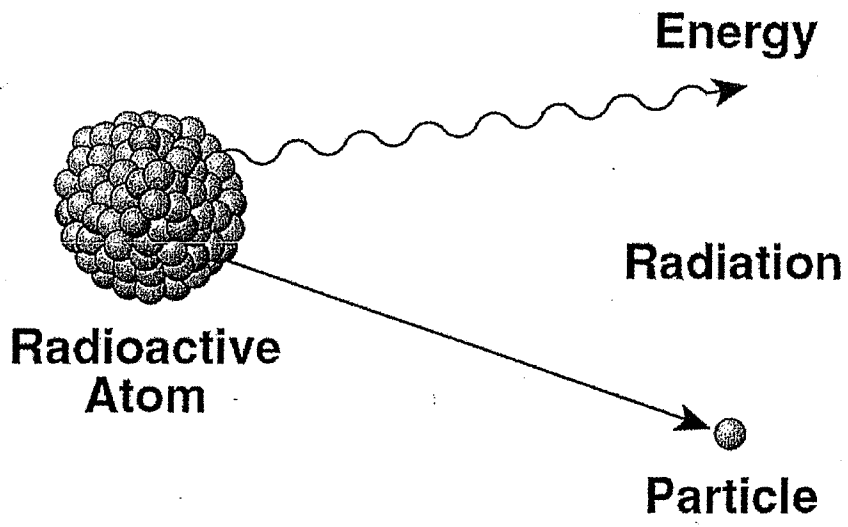
2018-2019
Key

Chemistry R Unit 14: Nuclear Chemistry



Major Understanding	Skill (you should be able to)	Page(s)
Stability of isotopes is based on the ratio of the neutrons and protons in its nucleus. Although most nuclei are stable, some are unstable and spontaneously decay emitting radiation.	Determine whether a nuclide is radioactive based on the number of neutrons and protons.	803-804
Each radioactive isotope has a specific mode and rate of decay (half-life).	Calculate the initial amount, the fraction remaining, or the half-life of a radioactive isotope, given two of the three variables.	803-808
A change in the nucleus of an atom that converts it from one element to another is called transmutation. This can occur naturally or can be induced by the bombardment of the nucleus by high-energy particles.	Determine whether or not an equation represents a transmutation reaction. Distinguish between equations that represent natural transmutation and artificial transmutation.	807-808
Spontaneous decay can involve the release of alpha particles, beta particles, positrons, and/or gamma radiation from the nucleus of an unstable isotope. These emissions differ in mass, charge, ionizing power, and penetrating power.	Determine decay mode and write nuclear equations showing alpha and beta decay	799-802
Nuclear reactions include natural and artificial transmutation, fission, and fusion.	Compare and contrast fission and fusion reactions	810-813
There are benefits and risks associated with fission and fusion reactions.	Explain advantages and disadvantages of nuclear fission and nuclear fusion	810-813

Nuclear reactions can be represented by equations that include symbols that represent atomic nuclei (with the mass number and atomic number), subatomic particles (with mass number and charge), and/or emissions such as gamma radiation.	Complete nuclear equations; predict missing particles from nuclear equations	799-808
Energy released in a nuclear reaction (fission or fusion) comes from the fractional amount of mass converted into energy. Nuclear changes convert matter into energy.	Explain why nuclear reactions produce more energy than ordinary chemical reactions.	810-813
Energy released during nuclear reactions is much greater than the energy released during chemical reactions.	Identify nuclear reactions as reactions that produce more energy than ordinary chemical reactions.	810-813
There are inherent risks associated with radioactivity and the use of radioactive isotopes. Risks can include biological exposure, long-term storage and disposal, and nuclear accidents.	Explain the risks associated with radioactivity and exposure to radiation.	799-802
Radioactive isotopes have many beneficial uses. Radioactive isotopes are used in medicine and industrial chemistry, e.g., radioactive dating, tracing chemical and biological processes, industrial measurement, nuclear power, and detection and treatment of diseases.	Identify specific uses of some common radioisotopes, such as: I-131 in diagnosing and treating thyroid disorders; C-14 to C-12 ratio in dating living organisms; U-238 to Pb-206 ratio in dating geological formations; Co-60 in treating cancer	814-819

