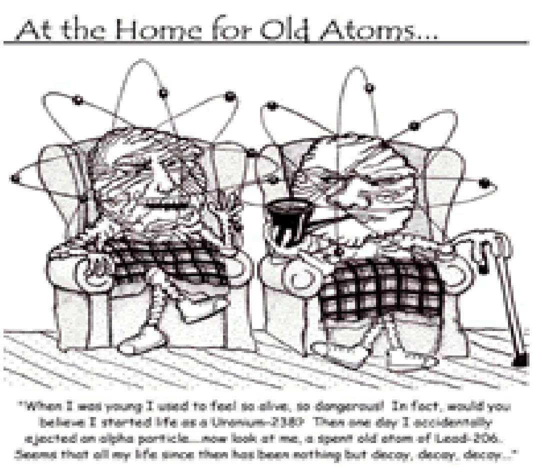
Nuclear Chemistry



Textbook: read Chapter 19 pp. 606-629

Quizlet questions: Read Chapter 3 p. 24-30

- Quizlet Questions: Part A-B1 p. 27-28 #1-11, part A-B1 p. 30 # 12-22.
  (on scantron to be collected for quiz grade)
- Chapter Review p. 31-33 #1-33 (additional review not collected)

Nuclear packet Check: Wednesday May 15

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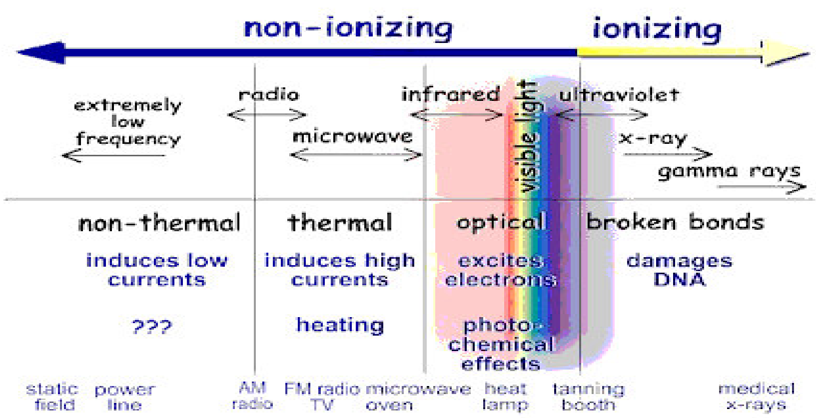


Nuclear Chemistry student outline

- Radioactivity- decay of an unstable nucleus into a more stable nucleus
- Transmutation-
  - Natural Transmutation- spontaneous decay
  - Artificial transmutation- when a normally stable atom is bombarded (look for 2 things on the left side of the reaction: one element and one particle)
- Decay particles
  - Alpha
  - Beta
  - Gamma
- Separating nuclear decay particle emissions – pass all particles through a magnetic or electric field
  - Alpha deflects toward negative pole
  - Beta deflects toward positive pole
  - Gamma will pass right through…. Unaffected by the charges of the poles
- Balancing nuclear equations: The sum of atomic #'s and the mass #'s on both sides must be equal.
- Half Life – Time it takes for half of the mass to decay. The half-life on an element **NEVER** changes.
- Nuclear Reactions
  - Fission
  - Fusion
- Binding energy
- Mass defect
- Nuclear Reactors – device used for controlling nuclear fission reactions so that energy can be liberated and be converted to useful energy
  - A) Breeder reactor – produces new source of fuel for nuclear reactor
  - B) Fission reactor – produces fuel from the fission of Uranium235
  - C) Fusion reactor – fuel is deuterium (small and inexpensive) clean process, gives off huge burst of energy but short lived, produces stable isotope (no radioactive wastes) needs high temperature, and research is expensive. Occurs naturally on the sun, between He and H atoms.
- Parts of a nuclear reactor
  - *Particle accelerators* - increase the speed of particles before directing them toward target material to undergo fission (neutrons not affected by a particle accelerator because neutrons have no charge)
  - *Fuel* – U-235, sometimes U-233, and Pt-239
  - *Control rods*- control the rate of fission and the capturing of neutrons. (cadmium and boron)
  - *Moderator* –control after reaction has begun, slow down neutrons resulting from fission, (Hydrogen, Deuterium (isotope of hydrogen with a mass of 2), Beryllium, Graphite, molten metals)
  - *Coolants* – used to control the large amounts of heat released. Examples: water, heavy water (D_2 0), Molten sodium and lithium, air, helium, CO_2
  - *Shielding*- concrete reinforced with lead and steel
- Fusion reactor -Occurs naturally on the sun, between He and H atoms.
- Radioisotopes and their uses-
  - Tracers- used to follow a chemical process in living things
    - I – 131 – thyroid disorders
    - Tc – 99 – brain tumors
    - C-14 – photosynthesis and carbon dating
    - U-238 to Pb – 206 – dating minerals
    - Radium and Cobalt – treatment of cancer, also destroys healthy cells
  - Radiation- kills living tissue (used in cancer treatment), also used to kill yeast's, molds and bacteria in foods and to slow down the decay of foods → prolongs shelf life

