## Activity 8.7 - Physics 30 – Mr. Immel

## Nuclear Physics Pre-Test

Due Date: ______________________

1. Complete the following chart

| | Isotopic notation | Name | Atomic number (Z) | Atomic mass (A) | Number of neutrons (n) |
|---|---|---|---|---|---|
| a. | $^{234}_{92}U$ | Uranium 234 | 92 | 234 | 142 |
| b. | $^{234}_{90}Th$ | thorium 234 | 90 | 234 | 144 |
| c. | $^{12}_{6}C$ | carbon-12 | 6 | 12 | 6 |
| d. | $^{16}_{8}O$ | oxygen 16 | 8 | 16 | 8 |

2. Write the nuclear decay equation for each of the following radioactive elements. Use the decay series on page 318 of your workbook.

a) Uranium – 238

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}\alpha$$

b) Polonium 218

$$^{218}_{84}Po \rightarrow {}^{214}_{82}Pb + {}^{4}_{2}\alpha$$

c) Lead 210

$$^{210}_{82}Pb \rightarrow {}^{210}_{83}Bi + {}^{0}_{-1}\beta + {}^{0}_{0}\bar{\nu}$$

d) Lead 214

$$^{214}_{82}Pb \rightarrow {}^{214}_{83}Bi + {}^{0}_{-1}\beta + {}^{0}_{0}\bar{\nu}$$

parent nucleus    daughter nucleus

3. Briefly describe 2 applications of radioactivity to technology discussed in this unit.

examples include

- food preservation using gamma radiation
- radioactive tracers (medical application)
- Carbon 14 dating
- radiation treatment for cancer

4. List 3 ways of improving safety when working with a radioisotope.

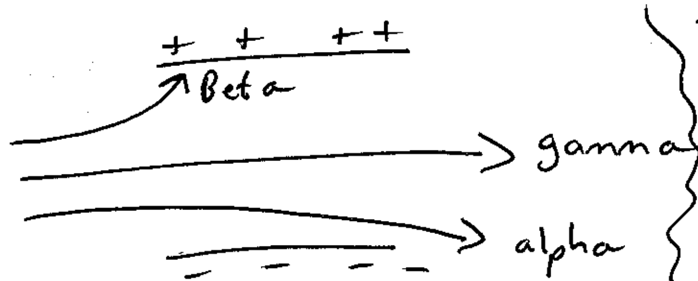
Limit exposure time, maximize distance from source, do not touch source of radiation, wear shielded clothing.

5. List radioactive particles from least penetrating to most penetrating.

$${}^{4}_{2}\alpha \, , \; {}^{0}_{-1}\beta \, , \; {}^{0}_{0}\gamma$$

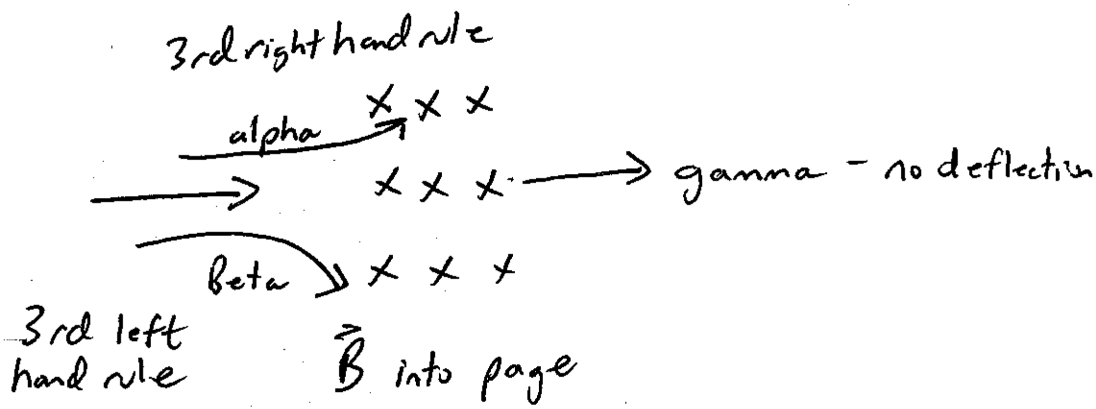
increase penetrating ability →

6. Using a uniform electric field, describe how you could separate the 3 types of nuclear radiation.




- gamma - no deflection (no charge)
- beta - highly deflected to + plate
- alpha - slightly deflected to negative plate