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Nuclear Equations Practice

Part 1: Write the balanced nuclear equations for the following:

1) ^{85}Br undergoes positron emission

$^{85}_{35}Br \rightarrow {}^{0}_{+1}e + {}^{85}_{34}Se$

2) ^{214}Bi decays by the emission of a beta particle

$^{214}_{83}Bi \rightarrow {}^{0}_{-1}e + {}^{214}_{84}Po$

3) ^{206}Po decays by emitting an alpha particle

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

4) Rn-198 undergoes alpha decay

$^{198}_{86}Rn \rightarrow {}^{4}_{2}He + {}^{194}_{84}Po$

5) Si-26 undergoes positron emission

$^{26}_{14}Si \rightarrow {}^{0}_{+1}e + {}^{26}_{13}Al$

Part 2: Fill in the missing information given the nuclear equations below.

6) $^{129}_{53}I \rightarrow {}^{0}_{-1}e + \underline{{}^{129}_{54}Xe}$

7) $^{9}_{4}Be + \underline{{}^{4}_{2}He} \rightarrow {}^{12}_{6}C + {}^{1}_{0}n$ * artificial transmutation

8) $\underline{{}^{235}_{86}Rn} \rightarrow {}^{4}_{2}He + {}^{231}_{84}Po$

9) $^{40}_{19}K + \underline{{}^{0}_{-1}e} \rightarrow {}^{40}_{18}Ar$ * artificial transmutation

10) $^{237}_{92}U \rightarrow {}^{0}_{-1}e + \underline{{}^{237}_{93}Np}$

Nuclear Chemistry MC WS 1 Name: _____ Key

C 1) Which type of reaction converts one element to another element?

A) substitution C) transmutation
B) neutralization D) polymerization

D 2) According to the *Selected Radioisotopes* chemistry reference table, which pair of isotopes spontaneously decays?

A) C-12 and N-16 C) C-14 and N-14
B) C-12 and N-14 D) C-14 and N-16 on Table N

B 3) The stability of an isotope is based on its

A) number of neutrons, only C) ratio of electrons to protons
B) ratio of neutrons to protons D) number of protons, only

D 4) For most atoms with an atomic number less than 20, nuclear stability occurs when the ratio of neutrons to protons is 1:1. Which of the following atoms would be most likely to have an unstable nucleus?

A) $^{12}_{6}C$ p: 6 n: 6 B) $^{4}_{2}He$ p: 2 n: 2 C) $^{24}_{12}Mg$ p: 12 n: 12 D) $^{16}_{7}N$ p: 7 n: 9

D 5) Which of the following equations represents a transmutation reaction?

A) $nC_2H_4 \xrightarrow{\text{catalyst}} (-C_2H_4-)_n$ polymerization C) $^{239}_{92}U \rightarrow {}^{239}_{92}U + {}^{4}_{2}\gamma$ same identity

B) $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$ combustion D) $^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$

A 6) Which nuclear emission has the *greatest* mass?

A) α $^{4}_{2}He$ B) γ $^{0}_{0}\gamma$ C) β^+ $^{0}_{+1}e$ D) β^- $^{0}_{-1}e$

C 7) Which type of radiation is identical in mass and charge to a helium nucleus?

A) positron B) proton C) alpha D) beta

B 8) Alpha particles are emitted during the radioactive decay of Table N

A) carbon-14 B) radon-222 C) neon-19 D) calcium-37

D 9) Which reaction is an example of natural transmutation? one reactant, at least 2 products

A) $^{27}_{13}Al + {}^{4}_{2}He \rightarrow {}^{30}_{15}P + {}^{1}_{0}n$ C) $^{238}_{92}U + {}^{1}_{0}n \rightarrow {}^{239}_{94}Pu + 2{}^{0}_{-1}e$

B) $^{239}_{94}Pu + {}^{1}_{0}n \rightarrow {}^{147}_{56}Ba + {}^{90}_{38}Sr + 3{}^{1}_{0}n$ D) $^{239}_{94}Pu \rightarrow {}^{235}_{92}U + {}^{4}_{2}He$

A 10) Which equation represents the radioactive decay of $^{226}_{88}Ra$? Table N. α decay.

