KEY

First Name:_____ Last Name:_____

L11 – Worksheet - Nuclear Physics Review — 24 marks

PART 5 – Period Table

Use the following information to answer Q1:

Selected Elements from the Periodic Table

5 B	6 C	7 N	8 O
10.81	12.01	14.01	16.00
boron	carbon	nitrogen	oxygen

Q1: Boron-11 has __*i*__ protons and __*ii*__ neutrons in its nucleus.

	i	*ii*
A.	5	5
B.	5	6
C.	6	5
D.	6	6

Q2: What is the approximate mass difference between Carbon-12 and Carbon-14?

a. 9.11×10^{-31} kg
b. 1.82×10^{-30} kg
c. 1.66×10^{-27} kg
d. 3.32×10^{-27} kg

$\sim 2u$ or $2(1.66 \times 10^{-27} kg)$

Since $1u = 1.66 \times 10^{-27} kg$

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PART 6 – Alpha, Beta, and Gamma Decay

Q3: Which type of radiation would exhibit nodes and antinodes in a modified Young's double-slit diffraction experiment?

I – Alpha Particles → Too large
II – Beta-positive particles → $p = mv$ $p = \frac{h}{\lambda}$ so $\lambda = \frac{h}{mv}$
III – Beta-negative particles →
IV – Gamma particles → EMR

a. ***I*** and ***II***
b. ***II***, ***III***, and ***IV***
c. ***III*** and ***IV***
d. ***IV*** only

Use the following information to answer Q4 and Q5:

Household smoke detectors use a sample of 0.30μg of Americium-241. This sample has an activity of 37 kBq, and decays via Alpha-decay. Americium-241 has a half-life of 432.6 years.

Q4: Which of the following statements is ***false***?

a. Alpha particles are blocked by the plastic casing. → Even paper!
b. Approximately 37,000 alpha particles are emitted per second. → 37 kBq = 37,000 Bq
c. The radioactive sample is continuously losing mass. → As it loses alpha particles.
d. None of the above.

Q5: Write the radioactive decay for Americium-241.

$^{241}_{95}Am \rightarrow {}^{4}_{2}\alpha + {}^{237}_{93}Np$

Q6: When predicting products in a radioactive decay, which two physics principles are necessary?

*(Record your **two digit** answer in the Numerical Response boxes below)*

7	8		

7 - Conservation of Charge
8 - Conservation of Nucleons

or

87

KEY

Q7: The most penetrating type of radiation is:

a. Alpha
b. Beta-negative
c. Beta-positive
d. Gamma

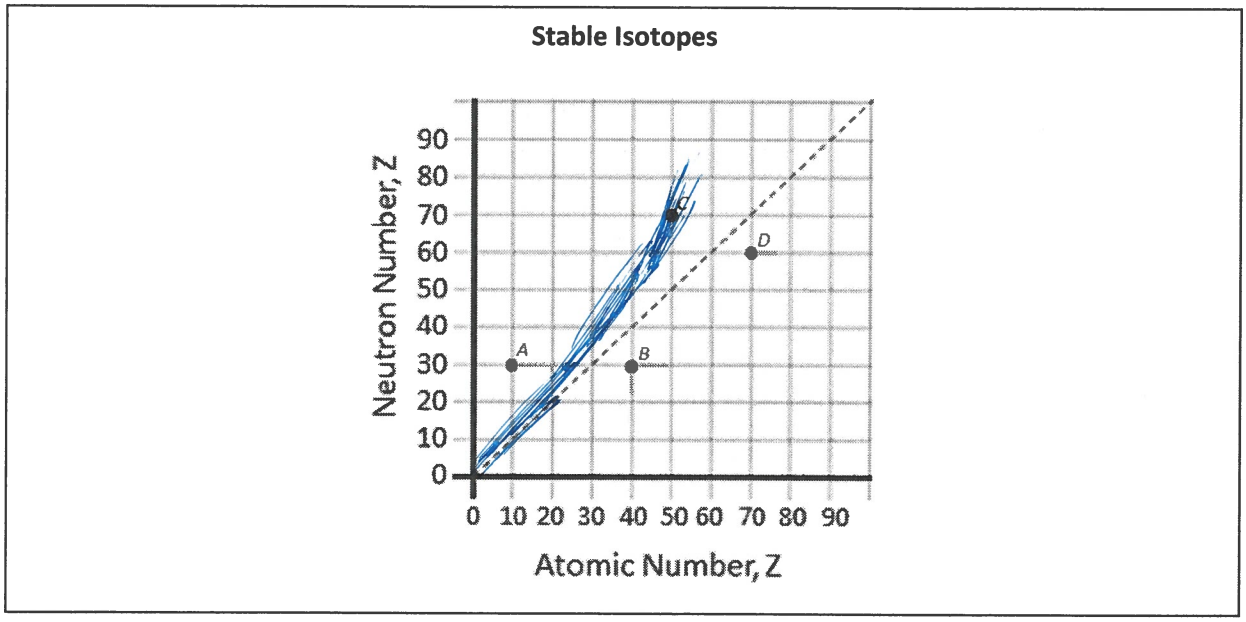
Q8: Which type of particle is emitted when an up quark changes to a down quark?