Vocabulary

Radioactivity	Nuclear Reactions	Particle accelerators	I – 131
Transmutation	Fission	Fuel	Tc – 99
Natural Transmutation	Fusion	Control rods	C-14
Artificial transmutation	Binding energy	Moderator	U-238
Decay particles	Mass defect	Coolants	Radium
Alpha	Nuclear Reactors	Shielding	Cobalt
Beta	Breeder reactor	Fusion reactor	Radiation
Gamma	Fission reactor	Radioisotopes	
Half Life	Fusion reactor	Tracers	

Nuclear Chemistry Class Notes

- What is Nuclear Chemistry?

- Radioactivity-

All elements with more than 83 protons have unstable nuclei and are said to be ***radioactive***. This is because there are too many protons and neutrons in too small a volume to be stable – the repulsive forces among the protons are too strong to allow such nuclei to exist. There are also some isotopes of elements smaller than 82 that are also unstable. Scientists view nuclear instability not only in terms of nuclear size but also due to nuclear binding energy and the ratio of neutrons to protons.

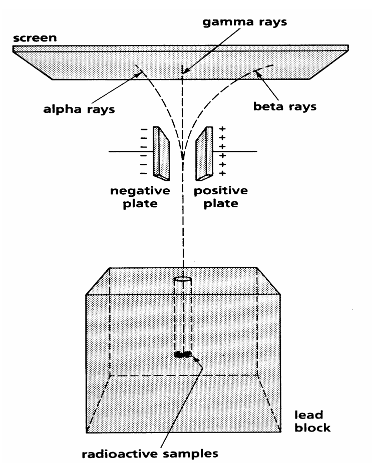
  - Nuclear forces cannot permanently exceed repulsive forces when more than 83 protons.

Mass defect:

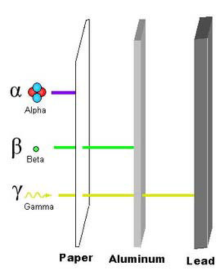
Nuclear hold / Binding Energy:

Radioactive elements become stable by emitting particle radiation and high energy electromagnetic radiation. These occur as three basic types and they were discovered when a radioactive source (such as U-238) was placed in a lead container with a small opening. The radiation coming out of the opening was subjected to an electric field and it was shown that the radiation consisted of three types:

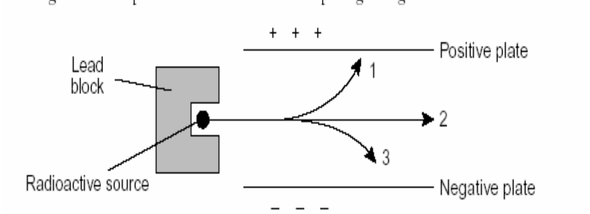
- Decay particles and types of decay modes (listed on ref table N & O)



- Particles deflected toward the negative plate – called alpha (α) particles
- Particles deflected toward the positive plate – called beta (β) particles
- Electromagnetic waves unaffected by the plates – called gamma (χ) waves



The diagram below represents radioactive emanations passing through an electric field.



Which type of emanation is represented by the arrow labeled 1?

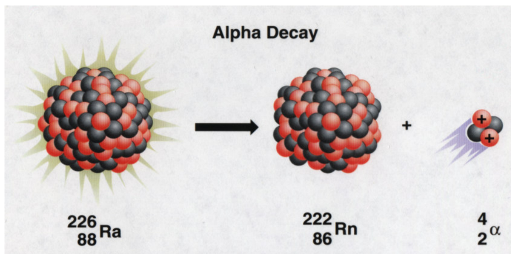
(1) alpha particle
(2) beta particle
(3) positron
(4) gamma ray

Alpha Decay

- Involves emission of a 2 proton-2 neutron unit from the nucleus;
- this unit is a helium nucleus
- Symbol is $^{4}He_{2}$ (α)
- Slow speed
- Poor penetrating power (can be stopped by sheet of paper)
- High ionizing capacity (when hitting an atom it can "knock off" an atom's valence electron causing it to become an ion

