Name: _____ Date: _____

Nuclear Reactions

Homework Unit 13 - Topic 4

Use the laws of conservation of mass number and charge to determine the identity of X in the equations below. Refer to a periodic table as needed.

a. $^{222}_{86}Rn \rightarrow ^{4}_{2}He + X$ $X =$ _____

b. $X \rightarrow ^{0}_{+1}e + ^{19}_{9}F$ $X =$ _____

After filling in the symbol (with mass and atomic #'s shown):

a) circle the ***spontaneous*** decay (natural transmutation) reactions
b) **identify those decay reactions as α, β^-, or β^+**

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

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

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

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

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

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

7. $^{9}_{4}Be + ^{1}_{1}H \rightarrow$ _____ $+ ^{4}_{2}He$

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Isotopes - Most of the potassium in the world exists as K-39. This can be written as $_{19}{}^{39}K$. This means there are 19 protons and 20 neutrons.

BETA-EMISSION

Some isotopes of potassium are radioactive. For example, K-42 has 19 protons and 23 neutrons. It is unstable and spontaneously emits an electron as follows:

$$_{19}{}^{42}K \rightarrow {}_{-1}{}^{0}e + {}_{20}{}^{42}Ca$$

This means that a neutron in the nucleus becomes a proton and emits an electron. That converts potassium with 19 protons to calcium having 20 protons.

$$_{0}{}^{1}n \rightarrow {}_{-1}{}^{0}e + {}_{1}{}^{1}p$$

Write equations for the following:

1. Sr-90 emits beta radiation ($_{-1}{}^{0}e$)

2. Tc-99 emits beta radiation

3. N-16 emits beta radiation

POSITRON-EMISSION

In this case, a proton in the nucleus becomes a neutron and emits a positron.

$$_{1}{}^{1}p \rightarrow {}_{+1}{}^{0}e + {}_{0}{}^{1}n$$

This means that K-37 emits a positron and becomes Argon having 18 protons and 19 neutrons

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

Write equations for the following:

4. Ne-19 emits positrons

5. Fe-53 emits positrons

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ALPHA PARTICLE EMISSION

These particles are Helium nuclei, which means that 2 protons and 2 neutrons are lost from the nucleus. For example, Pu-239 emits an alpha particle to form U-235

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

This U-235 that is formed loses another alpha particle.

6. Write the equation for this spontaneous radiation.

7. Write the equation for the decomposition of Ra-226 by alpha emission.

8. Write the equation for the decomposition of Th-232 by alpha emission.

USING TABLE N

Use the information on Table N to write the transmutation equation for each of these radioisotopes as they undergo radioactive decay.

9. Ca-37

10. Rn-222

11. Cs-137

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Writing Nuclear Equations

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

Rules for writing nuclear equations

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

General Format

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

A *or* a = mass number
Z *or* z = charge; atomic number
X = original element
x = radioactive emission
Y = new element

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

Nuclear equations for alpha decay:

- ★ General format: ${}^{A}_{Z}X \rightarrow {}^{4}_{2}He + {}^{A-4}_{Z-2}Y$
- ★ Example: ${}^{235}_{92}U \rightarrow {}^{4}_{2}He + {}^{231}_{90}Th$

Nuclear equations for beta decay:

- ★ General format: ${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e$
- ★ Example: ${}^{234}_{90}Th \rightarrow {}^{234}_{91}Pa + {}^{0}_{-1}e$

Nuclear equations for positron emission:

- ★ General format: ${}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + {}^{0}_{+1}e$
- ★ Example ${}^{37}_{19}K \rightarrow {}^{37}_{18}Ar + {}^{0}_{+1}e$

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

Sample Problem

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

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

Step 2: Look up the atomic number of the known element and write an equation showing the known information
${}^{222}_{86}Rn \rightarrow {}^{4}_{2}He + {}^{222-4}_{86-2}Y$

Step 3: Subtract the weight and charge of the emission from the weight and charge of the original element to determine the weight and charge of the new element
${}^{222}_{86}Rn \rightarrow {}^{4}_{2}He + {}^{218}_{84}Y$

Step 4: Identify the new element based on the nuclear charge or atomic number
${}^{222}_{86}Rn \rightarrow {}^{4}_{2}He + {}^{218}_{84}Po$

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 from the decay of francium-220?

4. What forms from the decay of potassium-37

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1. Alpha particles are emitted during the radioactive decay of

1. carbon-14
2. neon-19
3. calcium-37
4. radon-222

2. Which nuclear reaction is classified as alpha decay?

(1) $^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$

(2) $^{42}_{19}K \rightarrow {}^{42}_{20}Ca + {}^{0}_{-1}e$

(3) $^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$

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

3. Which substance has chemical properties similar to those of radioactive ^{235}U?

1. ^{235}Pa
2. ^{233}Pa
3. ^{233}U
4. ^{206}Pb

4. 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

5. Which type of radioactive emission has a positive charge and weak penetrating power?

1. alpha particle
2. beta particle
3. gamma ray
4. neutron

6. Given the reaction:
Which type of reaction is represented?

1. natural transmutation
2. artificial transmutation
3. fission
4. fusion

7. Given the nuclear reaction:

$$^{14}_{7}N + {}^{4}_{2}He \rightarrow {}^{1}_{1}H + X$$

Which isotope is represented by the *X* when the equation is correctly balanced?