a. Alpha
b. Electron
c. Gamma
d. Positron

Proton $(+2/3, +2/3, -1/3)$ → Neutron $(+2/3, -1/3, -1/3)$ + $^{0}_{+1}\beta$ Positron (Conservation of Charge)

$uud \rightarrow udd + {}^{0}_{+1}\beta + \nu$

Use the following information to answer Q9:



Q9: Which of the following isotopes would be stable?

a. Isotope ***A***
b. Isotope ***B***
c. Isotope ***C***
d. Isotope ***D***

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Q10: When ^{59}Cu undergoes positron emission, what is the immediate nuclear product?

a. ^{59}Ni
b. ^{58}Ni
c. ^{58}Cu
d. ^{59}Zn

$$^{59}_{29}Cu \rightarrow {}^{0}_{+1}\beta + {}^{59}_{28}Ni$$

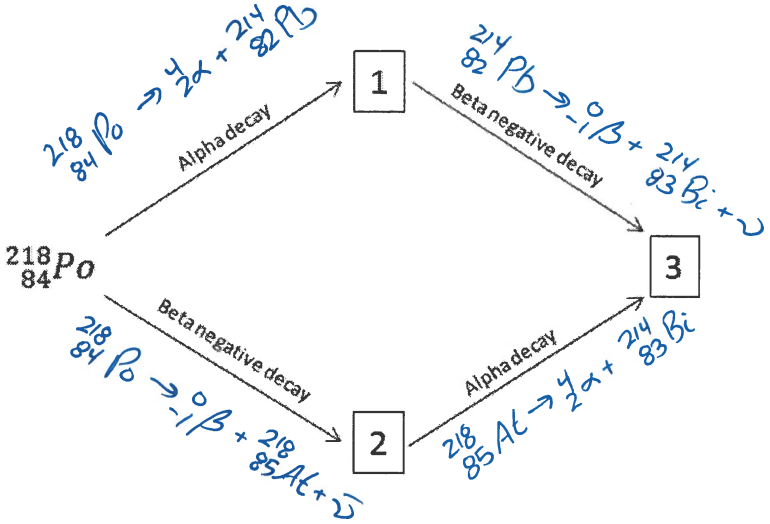
Q11: When ^{235}U is bombarded with one neutron, fission occurs and the products are three neutrons, ^{94}K, and ___.

a. ^{139}Ba
b. ^{141}Ba
c. ^{139}Ce
d. ^{139}Xe

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

Use the following information to answer Q12:

There are two possible sequences through which the unstable radioactive nucleus Polonium-218 can decay. They are shown below. The daughter nuclei are labelled 1, 2, 3, and 4.



Q12: Match each of the boxed numbers above to the daughter nucleus that it represents, below.