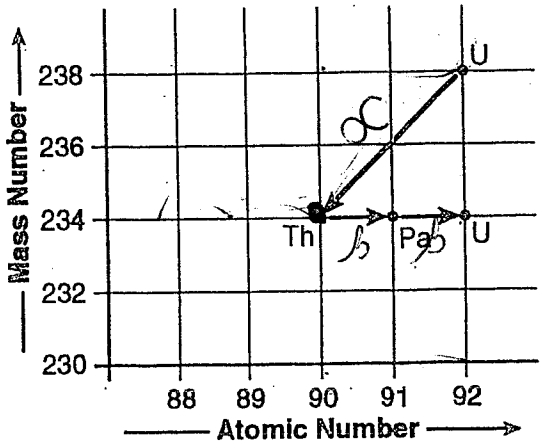
A) $^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$ C) $^{226}_{88}Ra \rightarrow {}^{226}_{87}Fr + {}^{0}_{+1}e$

B) $^{226}_{88}Ra \rightarrow {}^{226}_{89}Ac + {}^{0}_{-1}e$ D) $^{226}_{88}Ra \rightarrow {}^{225}_{88}Ra + {}^{1}_{0}n$

C 11) Radioactive cobalt-60 is used in radiation therapy treatment. Cobalt-60 undergoes beta decay. This type of nuclear reaction is called

A) artificial transmutation C) natural transmutation
B) nuclear fusion D) nuclear fission

D 12) 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?

A) α decay, α decay, β⁻ decay
B) β⁻ decay, γ decay, β⁻ decay
C) β⁻ decay, β⁻ decay, α decay
D) α decay, β⁻ decay, β⁻ decay

C 13) What does *X* represent in the following reaction?

$$^{239}_{93}\mathrm{Np} \rightarrow {}^{239}_{94}\mathrm{Pu} + X$$

A) a proton
B) an alpha particle
C) a beta particle
D) a neutron

B 14) Which statement *best* describes gamma radiation?

A) It has a mass of 0 and a charge of -1.
B) It has a mass of 0 and a charge of 0.
C) It has a mass of 4 and a charge of +2.
D) It has a mass of 1 and a charge of 1.

D 15) Which of these types of nuclear radiation has the *greatest* penetrating power?

A) beta
B) alpha
C) neutron
D) gamma

no mass, no charge

C 16) Given the nuclear equation:

$$^{19}_{10}\mathrm{Ne} \rightarrow X + {}^{19}_{9}\mathrm{F}$$

Which particle is represented by *X*?

A) alpha
B) neutron
C) positron
D) beta

HALF LIFE PROBLEMS - Use table N & T and show all work...

1) A sample of I-131 decays to 1.0 grams in 40 days. What was the mass of the original sample?

$\frac{40 \text{ days}}{8.021 \text{ days}} = 5$ half lives

32.0 g ← 16.0 g ← 8.0 g ← 4.0 g ← 2.0 g ← 1.0 g

32.0 g

2) What is the total number of hours required for Potassium-42 to undergo three half life periods?

$3(12.36 \text{ hr}) =$ **37.08 hr**

3) In 6.20 hours, a 100 gram sample of Ag-112 decays to 25.0 grams. What is the half life of Ag-112?

100 g → 50 → 25.0

$\frac{6.20 \text{ hr}}{2} =$ **3.10 hr**

4) A 2.5 g sample of an isotope of Strontium-90 was formed in a 1960 explosion of an atomic bomb at Johnson Island in the Pacific Test Site. In what year will only 0.625 grams of the Strontium-90 remain?

2.5 g → 1.25 g → 0.625 g

2 (29.1 yr) = 58.2 years

1960 + 58.2 =

2018

5) An 80 g sample of a radioisotope decayed to 10 g after 24 days. What was the total number of grams of the original sample that remained unchanged after the first 8 days?

80 g → 40 → 20 → 10

40 g

6) What mass of a 32.0 g sample of ^{32}P will remain after 71.5 days of decay?

$\frac{71.5 \text{ days}}{14.28 \text{ days}} = 5$ half lives

32 g → 16 g → 8 → 4 g → 2 → 1 g

1.0 g

7) After 60 days, 10.0 grams of radioactive isotope remains from an original 80.0 g sample. What is the half life of this element?