7. Using a magnetic field describe how you could separate the 3 types of nuclear radiation.



8. What is transmutation? Do all types of nuclear decay result in transmutation?

Transmutation is the process of changing one element into another through nuclear decay. The proton number changes during transmutation.
Only $^{4}_{2}\alpha$ and $^{0}_{-1}\beta$, $^{0}_{+1}\beta$ decay cause transmutation.

9. Can deuterium undergo alpha decay? Describe using conservation laws.

deuterium is $^{2}_{1}H$ ... it could not emit an $^{4}_{2}He$ particle as this would violate conservation of nucleons.

10. 140 mg of tungsten 188 undergoes beta –negative decay with a half life of 65 days.

a) Write the nuclear decays equation clearly labeling the parent and daughter nuclei.

$$^{188}_{74}W \rightarrow \, ^{188}_{75}Re + \, ^{0}_{-1}\beta + \, ^{0}_{0}\bar{\nu}$$

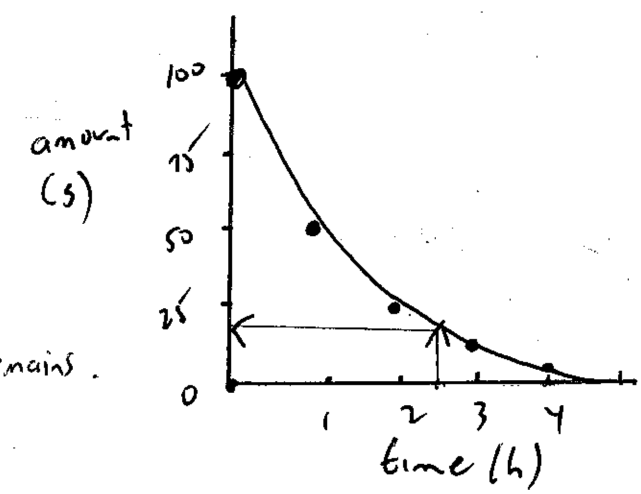
b) Determine the mass remaining after 74 days.

$$n = \frac{\text{time elapsed}}{t_{1/2}} = \frac{74}{65} = 1.138\ldots$$

$$N = N_0 \cdot .5^{n}$$
$$= 140 \cdot .5^{1.138}$$

$N = 62.6\ mg$

11. 100 g of a radioisotope A has a half life of 1.0 h. It then decays into another element called B. Plot the decay curve for the isotope. Use the curve to determine the amount of A remaining after 2.5 hours.




After 2.5 h about 18 g remains.

12. Germanium -68 has a half life of 250 days. Determine the fraction of a sample of germanium remaining after 4.2 years.

① find $n = \frac{\text{time elapsed}}{t\frac{1}{2}}$ $\left(\frac{4.2 \times 365}{250 \text{ days}}\right)$ day $= 6.132$

② $N = ?\%$

$N_0 = 100\%$

so...

$N = N_0 \cdot .5^n$

$= 100 \cdot .5^{6.132}$

$= 1.43\%$ or $\frac{1.43}{100}$

13. Geiger counters detect nuclear radiation. Each time they detect an alpha particle, beta particle or gamma photon they register a "count". A radioactive substance registers 1280 counts per minute on a Geiger counter. After 6.0 hours its activity decrease to 320 counts per minute. Calcualte the half life of the radioisotope.