1. $^{17}_{8}O$
2. $^{18}_{8}O$
3.
4. $^{18}_{9}F$

8. A particle accelerator can increase the kinetic energy of

1. an alpha particle and a beta particle
2. an alpha particle and a neutron
3. a gamma ray and a beta particle
4. a neutron and a gamma ray

9. Given the nuclear reaction: $^{32}_{16}S + {}^{1}_{0}n \rightarrow {}^{1}_{1}H + X$
What does *X* represent in this reaction?

1.
2. $^{32}_{15}P$
3. $^{31}_{16}S$
4. $^{32}_{16}S$

10. Which equation is an example of artificial transmutation?

1. $^{9}_{4}Be + {}^{4}_{2}He \rightarrow {}^{12}_{6}C + {}^{1}_{0}n$
2. $U + 3F_2 \rightarrow UF_6$
3. $Mg(OH)_2 + 2HCl \rightarrow 2H_2O + MgCl_2$
4. $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$

12. Which nuclear equation represents artificial transmutation?

(1) $^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$

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

(3) $^{226}_{88}Ra \rightarrow {}^{4}_{2}He + {}^{222}_{86}Rn$

(4) $^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$

13. Which particle *cannot* be accelerated in a magnetic field?

1. alpha particle
2. beta particle
3. neutron
4. proton

14. Given the nuclear equation:

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

What is the identity of particle *X* in this equation?

(1) $^{1}_{1}H$

(2) $^{2}_{1}H$

(3) $^{0}_{-1}e$

(4) $^{1}_{0}n$

15. Given the equation:

When the equation is balanced correctly, which particle is represented by *X*?

1. $^{0}_{-1}e$
2. $^{1}_{1}H$
3.
4. $^{1}_{0}n$

16. Bombarding a nucleus with high-energy particles that change it from one element into another is called

1. a half-reaction
2. a breeder reaction
3. artificial transmutation
4. natural transmutation

17. Which process converts an atom from one element to another, when the nucleus of an atom is bombarded with high-energy particles?

1. artificial transmutation
2. natural transmutation
3. addition polymerization
4. condensation polymerization

18. Which fields are used in accelerators to speed up charged particles?

1. magnetic fields, only
2. electric fields, only
3. magnetic and electric fields
4. magnetic and gravitational fields

19. What is the name of the process in which the nucleus of an atom of one element is changed into the nucleus of an atom of a different element?

1. decomposition
2. transmutation
3. substitution
4. reduction

20. Given the reaction:

Which particle is represented by X?

1. alpha
2. beta
3. neutron
4. proton

21. Given the equation: $^{14}_{6}C \rightarrow {}^{14}_{7}N + X$

Which particle is represented by the letter *X*?

1. an alpha particle
2. a beta particle
3. a neutron
4. a proton

22. In the equation:

$^{234}_{90}Th \rightarrow {}^{234}_{91}Pa + X$

the symbol *X* represents

(1) $^{0}_{+1}e$

(2) $^{0}_{-1}e$

(3) $^{1}_{0}n$

(4) $^{1}_{1}H$

23. Which type of radiation has *neither* mass nor charge?

1. gamma
2. neutron
3. alpha
4. beta

24. Which radioisotope is a beta emitter?

1. ^{90}Sr
2. ^{220}Fr
3. ^{37}K
4. ^{238}U

25. Which kind of particle, when passed through an electric field, would be attracted to the negative electrode?

1. an alpha particle
2. a beta particle
3. a neutron
4. an electron

26. Which kind of radiation will travel through an electric field on a pathway that remains unaffected by the field?

1. a proton
2. a gamma ray
3. an electron
4. an alpha particle

28. Which of these types of nuclear radiation has the greatest penetrating power?

1. alpha
2. beta
3. neutron
4. gamma

29. Given the nuclear reaction:

$^{60}_{27}Co \rightarrow {}^{0}_{-1}e + {}^{60}_{28}Ni$

This reaction is an example of

1. fission
2. fusion
3. artificial transmutation
4. natural transmutation

30. Which type of radiation would be attracted to the positive electrode in an electric field?

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

31. Which radioactive emanations have a charge of 2+?

1. alpha particles
2. beta particles
3. gamma rays
4. neutrons

32. In Rutherford's gold foil experiments, some alpha particles were deflected from their original paths but most passed through the foil with no deflection. Which statement about gold atoms is supported by these experimental observations?

1. Gold atoms consist mostly of empty space.
2. Gold atoms are similar to alpha particles.
3. Alpha particles and gold nuclei have opposite charges.
4. Alpha particles are more dense than gold atoms