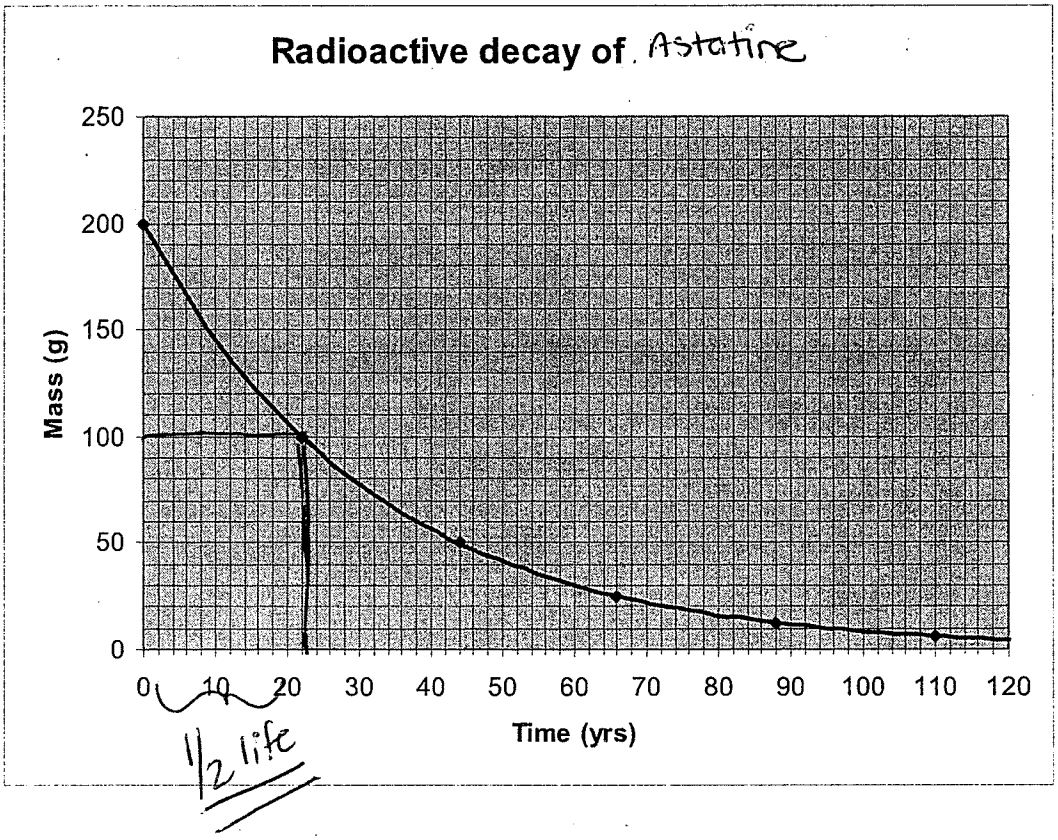
80 g → 40 g → 20 g → 10 g

$\frac{60 \text{ days}}{3} =$ **20 days**

5

GRAPHING RADIOACTIVE DECAY

The graph for the decay of actinium below to answer questions 1-8.



1) What was the original mass of the astatine sample? 200 g
2) How many grams of astatine remain after 40 years? 57 g
3) What is the half life of astatine? 22 yrs
4) What mass of astatine remains after one half-life? 100 g
5) What fraction of astatine remains after one half-life? 1/2
6) How many half-lives must astatine go through until only 25% of the original sample mass remains? 2 half lives
7) How many half-lives until only 6.25% remains? $1 \rightarrow \frac{1}{2} \rightarrow \frac{1}{4} \rightarrow \frac{1}{8} \rightarrow \frac{1}{16}$ 4
8) How many half-lives will it take for all of the original sample to decay? infinite (asymptote)

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Nuclear Chemistry: Half-Life Problems

1. How much of a 100.0 g sample of ^{32}P would remain after 42.84 days?

$\frac{42.84 \text{ days}}{14.28 \text{ days}} = 3$ half-lives $100\text{ g} \rightarrow 50 \rightarrow 25 \rightarrow$ **12.5 g**