Example: $^{226}_{88}Ra \rightarrow ^{4}_{2}He + ^{222}_{86}Rn$

*note the mass number (P + N) decreases by 4 and the atomic number (P only) decreases by 2

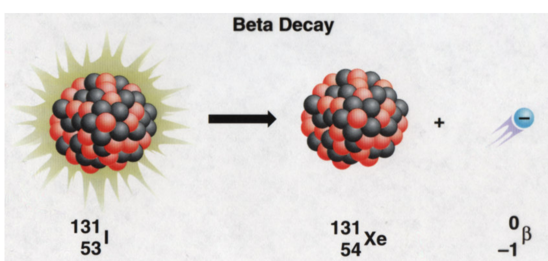


Beta Decay

- Involves emission of a high speed electron from the nucleus
- A neutron breaks down to a proton (which remains in the nucleus) and an electron which is ejected from the nucleus
- fairly high speed
- Moderate penetrating power (can be stopped by the thickness of your chemistry textbook
- Moderate ionizing capacity
- Symbol is $^{o}_{-1}e$ (β)

Example: $^{214}_{82}Pb \rightarrow ^{o}_{-1}e + ^{214}_{83}Bi$

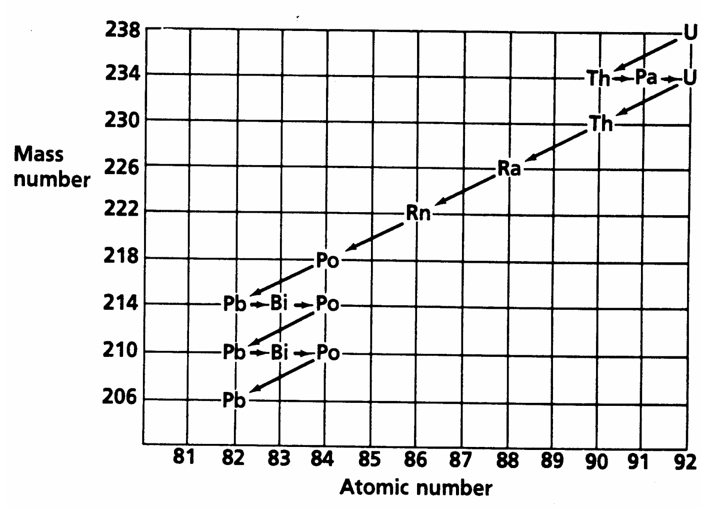
*note the atomic number increases by 1 while the mass number stays the same



Gamma Radiation

- Travel at speed of light
- High penetrating power
- Very small ionizing capacity
- Emissions of gamma rays reduce the energy content of a nucleus without change in atomic or mass number
- Symbol is γ

Note the decay series of the isotope U-238 to the stable Pb-206 isotope. U-238 has a half-life of about 4.5 X 10^9 years (approximately the age of the earth). The ratio of U-238 to Pb-206 in a sample rock is used in geologic dating. The diagram below illustrates the decay series of uranium-238.



Positron production

- Particle with same mass as an electron but opposite charge
- Has the effect of changing a proton to a neutron
- Results no change in mass number but a decrease of 1 in atomic number
- Symbol is $^{0}_{+1}e$

Example: $^{22}_{11}Na \rightarrow {}^{0}_{+1}e + {}^{22}_{10}Ne$

Electron Capture

- An inner-orbital electron is captured by the nucleus
- Does not occur often and is accompanied by gamma radiation

Example $^{201}_{80}Hg + {}^{0}_{-1}e \rightarrow {}^{201}_{79}Au + {}^{0}_{0}\lambda$

The Regents reference table (Table O) below shows the notation and symbols used in nuclear chemistry. You should become very familiar with the notation and symbols.