easy way (chart)

| n | amount remain |
|---|---|
| 0 | 1280 |
| 1 | 640 |
| 2 | 320 |
| 3 | 160 |

half life is therefore 3.0 hours

or

$N = N_0 \cdot .5^n$

$\frac{320}{1280} = .5^n$

$.25 = .5^n$

$\log .25 = n \log .5$

$-.602 = n \cdot (-.301\ldots)$

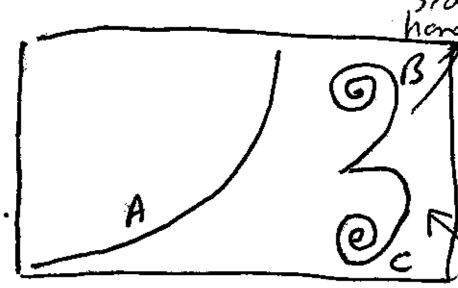
$2 = n$

$n = \frac{\text{time}}{t\frac{1}{2}}$

$2 = \frac{6}{t\frac{1}{2}} \Rightarrow t\frac{1}{2} = 3.0\text{h}$

14. A photograph was taken showing the tracks of 3 subatomic particles (A, B and C) through a bubble chamber inside an external magnetic field directed into the page. Identify the negative particles.

particles enter from here.




3rd right hand rule (positive)

3rd left hand rule (negative)

A - proton {curves in same direction as B}

B - positron

C - beta particle (electron)

} pair production.

15. When analyzing particle tracks. (fill in missing blanks)

positive and negative particles curve in opposite directions.

The electric charge of the particles is identified using 3rd magnetic hand rule.
(left → negative)
(right → positive)

Heavier or faster moving particles curve Less.

Lighter or slower moving particles curve More.

neutral particles don't leave tracks (eg gamma photons)

All conservation laws must be obeyed.

16. What is pair annihilation? (hint see page 335)

When a positron and electron collide, they destroy each other and 2 gamma photons are produced.

$${}^{0}_{1}\beta \rightarrow \gamma \leftarrow {}^{0}_{-1}\beta$$

17. Write the transformation of a neutron into a proton using

a) Quarks

$${}^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}\beta + {}^{0}_{0}\bar{\nu}$$

neutron proton electron antineutrino

b) Nucleons.

$$\underset{\frac{2}{3}}{u}\,\underset{-\frac{1}{3}}{d}\,\underset{-\frac{1}{3}}{d} \rightarrow \underset{\frac{2}{3}}{u}\,\underset{\frac{2}{3}}{u}\,\underset{-\frac{1}{3}}{d} + {}^{0}_{-1}\beta + {}^{0}_{0}\bar{\nu}$$

18. High energy gamma photons can be used to create an electron and a positron. Calculate the minimum energy needed (in eV) to produce an electron and positron.

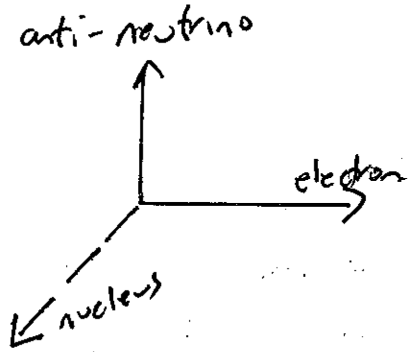
note: this is the opposite process described in #16. It is called pair production!

$$E = mc^2$$

$$E = (2 \times 9.11 \times 10^{-31})(3.00 \times 10^{8})^2$$

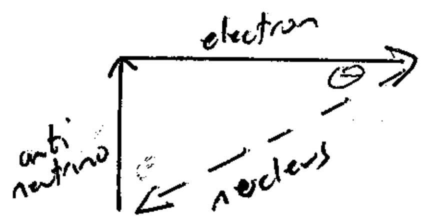
$$E = 1.6398 \times 10^{-13}\ \text{J} \times \frac{1\ \text{eV}}{1.60 \times 10^{-19}\ \text{J}} = 1.02 \times 10^{6}\ \text{eV}$$

19. An isotope emits an electron and an anti-neutrino during radioactive decay. The electron moves east with a momentum of $9.28 \times 10^{-26}$ kg.m/s and the antineutrino moves north with a momentum of $7.47 \times 10^{-27}$ kg.m/s Determine the momentum of the recoiling nucleus.