2. After 32.19 years, how much of a 30.0 g sample of ^{85}Kr remains unchanged?

$\frac{32.19 \text{ yrs}}{10.73 \text{ yrs}} = 3$ half-lives $30\text{ g} \rightarrow 15 \rightarrow 7.5 \rightarrow 3.75\text{ g}$

$\downarrow\downarrow$

s.f. **3.8 g**

3. How long does it take a 100.0 g sample of Au-198 to decay to 6.25g?

$100\text{ g} \rightarrow 50 \rightarrow 25 \rightarrow 12.5 \rightarrow 6.25\text{ g}$

$4(2.695 \text{ days}) =$ **10.780 days**

4. How much time does it take for a 40.0 g sample of ^{19}Ne to decay to 5.0 g?

$40 \rightarrow 20 \rightarrow 10 \rightarrow 5$

$(17.22)\,3 = 51.66 \text{ sec}$

5. What is the half-life of a 100.0 g sample of a radioisotope that decays to 12.5 g in 21.6 s?

$100\text{ g} \rightarrow 50 \rightarrow 25 \rightarrow 12.5$

$\frac{21.6 \text{ s}}{3} = 7.2 \text{ sec}$

6. If 100.0 g of a radioisotope decays until only 25.0 g is left after 11,460 years, what is the half-life of this radioisotope?

$100 \rightarrow 50 \rightarrow 25$

$\frac{11{,}460 \text{ yrs}}{2} = 5{,}730 \text{ yrs.}$

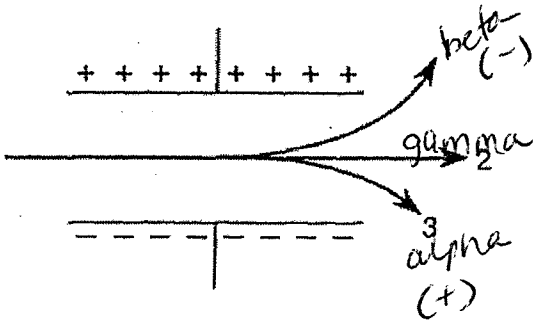
7. If the half-life of a radioisotope is 3 hours, what fraction of an original amount remains unchanged after 15 hours?

$\frac{15}{3} = 5$ half-lives $1 \rightarrow 1/2 \rightarrow 1/4 \rightarrow 1/8 \rightarrow 1/16 \rightarrow$ **1/32**

Nuclear Homework

1. An electron has a charge identical to that of
   A) a beta particle B) an alpha particle
   C) a neutron D) a proton

2. A mixture of emanations from radioactive atoms is passed through electrically charged plates, as shown in the diagram below.



   The nuclear emanations 1, 2, and 3 are called, respectively,
   A) gamma, alpha, and beta
   B) gamma, beta, and alpha
   C) alpha, beta, and gamma
   D) beta, gamma, and alpha

3. An alpha particle has the same composition as a
   A) deuterium nucleus B) beryllium nucleus
   C) helium nucleus D) hydrogen nucleus

4. As a radioactive element emits gamma radiation only, the atomic number of the element
   A) decreases B) increases
   C) remains the same

5. Which radioactive emanations have a charge of 2^+?
   A) alpha particles B) neutrons
   C) beta particles D) gamma rays

6. When an atom emits a beta particle, the total number of nucleons
   A) decreases B) increases
   C) remains the same

7. Which of these types of radiation has the greatest penetrating power?
   A) alpha B) beta
   C) positron D) gamma

8. Which kind of nuclear radiation has high energy and no mass?
   A) beta B) gamma
   C) neutron D) alpha

9. Which equation represents alpha decay?
   A) $^{234}_{90}Th \rightarrow {}^{234}_{91}Pa + X$
   B) $^{38}_{19}K \rightarrow {}^{38}_{18}Ar + X$
   C) $^{222}_{86}Rn \rightarrow {}^{218}_{84}Po + {}^{4}_{2}X$ or $^{4}_{2}He$
   D) $^{116}_{49}In \rightarrow {}^{116}_{50}Sn + X$

10. Given the equation:
    $^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}X$ or $^{0}_{-1}e$
    Which particle is represented by the letter X?
    A) a neutron B) a proton
    C) an alpha particle D) a beta particle