Number:	2	3	1
Daughter Nucleus:	^{218}At	^{214}Bi	^{214}Pb

*(Record your **three digit** answer in the Numerical Response boxes below)*

2	3	1	

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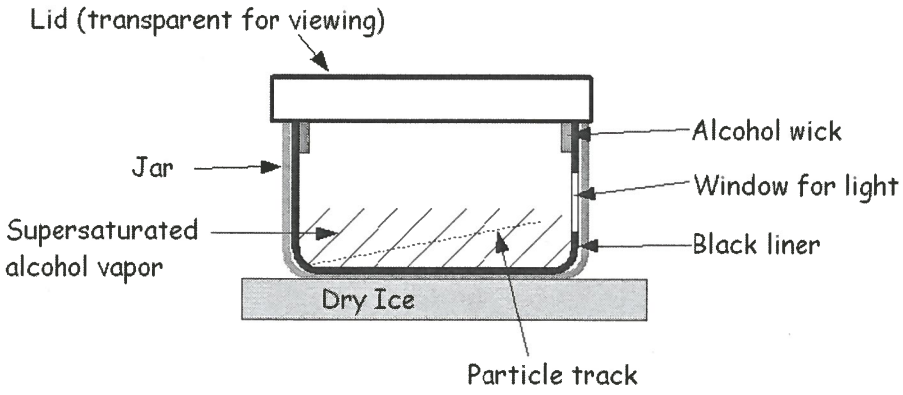
PART 7 – Radiation and Magnetic Fields, Cloud Chambers

Use the following information to answer Q13:

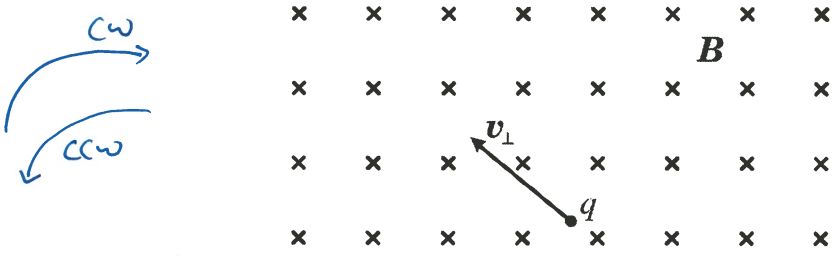
Household smoke detectors use a sample of 0.30μg of Americium-241. This sample has an activity of 37 kBq, and decays via Alpha-decay. Americium-241 has a half-life of 432.6 years.

The radioactive sample is placed in a cloud chamber, as depicted below:



When the charged alpha particle interacts with the mixture, the fluid is ionized. The resulting ions act as condensation nuclei, around which a mist will form. The high energies of alpha particles mean that a trail is left, due to many ions being produced along the path of the charged particle.

A uniform magnetic field is applied across the cloud chamber, as depicted below.



Q13: Explain how the path of the alpha particle would differ from that of Beta-negative radiation in the same cloud chamber.

Alpha Particle

Positive charge → Right Hand Rule
Rotates CCW.
Heavy, so large radius of curvature (barely deflected)