Table O
Symbols Used in Nuclear Chemistry

Name	Notation	Symbol
alpha particle	$^{4}_{2}He$ or $^{4}_{2}\alpha$	α
beta particle (electron)	$^{0}_{-1}e$ or $^{0}_{-1}\beta$	β^-
gamma radiation	$^{0}_{0}\gamma$	γ
neutron	$^{1}_{0}n$	n
proton	$^{1}_{1}H$ or $^{1}_{1}p$	p
positron	$^{0}_{+1}e$ or $^{0}_{+1}\beta$	β^+

- Transmutation-

- Balancing nuclear equations:

  Natural Transmutation:

Example

The decay mode of gold-198 is β^- therefore, Au-198 transmutes naturally into Hg-198 by giving off a beta particle.

$$^{198}_{79}Au \longrightarrow {}^{198}_{80}Hg \; +$$

Example

The decay mode of Ca-37 is β^+ therefore, Ca-37 transmutes naturally into K-37 by giving off a positron.

$$^{37}_{20}Ca \longrightarrow \qquad\qquad + \; {}^{0}_{+1}e$$

Artificial Transmutation: Balance the equation

The first artificial transmutation was accomplished in 1919 by Rutherford who bombarded nitrogen-14 with α particles.

$$^{14}_{7}N + {}^{4}_{2}He \longrightarrow {}_{8}\qquad + \; {}^{1}_{1}H$$

Later, in 1930, Irene Curie and her husband Frederic bombarded stable Al-27 with alpha particles.

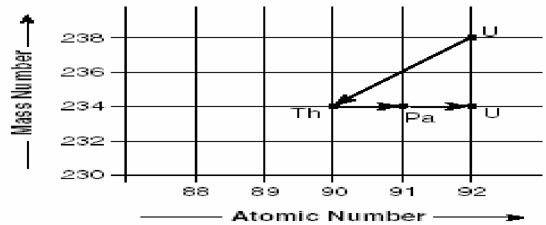
$${}^{27}_{13}Al + {}^{4}_{2}He \longrightarrow {}^{30}_{15}P +$$

Practice questions:

- Find what X is in the following nuclear reactions.

$${}^{9}_{4}Be + {}^{1}_{1}H \longrightarrow {}^{6}_{3}Li + X$$

- The chart below shows the spontaneous nuclear decay of U-238 to Th-234 to Pa-234 to U-234.



What is the correct order of nuclear decay modes for the change from U-238 to U-234?

(1) β− decay, γ decay, β− decay
(2) β− decay, β− decay, α decay
(3) α decay, α decay, β− decay
(4) α decay, β− decay, β− decay

Write balanced nuclear equations for the following processes:

a) the decay of gold-198:

b) the decay of phosphorous-32:

c) the decay of potassium-37:

Half Life

The half-life of an unstable isotope is the time required for one-half of the nuclei in a sample to decay:

X g → 1/2X g → 1/4X g → 1/8X g → 1/16X g → etc

The half-life of a radioactive isotope is independent of **temperature** and **pressure** and the **mass** of the unstable element. The half-life is also characteristic of that particular isotope. The Regents reference table (Table N) lists the half-life and decay mode for selected nuclides.

Table N
Selected Radioisotopes

Nuclide	Half-Life	Decay Mode	Nuclide Name
^{198}Au	2.69 d	β^-	gold-198
^{14}C	5730 y	β^-	carbon-14
^{37}Ca	175 ms	β^+	calcium-37
^{60}Co	5.26 y	β^-	cobalt-60
^{137}Cs	30.23 y	β^-	cesium-137
^{53}Fe	8.51 min	β^+	iron-53
^{220}Fr	27.5 s	α	francium-220
^{3}H	12.26 y	β^-	hydrogen-3
^{131}I	8.07 d	β^-	iodine-131
^{37}K	1.23 s	β^+	potassium-37
^{42}K	12.4 h	β^-	potassium-42
^{85}Kr	10.76 y	β^-	krypton-85
^{16}N	7.2 s	β^-	nitrogen-16
^{19}Ne	17.2 s	β^+	neon-19
^{32}P	14.3 d	β^-	phosphorus-32
^{239}Pu	2.44×10^4 y	α	plutonium-239
^{226}Ra	1600 y	α	radium-226
^{222}Rn	3.82 d	α	radon-222
^{90}Sr	28.1 y	β^-	strontium-90
^{99}Tc	2.13×10^5 y	β^-	technetium-99
^{232}Th	1.4×10^{10} y	α	thorium-232
^{233}U	1.62×10^5 y	α	uranium-233
^{235}U	7.1×10^8 y	α	uranium-235
^{238}U	4.51×10^9 y	α	uranium-238

ms = milliseconds; s = seconds; min = minutes;
h = hours; d = days; y = years

1. **A radioactive element has a half-life of 2 days. Which fraction represents the amount of an original sample of this element remaining after 6 days?**