11. Which particle has a negative charge?
    A) a lithium ion B) an aluminum ion
    C) an alpha particle D) a beta particle

12. Which of the following particles has the greatest mass?
    A) an alpha particle B) an electron
    C) a proton D) a beta particle

13. When a beta particle ($^{0}_{-1}e$) is emitted by the nucleus of an atom, the mass number of the atom
    A) decreases B) increases
    C) remains the same

14. Gamma rays are emanations that have
    A) mass but no charge
    B) charge but no mass
    C) neither mass nor charge
    D) both mass and charge

15. Which of the following particles has the *least* mass?
    A) proton B) beta particle
    C) alpha particle D) neutron

16. Which type of radiation would be attracted to the positive electrode in an electric field?
    A) $^{0}_{-1}e$
    B) $^{1}_{1}H$
    C) $_{32}He$
    D) $_{10}n$

17. Given the reaction:

$$^{24}_{11}Na \rightarrow {}^{24}_{12}Mg + {}^{0}_{-1}e$$

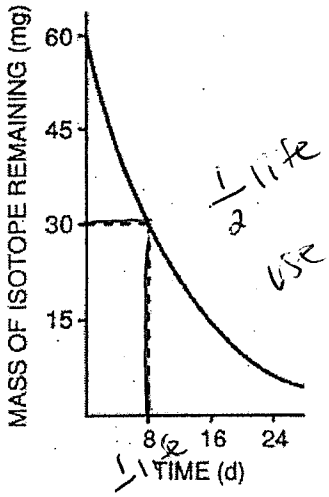
    This reaction is best described as
    A) beta decay B) fission
    C) alpha decay D) fusion

Nuclear Homework - Half-life/Transmutation

B 1. Which sample will decay *least* over a period of 30 days?

A) 10 g of I-131 (8.021 days) B) 10 g of P-32 (14.28 days)
C) 10 g of Rn-222 (3.823 days) D) 10 g of Au-198 (2.695 days)

2. The graph below represents the decay of a radioactive isotope.



1/2 life = 8 days
Use Table N

A Based on Reference Table *H*, which radioisotope is best represented by the graph?

A) ^{131}I
B) ^{222}Rn
C) ^{198}Au
D) ^{32}P

C 3. A sample of ^{131}I decays to 1.0 gram in 40. days. What was the mass of the original sample?

A) 8.0 g B) 16 g
C) 32 g D) 4.0 g

32 ← 16 ← 8 ← 4 ← 2 ← 1
40 / 8.021 = 5 half-lives.

D 4. What is the number of half-life periods required for a sample of a radioactive material to decay to one-sixteenth its original mass?

A) 8 B) 16
C) 3 D) 4

4 arrows
1 → 1/2 → 1/4 → 1/8 → 1/16

A 5. In how many days will a 12-gram sample of $^{131}_{53}I$ decay, leaving a total of 1.5 grams of the original isotope?

A) 24 B) 8.0
C) 16 D) 20.

12g → 6g → 3g → 1.5g
3 half lives
3(8.021 days) = 24 days

C 6. As a sample of the radioactive isotope ^{131}I decays, its half-life

A) decreases B) increases
C) remains the same

A 7. Given the nuclear reaction:

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

What is the identity of particle *X*?

A) alpha particle B) beta particle
C) proton D) neutron

C 8. Given the correctly balanced nuclear equation:

$$^{12}_{6}C + ^{249}_{98}Cf \rightarrow ^{257}_{104}Unq + 4X$$

Which particle is represented by the *X*?

A) $^{1}_{1}H$
B) $^{0}_{-1}e$
C) $^{1}_{0}n$
D) $^{4}_{2}He$

B 9. In the reaction:

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

The *X* represents

A) $^{1}_{0}n$
B) $^{1}_{1}H$
C) $^{0}_{-1}e$
D) $^{0}_{+1}e$

A 10. Given the nuclear reaction:

$$^{32}_{16}S + ^{1}_{0}n \rightarrow ^{1}_{1}H + ^{32}_{15}P$$

What does *X* represent in this reaction?