note $p_{before} = p_{after}$

$0$ = electron + antineutrino must cancel nucleus




$$p_r = \sqrt{(9.28 \times 10^{-26})^2 + (7.47 \times 10^{-27})^2}$$

$$= 9.31 \times 10^{-26}\ \text{kg}\cdot\text{m/s}$$

$$\tan\theta = \frac{7.47 \times 10^{-27}}{9.28 \times 10^{-26}}$$

$$\theta = 4.60^\circ \text{ S of W}$$

Name: Key Class: ______ Date: ______ ID: A

# Nuclear Physics Practice

**Multiple Choice**
*Identify the choice that best completes the statement or answers the question.*

C 1. Identify the number of subatomic particles found in the $^{207}_{82}$Pb nucleus. pg 313

a. 207 protons and 82 neutrons
b. 207 electrons and 82 neutrons
c. 82 protons and 125 neutrons
d. 125 protons and 82 neutrons

D 2. Isotopes can be defined as similar pg 312

a. atoms that have the same number of nucleons.
b. atoms that have the same number of neutrons.
c. ions that have the same number of electrons.
d. atoms that have the same number of protons. but different neutrons

A 3. In order of **increasing** magnitude, what is the order of the following forces of nature? see page 345 in work book

a. gravity, weak nuclear, electromagnetism, strong nuclear
b. strong nuclear, electromagnetism, gravity, weak nuclear
c. weak nuclear, strong nuclear, electromagnetism, gravity
d. electromagnetism, gravity, weak nuclear, strong nuclear

B 4. Binding energy refers to see 332

a. the net energy required to trap all nucleons in the nucleus.
b. the net energy required to liberate all nucleons from the nucleus.
c. the net energy required to liberate all electrons from the ground state.
d. the net energy required to cause radioactive decay.

B 5. According to Einstein's theory of mass-energy equivalence, the amount of energy equivalent to 1.00 amu is

a. $3.11 \times 10^{1}$ eV.
b. $9.34 \times 10^{8}$ eV.
c. $3.00 \times 10^{8}$ eV.
d. $9.00 \times 10^{16}$ eV.

$E = mc^2$
$= 1.66\times10^{-27} \times (3\times10^{8})^2$
$= 1.494\times10^{-10}\text{ J} \times \frac{1\text{ eV}}{1.6\times10^{-19}\text{ J}}$
$= 9.34\times10^{8}$ eV ✓

D 6. What is the daughter product for $^{247}_{96}$Cm when it undergoes α-decay?

a. $^{247}_{95}$Am
b. $^{251}_{98}$Cf
c. $^{247}_{97}$Bk
d. $^{243}_{94}$Pu

$^{247}_{96}Cm \rightarrow {}^{4}_{2}\alpha + {}^{243}_{94}Pu$

C 7. What is the daughter product for $^{14}_{6}$C when it undergoes $\beta^-$ decay?

a. $^{10}_{4}$Be
b. $^{14}_{5}$B
c. $^{14}_{7}$N
d. $^{14}_{6}$C

$^{14}_{6}C \rightarrow {}^{0}_{-1}\beta + {}^{0}_{0}\bar{\nu} + {}^{14}_{7}N$

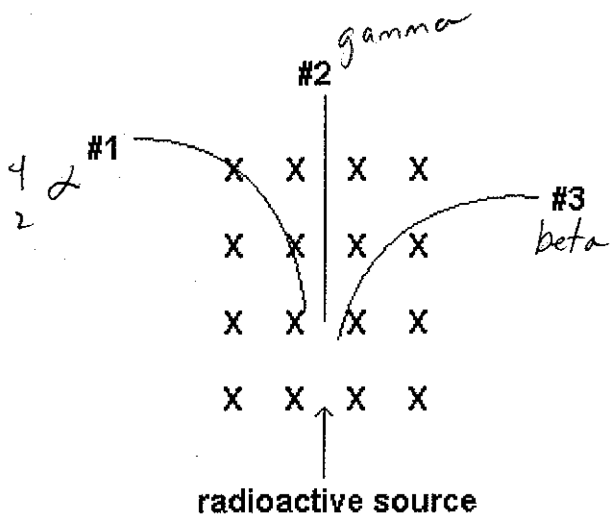
C 8. In the reaction $^{14}_{6}C \rightarrow {}^{14}_{5}B + X$, what does $X$ represent?

a. neutron
b. electron
c. positron
d. helium nuclei

$^{14}_{6}C \rightarrow {}^{14}_{5}B + {}^{0}_{1}\beta + {}^{0}_{0}\nu$

Name: ______________________ ID: A

C 9. Rutherford identified the various types of radiation by taking a radioactive source and directing the emissions through a magnetic field. In the diagram below, the magnetic field is directed *into* the page.