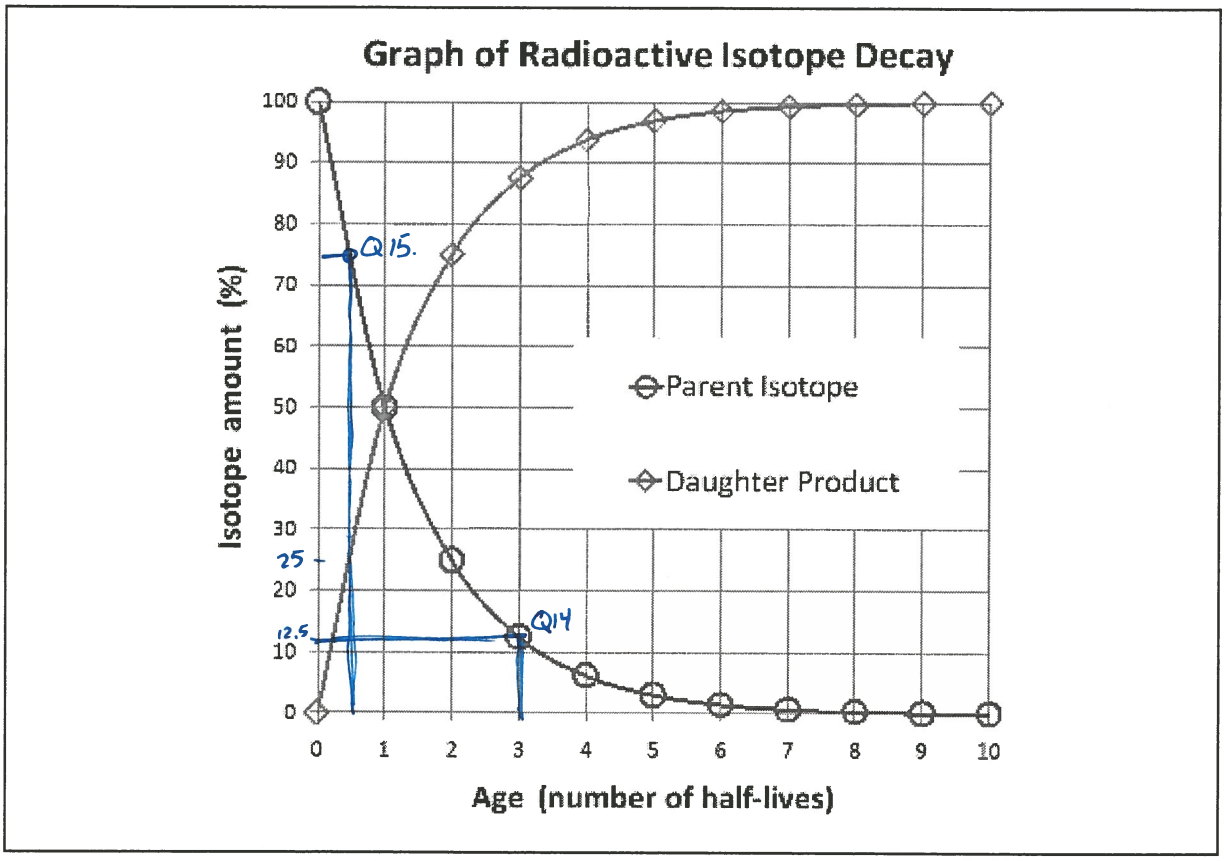
Electron

Negative charge → Left Hand Rule
Rotates CW.
Light, so easily deflected.
Small radius of curvature.

KEY

PART 8 – Half-Life Graphs

Use the following information to answer Q14:



Q14: How many half-lives would it take for only 12.5% of a radioactive isotope to remain?

a. ½
b. 1
c. 2
d. 3

Q15: Carbon-14 decays via Beta-negative decay to form Nitrogen-14. If a sample is tested and 25% of the radioactive Carbon-14 is now Nitrogen-14, approximately how many half-lives have passed?

a. ½
b. 1
c. 2
d. 3

75% of C-14 remaining.

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PART 9 – Half-Life Equations

Use the following information to answer Q16:

> Household smoke detectors use a sample of 0.30μg of Americium-241. This sample has an activity of 37 kBq, and decays via Alpha-decay. Americium-241 has a half-life of 432.6 years.

Q16: The activity of the Americium-241 after 1000 years will be ***a.bc*** x 10^{d} Bq, where ***a, b, c,*** and ***d*** are ___, ___, ___, and ___.