A) $^{32}_{15}P$
B) $^{32}_{16}P$
C) $^{31}_{15}P$
D) $^{31}_{16}P$

B 11. Artificial transmutation is brought about by using accelerated particles to bombard an atom's

A) valence shells
B) nucleus
C) occupied sublevels
D) inner principal energy levels

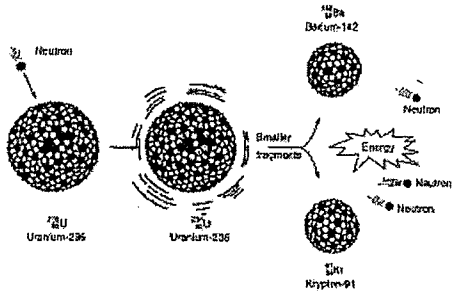
C 12. The nuclear reaction:

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

Is an example of

A) natural transmutation
B) nuclear fission
C) artificial transmutation
D) nuclear fusion

A 13. The diagram below represents a nuclear reaction in which a neutron bombards a heavy nucleus.



Which type of reaction does the diagram illustrate?

A) fission
B) fusion
C) alpha decay
D) beta decay

C 14. In which reaction is mass converted to energy by the process of fission?

A) $^{2}_{1}H + ^{2}_{1}H \rightarrow ^{4}_{2}He$
B) $^{226}_{88}Ra \rightarrow ^{222}_{86}Ra + ^{4}_{2}He$
C) $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{87}_{35}Br + ^{146}_{57}La + 3^{1}_{0}n$
D) $^{14}_{7}N + ^{1}_{0}n \rightarrow ^{14}_{6}C + ^{1}_{1}H$

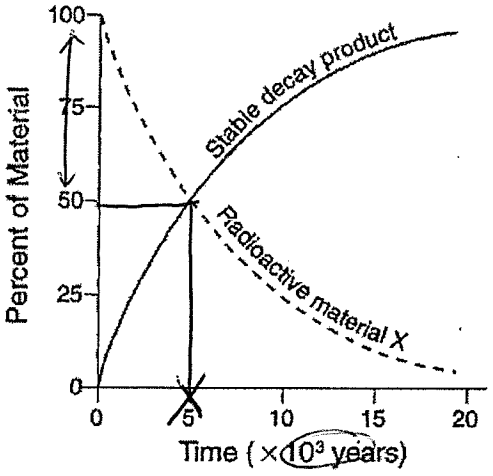
D 15. A radioisotope which is sometimes used by doctors to pinpoint a brain tumor is

A) lead-206
B) carbon-12
C) uranium-238
D) technetium-99

B 16. Which procedure is based on the half-life of a radioisotope?

A) radiating to kill cancer cells
B) dating to determine age
C) accelerating to increase kinetic energy
D) counting to determine a level of radioactivity

Base your answers to questions 17 through 20 on on the graph below. The graph represents the decay of radioactive material X into a stable decay product.

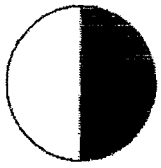


B 17. What is the approximate half-life of radioactive material X?

A) 10,000 yr
B) 5,000 yr
C) 100,000 yr
D) 50,000 yr

18. Which graph best represents the relative percentages of radioactive material X and its stable decay product after 15,000 years? **(The shaded region represents radioactive material while the non-shaded region represents stable decay products.)**

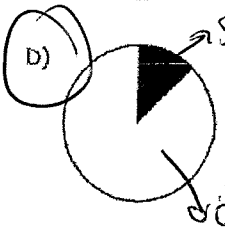
A)



B)

C)

D)



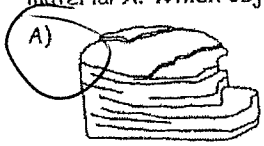
$\frac{15,000}{5,000}$ = 3 half-lives

$\frac{1}{1} \rightarrow \frac{1}{2} \rightarrow \frac{1}{4} \rightarrow \boxed{\frac{1}{8}}$ remaining

A

19. Each of the objects below has different amounts remaining of the original radioactive material *X*. Which object is most likely the oldest?