3rd hand rule

What type of radiation follows path #2?

a. alpha
b. beta
c. gamma
d. proton

D 10. When an unstable nucleus undergoes radioactive decay, what is conserved in the process?

a. mass-energy
b. charge
c. nucleon number
d. mass-energy, charge, and nucleon number

D 11. A radioactive isotope has a half-life of 4.5 days. What fraction of the original sample will exist after 9.0 and 18.0 days respectively?

a. $\frac{1}{9}$ and $\frac{1}{18}$
b. $\frac{1}{2}$ and $\frac{1}{4}$
c. $\frac{1}{4}$ and $\frac{1}{8}$
d. $\frac{1}{4}$ and $\frac{1}{16}$

| days | n | amount |
|---|---|---|
| 0 | 0 | 1 |
| 4.5 | 1 | $\frac{1}{2}$ |
| 9 | 2 | $\frac{1}{4}$ |
| 13.5 | 3 | $\frac{1}{8}$ |
| 18 | 4 | $\frac{1}{16}$ |

C 12. The radioactive isotope $^{209}_{84}Po$ has a half-life of 103 years. How long would it take for only 4.00 g to remain from an original 256 g sample?

a. 412 years
b. 4.00 years
c. 618 years
d. 309 years

$N = N_0 \cdot .5^n$

$4 = 256 \cdot .5^n$

$\frac{4}{256} = .5^n$

$\log .015625 = \log .5\ n$

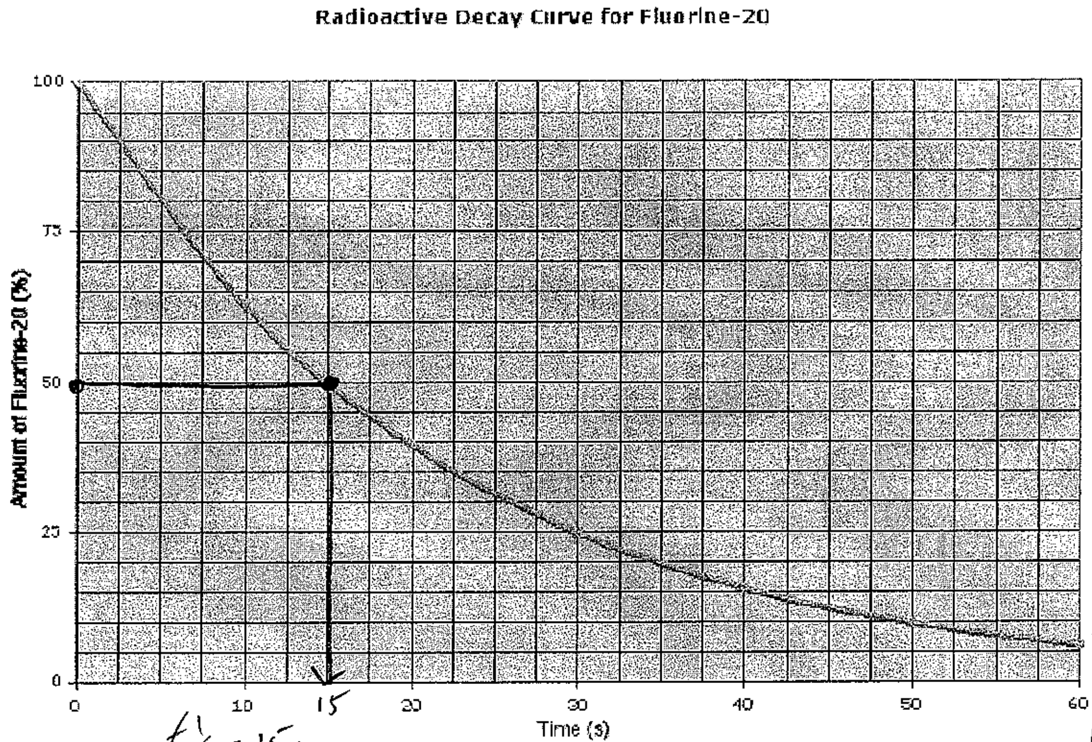
$6 = n$

$n = \frac{\text{time elapsed}}{t_{1/2}}$

$6 = \frac{\text{time}}{103}$

time = 618 a

Name: ______________________ ID: A




B 13. Based on the above graph, the time required for 17.0 g of fluorine-20 to decay to 4.25 g is

a. 37.5 s.
b. 30.0 s.
c. 22.5 s.
d. 45.0 s.

C 14. Based on the above graph, what is the time required for the sample of F-20 to go through two half-lives?

a. 15.0 s
b. 20.0 s
c. 30.0 s
d. 40.0 s

A 15. You are given a sample of a buffalo bone from the "Head-Smashed-In-Buffalo-Jump" site in southern Alberta. Using carbon-dating techniques, it is possible to estimate the age of the bone. Carbon-14 has a half-life of approximately 5700 years. If the bone sample contains an estimated 80% of the original carbon-14 amount, how old is the bone?