*(Record your **three digit** answer in the Numerical Response boxes below)*

7	4	5	3

$N = N_0 \left(\frac{1}{2}\right)^n$

$N = 37{,}000 \left(\frac{1}{2}\right)^{1000 \div 432.6}$

$N = 7453.14388873 \text{ Bq}$

$\approx 7.45 \times 10^3 \text{ Bq}$

Q17: At time zero, there are 10.0 grams of W-187. If the half-life is 23.9 hours, then after 7.0 days there will be how much remaining?

a. 0.0765 g
b. 0.628 g
c. 2.48 g
d. 4.98 g

$N = N_0 \left(\frac{1}{2}\right)^n$

$N = 10 \left(\frac{1}{2}\right)^{168 \div 23.9}$

$= 7.655 \times 10^{-2}$

$\approx 0.0765 \text{ g}$

KEY

PART 10 – Fission, Fusion, Conservation of Mass-Energy, and Matter-Antimatter Annihilation

Use the following information to answer Q18-Q20:

Mass and Energy

Particle	Atomic Mass
Proton	1.007276 u
Neutron	1.008665 u
Carbon-14	14.003241 u
Rubidium-90	89.914802 u
Strontium-89	88.907451 u
Cesium-143	142.927352 u
Uranium-235	235.043924 u

Q18: Carbon-14 has an atomic mass of 14.003241 u. The mass defect of Carbon-14 is ***a.b*** x 10^{-cd} kg, where ***a, b, c,*** and ***d*** are ___, ___, ___, and ___.

*(Record your **four digit** answer in the Numerical Response boxes below)*

1	8	2	8

$6p^+ = 6(1.007276) = 6.043656$

$8n^0 = 8(1.008665) = 8.06932$

14.112976

Diff = 0.109735 u

or 1.821601×10^{-28} kg $\approx 1.8 \times 10^{-28}$ kg

Use the additional information to answer Q19 and Q20:

The fission of Uranium-235 can occur as follows:

$$^{235}U + {}^{1}n \rightarrow 3\,{}^{1}n + {}^{143}Cs + X.$$

Q19: Predict the other product of the fission reaction.

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow 3\,{}^{1}_{0}n + {}^{143}_{55}Cs + {}^{90}_{37}Rb$$

Q20: The energy released in this process is ***a.b*** x 10^{-cd} J, where ***a, b, c,*** and ***d*** are ___, ___, ___, and ___.

*(Record your **four digit** answer in the Numerical Response boxes below)*

2	8	1	1

$^{235}_{92}U + {}^{1}_{0}n \rightarrow 3\,{}^{1}_{0}n + {}^{143}_{55}Cs + {}^{90}_{37}Rb$

$235.043924 + 1.008665 \rightarrow 3(1.008665) + 142.927352 + 89.914802$

$\Delta m = 0.18444u = 3.061704 \times 10^{-28}$ kg

$\Delta E = \Delta m c^2 = 2.7555336 \times 10^{-11}$ J

$\approx 2.8 \times 10^{-11}$ J

KEY

PART 11 – Miscellaneous Questions

Use the following information to answer Q21 and Q22:

The centers of two protons in a helium nuclear are separated by a distance of 2.30 femtometers.

Q21: The magnitude of the electrostatic repulsion between these protons is approximately ***a.bc*** x 10^{d} N, where ***a, b, c,*** and ***d*** are ___, ___, ___, and ___.

*(Record your **four digit** answer in the Numerical Response boxes below)*

4	3	5	1

$$F_e = \frac{kq_1q_2}{r^2} = \frac{(8.99\times10^{9})(1.60\times10^{-19})(1.60\times10^{-19})}{(2.30\times10^{-15})^2}$$

$$= 43.5054820416\ N$$

$$\approx 4.35\times10^{1}\ N$$

Q22: Which of the following attractive forces overcomes this electrostatic repulsion?

a. The gravitational force.
b. The strong nuclear force.
c. The weak nuclear force.
d. A combination of all three forces. → weak force is involved in Beta-decay only.

Q23: A positron has a mass number of 0, a charge of +1, and a mass equal to that of a(an) Electron

0 → No nucleons
+1 → Positive Electron

a. 0, 1+, proton
b. 1, 2+, proton
c. 0, 1+, electron
d. 1, 2+, electron

Q24: Which of the following quark configurations best describes a proton?

a. uuu
b. uud → $+\frac{2}{3} + \frac{2}{3} - \frac{1}{3} = +1$
c. udd
d. ddd

See "First Generation Fermions" on your formula sheet.