A)



Rock

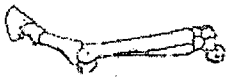
10% of the radioactive material remains

B)

Wood

33% of the radioactive material remains

C)



Bone

52% of the radioactive material remains

D)

Shell

41% of the radioactive material remains

C

20. If radioactive material *X* were heated, the length of its half-life period would

A) decrease B) increase

C) remain the same

D

21. Iodine-131 is used for diagnosing thyroid disorders because it is absorbed by the thyroid gland and

A) emits alpha radiation

B) has a very long half-life

C) emits gamma radiation

D) has a very short half-life

Name: _____ Key Period: _____

Chemistry R: Nuclear Chemistry Review

1. Write the decay equation for the following radioisotopes (use Table N):

positron a) $^{53}_{26}Fe \rightarrow {}^{0}_{+1}e + {}^{53}_{25}Mn$

alpha b) $^{232}_{90}Th \rightarrow {}^{4}_{2}He + {}^{228}_{88}Ra$

2. Balance the following nuclear equations by filling in the blanks.

a) $^{85}_{36}Kr \rightarrow {}^{0}_{-1}e + {}^{85}_{37}Rb$

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

c) $^{239}_{94}Pu \rightarrow {}^{4}_{2}He + {}^{235}_{92}U$

3. After 57.12 days, what mass of a 60.0 g sample of ^{32}P remains unchanged? (Use Table N)

$\frac{57.12 \text{ days}}{14.28 \text{ days}} = 4$ half-lives 60.0 g → 30.0 g → 15.0 g → 7.50 g → 3.75 g → **3.8 g** 2 s.f.

4. What is the half-life of a radioactive isotope if a 500.0 g sample decays to 125.0 g in 24.3 hours?

500.0 g → 250.0 g → 125.0 g

$\frac{24.3 \text{ hr}}{2} =$ **12.15 hrs**

5. There are 2.50 g left of Rn-222 after 15.292 days. How many grams were in the original sample? (Use Table N)

$\frac{15.292 \text{ days}}{3.823 \text{ days}} = 4$ half-lives

40.00 ← 20.00 g ← 10.00 g ← 5.00 g ← 2.50 g

13 **40.00 g**

Name: _____ Period: _____ Date: _____

STUDY!

Chemistry R: Nuclear Chemistry

Beneficial Uses of Radioisotopes

1) Carbon-14/Carbon-12 (dating):

"**Carbon dating**" is used to determine the age of **once living organisms.** All living organisms incorporate carbon-14 into their bodies through life processes, but when the organism expires, the carbon-14 is no longer replenished. The **ratio of carbon-14 to carbon-12** can indicate how long ago the organism expired.

2) Uranium-238/Lead-206 Ratio (dating):

Scientists can date **rocks and other geological formations** by determining and examining the **ratio of U-238 to Pb-206.** Unstable Uranium-238 decays through a series of steps to become the more stable Lead-206 isotope.

3) Phosphorus-31 and Carbon-14 (tracers):

A **tracer** is a radioisotope used to **follow the path of a material** in an organism. P-31 in fertilizer can help scientists determine the proper amounts and timing of fertilizing plants and crops. Scientists can use C-14 to map the path of carbon compounds in metabolic processes.

Ideal radioisotopes used in medicine have **short half-lives and are **eliminated from the body quickly.**

4) Iodine-131 (medicine):

Iodine-131 is used for both the **detection and treatment of thyroid disorders.** I-131 accumulates in the thyroid gland. Large doses of I-131 can destroy thyroid tissue to benefit patients with hyperthyroidism.

5) Cobalt-60 (medicine):

Cobalt-60 is useful in **radiation treatments to destroy cancerous cells.** Co-60 emits large amounts of gamma radiation as it decays. When aimed at cancerous tumors, the gamma radiation can kill rapidly growing cancer cells.

6) Technetium-99 (medicine):

Technetium-99 is used to help **diagnose or detect cancerous tumors.** Cancerous cells rapidly absorb Tc-99 making tumors are easily detectable with a scan.

7) Cobalt-60 and Cesium-137 (food industry):

Both cobalt-60 and cesium-137 are **good sources of gamma radiation.** Intense gamma radiation can **kill bacteria** in spices, produce, and meat so foods will not spoil as quickly and consumers will not suffer bacterial infections.