a. 1800 years old
b. 1100 years old
c. 13000 years old
d. 5700 years old

C 16. Complete the following fission reaction:

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{141}_{56}Ba + (3)^{1}_{0}n + ^{ab}_{cd}X$$

The values of ***ab, cd,*** and ***X*** are

a. 94, 36, and Kr.
b. 92, 36, and Rb.
c. 92, 36, and Kr.
d. 93, 36, and Rb.

Name: ____________________ ID: A

A 17. Tracks are left in either a cloud or bubble chamber by
- a. charged particles
- b. low-energy photons
- c. low-energy neutral particles
- d. high-energy neutral particles

B 18. High-energy particle accelerators are required for studying subatomic particles because
- a. primary cosmic rays are too weak
- b. nuclear forces are very strong
- c. ionization of atoms requires a lot of energy
- d. radioactive decay is too dangerous

D 19. A muon has a mass equivalent to 106 MeV/$c^2$. Determine the mass of a muon, in units of kilograms.
- a. $1.18 \times 10^{-9}$ kg
- b. $1.18 \times 10^{-15}$ kg
- c. $1.70 \times 10^{-15}$ kg
- d. $1.89 \times 10^{-28}$ kg

$E = mc^2$

$\frac{106 \times 10^6 \text{ eV}}{(3 \times 10^8)^2} = m$

$\frac{106 \times 10^6 \text{ eV} \times 1.6 \times 10^{-19} \text{ J/eV}}{9 \times 10^{16}} = m$

$1.88 \times 10^{-28} = m$

A 20. According to modern theory, a neutron is composed of smaller particles called
- a. quarks
- b. neutrinos
- c. positrons
- d. all of the above

B 21. According to the quark model, a neutron consists of quarks represented as
- a. uud
- b. udd
- c. uss
- d. cbb

u d d

$+\frac{2}{3}$ $-\frac{1}{3}$ $-\frac{1}{3}$ = $\phi$

**Numeric Response**

22. Which subatomic particle(s) will not leave tracks in a bubble chamber?

| | |
|---|---|
| 1 | proton |
| 2 | alpha particle |
| 3 | neutron |
| 4 | electron |

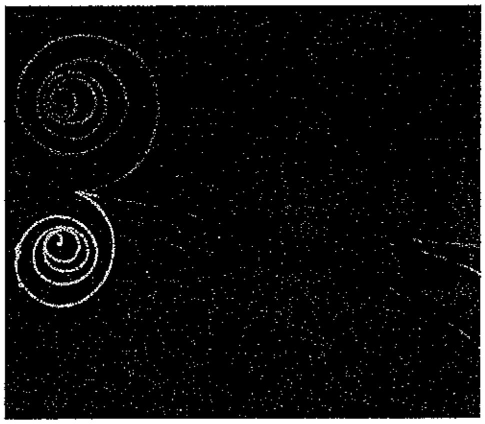
(Record all appropriate digits on the answer sheet.)