1/8 | 1/3

1/2 | 1/4

2. **Which sample will decay least over a period of 30 days?**

A) 10 g of P-32 | C) 10 g of I-131

B) 10 g of Au-198 | D) 10 g of Rn-222

3. **Which two radioisotopes have the same decay mode?**

A) ^{37}K and ^{42}K | C) ^{99}Tc and ^{19}Ne

B) ^{37}Ca and ^{53}Fe | D) ^{220}Fr and ^{60}Co

4. **An original sample of K-40 has a mass of 50 grams. After 3.9×10^9 years, 6.25 grams of the original sample remains unchanged. What is the half-life of K-40?**

   A) 1.3×10^9 yrs
   B) 3.9×10^9 yrs
   C) 2×10^9 yrs
   D) 1.2×10^{10} yrs

5. A radioactive element has a half-life of 4 hours. What fraction of an original sample will remain at the end of 12 hours?

6. A sample of Sr-90 has a mass of 1.0 gram after 112 years. Calculate the mass of the original sample.

7. Exactly 1.0 g of Na-24 decomposes by beta emission to 1/8 g in 45 hours. Determine its half-life.

8. A sample of fossilized wood that, when alive, would have contained 24 g of carbon-14. It now contains 1.5 g of carbon-14. Determine the approximate age of the sample.

9. A 64 g sample of germanium-66 is left undisturbed for 12.5 hours. At the end of that period, only 2.0 g remain. Calculate the half-life of this material.

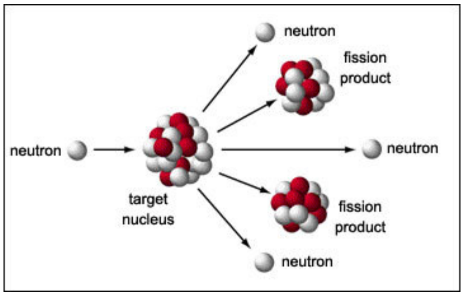
10. Cobalt-60 has a half-life of 5.26 years. If a pellet that has been in storage for 26.5 years contains 14.5 g of cobalt-60, determine the mass of this isotope that was present when the pellet was put into storage.

- **<u>Nuclear Reactions</u>**

Fission

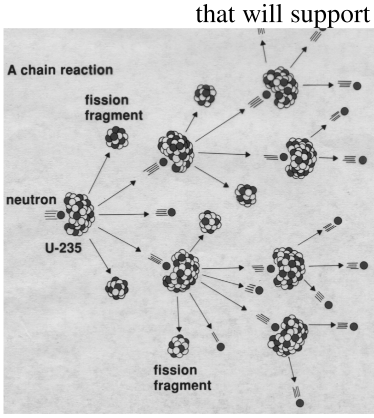
- splitting a large nucleus into smaller nuclei of similar size with release of energy
- there are two fissionable isotopes: U-235 and Pu-239

example: $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{139}_{56}Ba + ^{94}_{36}Kr + 3\ ^{1}_{0}n$



two factors of monumental consequence:

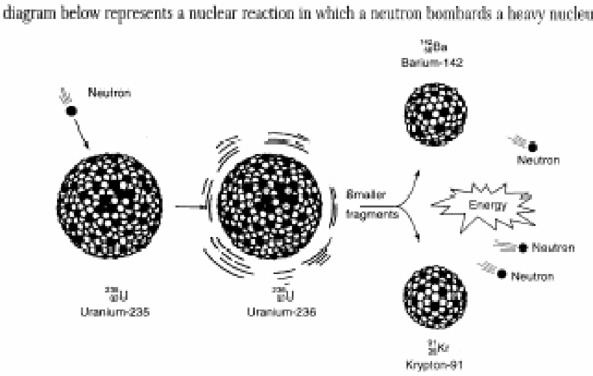
- the difference in mass between reactants and products indicated a significant mass lost – this mass was converted to energy via $E = mc^2$
- the potential for a **chain reaction** – a reaction that is self-sustaining – that is, the reaction generates the means to trigger additional reactions. The amount of fissionable material that will support a chain reaction is termed the **critical mass**.



Uncontrolled fission reaction = atomic bomb
Controlled fission reaction = nuclear power plant

Example:

The diagram below represents a nuclear reaction in which a neutron bombards a heavy nucleus.

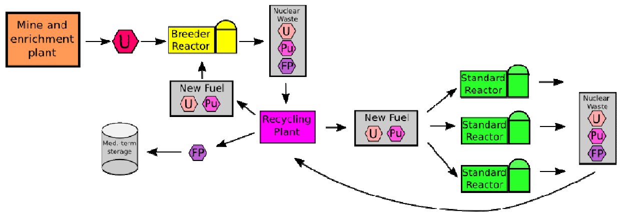


Which type of reaction does the diagram illustrate?

