
Radioactive material in the ground (avg.)	0.28
Radioactive material in food and water (avg.)	
➢ Carnivores	0.30
➢ Omnivores	0.40-0.50
➢ Herbivores	0.60-0.75
Radioactive Material in air (^{222}Rn)	2-3
Construction materials of residence	
➢ Masonry	0.35
➢ Wood	0.11
Cooking with natural gas	0.07-0.10
Tobacco usage (1.5 packs/day) or occupancy in a 6 foot vicinity thereof	**80**
Airplane travel (per travel hour)	0.02
Medical Procedures (X-rays) average	0.50
➢ Extremities	0.02
➢ Chest	0.10
➢ Upper gastrointestinal	2.40
➢ Thyroid Function Test	1.50
Color TV or computer monitor (per viewing hour) assumes within 6 feet of CRT	0.02
Living within a 50 mile radius of a Nuclear Power Generating Station	0.001
Living within a 50 mile radius of a Coal-Fired Power Generating Station	0.005
Sleeping with another person (8 hour exposure)	0.02
Your total estimated annual dose:	

***USNRC Regulatory Limit for annual dose: 50mSv**

Representative Hypothetical Example:

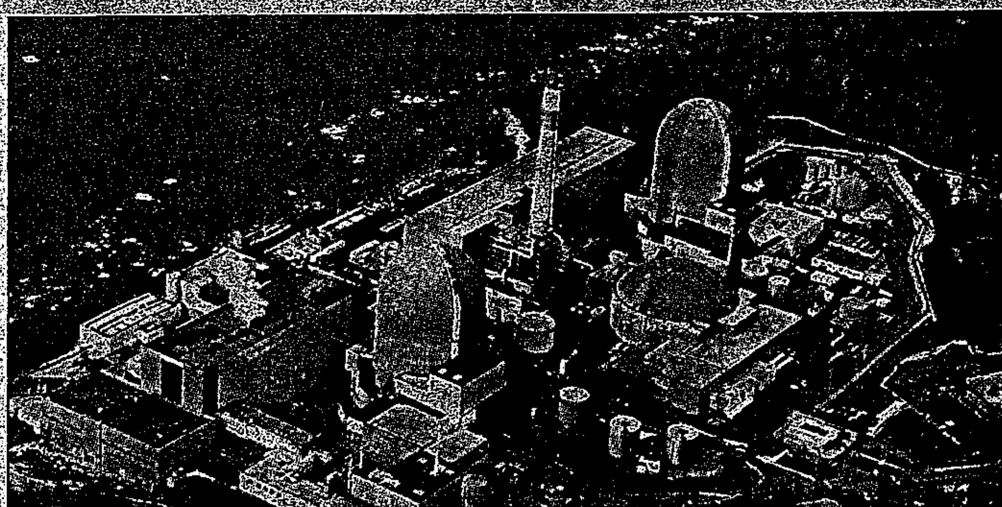
Commercial airline pilot,	19.20 (80 hours/month)
resides on a mountain,	0.52 (2500 ft. elevation)
in a concrete house.	0.35
His wife cooks him meals	6.00 (300 nights)
of meat and vegetables	0.45 (omnivore)
on a natural gas stove	0.10
while he watches TV.	14.4 (60 hours/month)
	≈41 mSv/yr

NOTE:
The current Solar Cycle attained its maximum on July 15-16,2000. The NOAA Space Environment Canter has posted warnings for higher than normal radiation exposures for airline travelers for the next year. Call Airline Passenger Radiation Warning Line @ 877-786-3527 for the latest conditions.

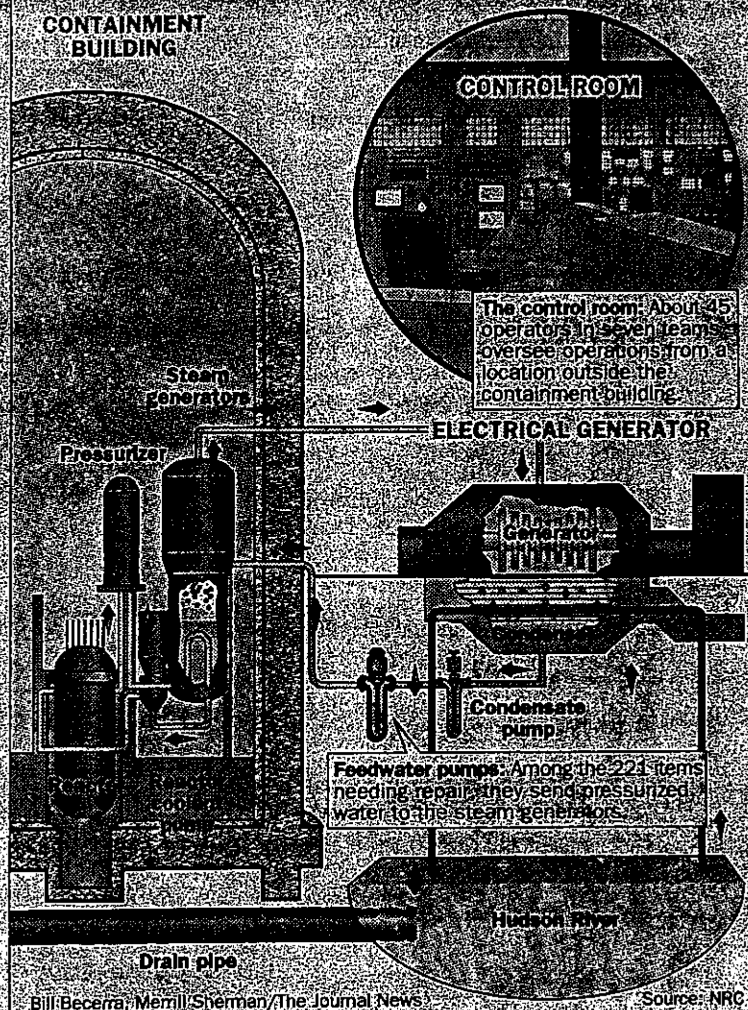
Serving Westchester, Rockland and Putnam counties since 1850

Inquiry at Indian Point 2

Entergy hopes to lose poor rating after nuclear experts' review



A special Nuclear Regulatory Commission inspection next month will determine if Indian Point 2 is no longer the least safe nuclear plant in the nation. The inspection team will look at improvements since a Feb. 15, 2000, accident and the procedures — dating back to 1997 — that contributed to it. These include:



Bill Becerra, Merrill Sherman/The Journal News

Source: NRC

1. Reactor and plant controls

Procedures for examining the condition of the reactor, the steam generator and backup systems had to be upgraded by Entergy, the plant's current owner. Failures in these procedures contributed to previous plant shutdowns and safety violations.

2. Steam generators

The faulty generators were replaced by Consolidated Edison before Entergy bought the plant. Entergy has had to replace the system for evaluating the condition of the 13,000 tubes within the generators and evaluating the condition of the reactor itself.

3. Plant equipment

Entergy took over a plant with a backlog of 3,500 items needing repair. The backlog is now down to 221 items. The company has spent millions of dollars replacing or repairing defective or worn equipment.

4. Training

Entergy has to upgrade training of the reactor operators. Mistakes made by reactor operators contributed to an August 1999 shutdown and the Feb. 15, 2000, incident. Four of the seven control room operator teams failed their relicensing exam last October.

5. Backup systems

The backup water and power systems have failed or been misread during real events and simulated tests.

37