3

23. Use the following list to aid in your analysis of the particle tracks shown in the diagram.

| | |
|---|---|
| 1 | antiproton |
| 2 | alpha particle |
| 3 | positron |
| 4 | neutron |
| 5 | electron |

Identify the two most probable particles responsible for the photographed tracks in the diagram.



3, 5

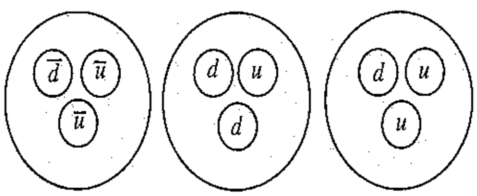
pair production

$^{0}_{0}\gamma \rightarrow {}^{0}_{-1}\beta + {}^{0}_{1}\beta$

electron positron

(Record the **two digits** of your answer on the answer sheet.)

24. Which of the following three quark diagrams represents a proton?




*1* 2 3

The proton is represented by __3__. (Record your **one-digit** answer on the answer sheet.)

u u d

$+\frac{2}{3}$ $+\frac{2}{3}$ $-\frac{1}{3}$ $= +1$

Name: ______________________ ID: A

## Essay

25. Since the onset of the nuclear era in the early 1940's, the world has been subject to regular examples of the hazards associated with radioactive material. Two of the most significant peacetime examples are the Three-Mile Island meltdown and the Chernobyl accident.

    In 1979, on Three-Mile Island, near Middletown Pennsylvania, America experienced its first nuclear meltdown. Luckily, the majority of radiation released in that meltdown is still trapped in the containment dome around the reactor. The now infamous Chernobyl accident occurred in 1986, when a nuclear reactor in the Ukraine failed dramatically.

    In Chernobyl, many thousands of people were exposed to radionuclides such as cesium-137, strontium-90, and plutonium-239 that were released from the reactor in the resulting explosion. Both cesium-137 and strontium-90 are beta decay sources with similar half-lives, 30.0 and 28.8 years respectively. Plutonium-239 is an alpha decay source with a half-life of over 24,000 years.

    Using the information provided above:

    - **Write** the decay equations for strontium-90 and plutonium-239 and **identify** the resulting nuclei.
    - **Discuss** the biological hazards associated with external and internal exposure to strontium-90.
    - **Describe** why strontium-90 posed the greatest risk to the residents of Chernobyl.
    - **Calculate** how long it will take for 99% of all the strontium-90 that was released in the Chernobyl explosion to decay.

$${}^{90}_{38}Sr \rightarrow {}^{0}_{-1}\beta + {}^{0}_{0}\bar{\nu} + {}^{90}_{39}Y$$

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

External exposure: Beta sources can penetrate through clothing and into skin to a depth of a few millimeters. This is enough to cause genetic damage as beta radiation is able to penetrate the cell and alter DNA.

Internal exposure: Beta sources can cause genetic damage as described with external exposure, but offers additional hazard due to its ionizing ability. Ionizing radiation can interfere with sensitive biochemistry and cause radiation sickness. Symptoms include nausea, vomiting, diarrhea, bleeding, and even death.

Strontium-90 is chemically similar to calcium according to the periodic table. Calcium is absorbed into bones and teeth. Strontium-90 would be absorbed into the body in a similar fashion.

$$N = N_0 \cdot .5^n$$

$$1 = 100 \cdot .5^n$$

$$\frac{1}{100} = .5^n$$

$$\log 0.01 = \log .5 \cdot n$$

$$6.6438\ldots = n$$

$$n = \frac{time}{t_{1/2}}$$

$$6.6438\ldots = \frac{time}{28.8 \text{ years}}$$

$$time = 191 \text{ years}$$