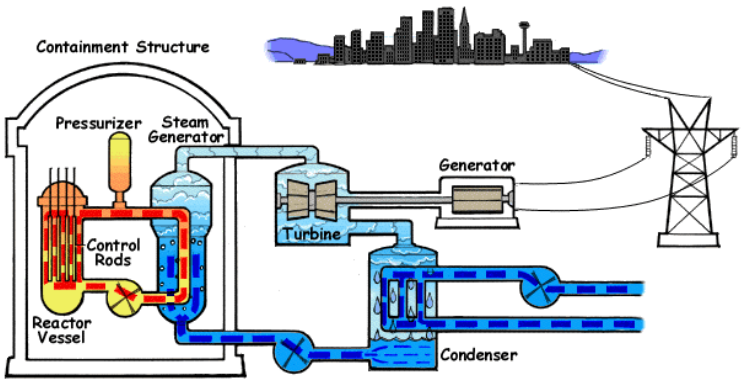
(1) fission
(2) fusion
(3) alpha decay
(4) beta decay

Nuclear Reactors

- ***Breeder reactor*** some control rods are replaced with rods containing U-238. The U-238 absorb neutrons and then decay to form fissionable Pu-239.
  - ○



Fission reactor



Main components:

Nuclear Fuel – Uranium-235 is the only naturally occurring isotope of uranium that will undergo fission. The percentage of U-235 in a pure sample of uranium is only 0.7% and this amount is insufficient to sustain a chain reaction. The U-235 is separated from pure uranium to produce “enriched” uranium (about 3% U-235). This mixture is used to produce uranium oxide for use as fuel in the reactor. Pellets of uranium oxide are packed in stainless steel tubes called **fuel rods**.

Moderators – used to slow down the neutrons produced as a result of fission reactions. The moderator functions to absorb some of the energy of the high kinetic energy neutrons to slow them down so they can be captured by the U-235 nuclei. Some common materials used for moderators include graphite, molten sodium, and heavy water (water containing a deuterium hydrogen).

Control Rods – function to control the rate of the fission reaction by absorbing neutrons. Substances such as cadmium or boron are very effective absorbers of neutrons. Control rods made from one of these substances are located side-by-side with the fuel rods in the reactor. By inserting and withdrawing these rods, the supply of neutrons can be regulated and, in cases of emergency, shut off completely.

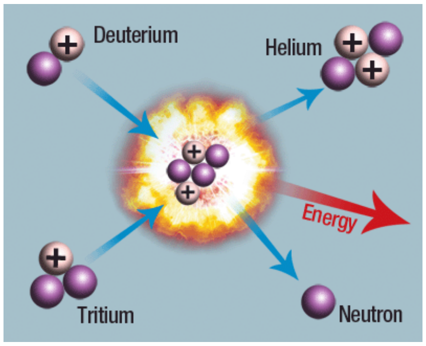
Coolants – the primary coolant, which is often water at high pressure, is circulated around the reactor core where it absorbs the tremendous amount of heat generated by the fission reaction. Since the water is under pressure it reaches 300^{o}C without boiling and is pumped into a steam generator. The steam generator contains water under normal pressure. The heat from the primary coolant is transferred to this water (secondary coolant) which causes it to form steam. The steam is then used to drive a turbine which generates electricity. The primary coolant, now at a lower temperature, is pumped back into the reactor core and the cycle continues.

Shields – the core of a reactor is surrounded by a containment vessel in which the primary coolant circulates. The walls of this vessel are lined with thick steel slabs to reduce the flow of radiation from the core. The containment vessel, in turn, is surrounded by thick concrete blocks designed to protect personnel from radiation exposure.

Advantages: provides much needed energy

Disadvantages: radioactive waste
thermal pollution of river water
possibility of mechanical/human error

Fusion



- two small nuclei (hydrogen) collide to form a bigger nucleus (He) the release of energy
- significant mass loss converted to energy
- no chain reaction; no critical mass
- fusion reactions are the source of the Sun's energy; millions of tons of matter (H) are converted to energy in the Sun every second
- in order for fusion reactions to occur, exceedingly high temperatures are needed (to overcome repulsive forces between protons); it is necessary to" confine" the plasma with electromagnets
- fusion bomb = uncontrolled fusion = hydrogen bomb

example: $$^{3}_{1}H + ^{2}_{1}H \rightarrow ^{4}_{2}He + {}_{1}1n + ENERGY$$

Advantages of nuclear fusion:

- clean
- few radioactive products
- fuel inexhaustible (H in water in oceans)
- no possibility of reaction going out of control

<u>Tracers</u>

Radiocarbon Dating

One of the best known radioactive isotopes is carbon-14. The half-life of carbon-14 is 5730 years. This radioactive isotope is produced in the Earth's atmosphere by the action of cosmic rays on ordinary atmospheric nitrogen (N-14). (Cosmic rays are streams of high-energy charged particles and neutrons from outer space that collide with atoms in the Earth's upper atmosphere.) This action results in the nitrogen-14 being converted to carbon-14. The reaction is as follows:

$$^{14}_{7}N + ^{1}_{0}n \rightarrow ^{14}_{6}C + ^{1}_{1}H$$

What makes C-14 such an important isotope? The answer is in the way in which carbon dioxide is used by plants and animals. Carbon dioxide is an essential part of the process of photosynthesis in plants. Photosynthesis is the process by which green plants use the sun's energy to convert carbon dioxide and water into sugars and starches. The sugars and starches, in turn, are food for animals that eat the plants and exhale carbon dioxide. Because this cycle exposes plants and animals to a constant source of C-14, the amount of this isotope in living plants and animals is constant. The emission of beta particles is likewise constant as the isotope decays.

The incorporation of C-14 into plant and animal tissues stops once the organism dies. The emission of beta particles will then drop as the C-14 decays. After 5730 years the rate of beta emissions will have dropped to one half the rate in living organisms; after 11, 460 years the rate will have dropped to one quarter, and so forth. By determining the rate of beta emission from plant and animal remains or products – such as wooden objects, textiles, and leather – scientists can estimate the age of these objects. Such estimates are accurate up to about 7000 years and give a reasonable approximation up to 30, 000 years. (After this length of time, the rate of beta emissions is too slow to be measured reliably.)

Radioisotopes and their uses-

- I – 131 ~ thyroid disease

- Tc – 99 ~ brain tumors

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- C-14
- U-238 → Pb – 206

- Radium and Cobalt

- Radiation

Nuclear Chemistry Homework

A. Nuclear particles and their representations: fill in the following chart (use table O)

Type of radiation	**Symbol**	**Charge**	**Mass**	**Penetrating ability**
Alpha				
Beta				
Gamma				

***B.* Isotopes and radioisotopes and their uses**

1. What is the difference between isotopes and ***RADIO***isotopes?

2. What is the function of a **radioactive tracer**?

3. Give an example of a **radioactive tracer** that is used in:
    a. Medicine:

    b. Dating:

    c. cancer therapy:

    d. thyroid treatment:

C. Balancing Transmutation reactions

1. Write the balanced equation for the transmutation of $\mathbf{I^{131}}$ according to the information found on the reference tables.

2. Write the balanced equation for the transmutation of $\mathbf{Fr^{220}}$ according to the information found on the reference tables.

3. **Nitrogen-13** undergoes beta-decay. Write the nuclear equation for this below:

D. <u>Half –Life Problems</u>

1. The half-life of nitrogen-13 is 10 minutes. If you have 1 gram of N-13 at 2PM, how much will you have left after

    a. 2:10pm b. 2:20pm c.2:30pm

2. Radon-222 has a half-life of 3.8 days, and decays to produce Polonium-218.

    (a) Write the nuclear equation that describes this decay. What type of particle is produced?

    (b) If you started with an 8 gram sample of radon-222, and 2 weeks goes by, how much radon-222 will be left?

3. The half-life of a radioactive element is 30 seconds. In what period of time would the activity of the sample be reduced to one-sixteenth of the original activity?

4. The half-life of francium is 21 minutes. Starting with 4×10^{18} atoms of francium, how many atoms would disintegrate in 1 hour and 45 minutes? What fraction of the original sample remains?

5. Three grams of Bismuth-218 decay to 0.375 grams in one hour. What is the half-life of this isotope

Fill in the missing parts of the chart below:

Radioisotope	Original mass	Time elapsed	Nuclear equation	Number of half lives	Mass remained unchanged
$^{60}Co_{27}$	60 g	21.2 years			
$^{220}Fr_{87}$	100g	82.5 seconds			

E. <u>Fission and Fusion reactions</u>

1. What is the difference between Nuclear Fusion and nuclear fission?

2. Name 2 "energy sources" for fusion?

3. Where does nuclear fusion occur naturally?

Fill in the chart below

Part of nuclear reactor	**Function**	**Substances used for this function**
Fuels		
Control rods		
Moderator		
Coolant		
shielding		

F. Reading Comprehension:

Base your answers to questions 1 through 6 on the information below and on your knowledge of chemistry.

Nuclear Waste Storage Plan for Yucca Mountain

In 1978, the U.S. Department of Energy began a study of Yucca Mountain which is located 90 miles from Las Vegas, Nevada. The study was to determine if Yucca Mountain would be suitable for a long-term burial site for high-level radioactive waste. A three dimensional (3-D) computer scale model of the site was used to simulate the Yucca Mountain area. The computer model study for Yucca Mountain included such variables as: the possibility of earthquakes, predicted water flow through the mountain, increased rainfall due to climate changes, radioactive leakage from the waste containers, and increased temperatures from the buried waste within the containers.

The containers that will be used to store the radioactive waste are designed to last 10,000 years. Within the 10,000-year time period, cesium and strontium, the most powerful radioactive emitters, would have decayed. Other isotopes found in the waste would decay more slowly, but are not powerful radioactive emitters. In 1998, scientists discovered that the compressed volcanic ash making up Yucca Mountain was full of cracks. Because of the arid climate, scientists assumed that rainwater would move through the cracks at a slow rate. However, when radioactive chlorine-36 was found in rock samples at levels halfway through the mountain, it was clear that rainwater had moved quickly down through Yucca Mountain. It was only 50 years earlier when this chlorine-36 isotope had contaminated rainwater during atmospheric testing of the atom bomb. Some opponents of the Yucca Mountain plan believe that the uncertainties related to the many variables of the computer model result in limited reliability of its predictions. However, advocates of the plan believe it is safer to replace the numerous existing radioactive burial sites around the United States with the one site at Yucca Mountain. Other opponents of the plan believe that transporting the radioactive waste to Yucca Mountain from the existing 131 burial sites creates too much danger to the United States. In 2002, after years of political debate, a final legislative vote approved the development of Yucca Mountain to replace the existing 131 burial sites.

1. State one uncertainty in the computer model that limits the reliability of this computer model.

2. Scientists assume that a manufacturing defect would cause at least one of the waste containers stored in the Yucca Mountain repository to leak within the first 1,000 years. State one possible effect such a leak could have on the environment near Yucca Mountain.

3. State one risk associated with leaving radioactive waste in the 131 sites around the country where it is presently stored.

4. If a sample of cesium-137 is stored in a waste container in Yucca Mountain, how much time must elapse until only 1/32 of the original sample remains unchanged?

5. The information states "Within the 10,000-year time period, cesium and strontium, the most powerful radioactive emitters, would have decayed." Use information from Reference Table *N* to support this statement.

6. Why is water flow a crucial factor in deciding whether Yucca Mountain is a suitable burial site?

Nuclear Chemistry Classwork

Reaction		Name
a)	$^{3}_{1}H \rightarrow$ _____ $+ ^{0}_{-1}e$	__________________
b)	$^{232}_{92}U \rightarrow ^{228}_{88}Ra +$ _____	__________________
c)	$^{144}_{58}Ce \rightarrow ^{144}_{59}\mathrm{Pr} +$ _____	__________________
d)	$^{65}_{30}Zn \rightarrow$ _____ $+ ^{0}_{+1}e$	__________________
e)	$^{40}_{19}K \rightarrow ^{40}_{18}Ar + ^{0}_{+1}e$	__________________
f)	$^{7}_{4}Be^{*} \rightarrow ^{7}_{4}Be +$ _____	__________________
g)	$^{1}_{0}n + ^{235}_{92}U \rightarrow ^{236}_{92}U^{*} \rightarrow ^{141}_{55}Cs +$ _____ $+ 3\,^{1}_{0}n$	__________________
h)	$^{222}_{86}Rn \rightarrow$ _____ $+ ^{4}_{2}He$	__________________
i)	$^{129}_{53}I \rightarrow ^{129}_{54}Xe +$ _____	__________________
j)	$^{1}_{1}H + ^{1}_{1}H \rightarrow$ _____ $+ ^{0}_{+1}e$	__________________
k)	$^{239}_{94}Pu \rightarrow$ _____ $+ ^{4}_{2}He$	__________________
l)	$^{15}_{8}O \rightarrow ^{15}_{7}N +$ _____	__________________

Using your knowledge of nuclear chemistry, write the equations for the following processes:

1) The alpha decay of radon-198

2) The beta decay of uranium -237

3) What is a "mass defect" and why is it important?

4) Name three uses for nuclear reactions.