**COMET BAY COLLEGE**

**Physics - Unit 1 - Task 2**

**Nuclear Energy Test**

**Name: SOLUTIONS Total Marks /52**

**Question 1:**

There is a uniform electric field between two charged parallel plates as shown below. Three particles (α, β and γ) are ejected from A into the field parallel with the plates with similar velocities. Their paths (X, Y and Z) are shown on the diagram below. **[1 mark]**

The particles and their paths are best named as

A X = γ Y = β Z = α

B X = α Y = β Z = γ

C X = β Y = α Z = γ

D X = α Y = γ Z = β

E X = γ Y = α Z = β

F X = β Y = γ Z = α

**Question 2:**

Within a nuclear reactor, uranium-235 is bombarded by a neutron to split into two daughter products also emitting two neutrons. Part of the nuclear equation is shown below.

a) Write the nuclide for the missing daughter product labelled **X**. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ **[1 mark]**

b) What is the atomic and mass numbers of the daughter product **X**:

143

54

Mass number \_\_\_\_\_\_\_\_\_\_ **[1 mark]** Atomic number \_\_\_\_\_\_\_\_\_\_\_ **[1 mark]**

**Question 3:**

A major source of energy in the Universe is a product of fusion reactions. These include many steps and are very complex. One reaction involves the combination of four protons and two electrons to form a helium nucleus, two neutrinos and six photons. Neutrinos and photons have no mass. The overall equation for this reaction can be written as

a) Use the information listed in the table below to calculate the energy (in MeV) released from this process due to the mass defect. **[3 marks]**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Particle** | **Proton** | **Helium** | **Electron** | **Neutron** |
| Mass (u) | 1.007276 | 4.002602 | 0.000549 | 1.008665 |

Electrons entering the nucleus, so it is included.

4 × 1.007276 + 2 × 0.000549 = 4.002602 + md (1 mark)

md = 0.0276 µ

E = 0.0276 × 931

= 25.696 MeV (or24.8 MeV via the long method)

b) The major component of the Sun is , which enables fusion reactions to take place. Explain why this is important to us on Earth. **[3 marks]**

The greatest number of decays per second occur at the beginning when there is a higher amount of unstable material. (1 mark)

The weight will remain equal over the length of the experiment (1 mark)

The decayed particles have been kept in the container (could say matter has changed into energy, so is slightly lighter) (1 mark)

H is the easiest for fusion or Larger atoms = larger Sun

**Question 4:**

A radioactive isotope has a count of 3.85 x 103 decays in one hour. Calculate the activity of the source. (NOTE: 1 activity is a measure of counts per second) **[2 marks]**

activity is counts per second so

A = (1 mark)

= 1.07 Bq (1 mark)

**Question 5:**

For an atomic bomb to explode the amount of uranium-235 must reach critical mass and then the fission reaction created from a neutron induced chain reaction becomes uncontrollable. What is a neutron induced chain reaction and why does it need critical mass to explode?

**[4 marks]**

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Neutron induced chain reaction is one in which a neutron strikes the U-235 causing the nucleus to become unstable and to break up (decay) producing daughter products and an average of three neutrons. (1 mark)

These neutrons themselves strike other U-235 causing more decay and a continuation of the chain reaction. (1 mark)

Critical mass is when the mass of the U-235 is such that the neutrons from the chain reaction remain within the material causing further chain reactions. (1 mark)

With lesser masses or increased surface area of the mass, many of the neutrons escape the material and are unavailable to continue the chain reaction. (1 mark)

**Question 6:**

If the original activity of a sample is 42.0 kBq and it has a half-life of 4.00 days, how much will be left after 12.0 days? **[3 marks]**

A0 = 42.0 kBq

Half-life = 4.00 days

Time = 12 days

n = =

n = 3 (1 mark)

A = A0 (0.5)n

= 42.0 (0.5)3 (1 mark)

= 42.0 × 0.125

A = 5.25 kBq (1 mark)

**Question 7:**

Calculate the binding energy per nucleon (in MeV) of the Helium-3 atom given the mass of He-3 when using a mass spectrometer measures 5.00 x 10-27 kg. **[5 marks]**

He-3 has 2 protons and 1 neutron (total of 3 nucleons)

Calculating the mass defect of an atom

md = [2 × mp + mn] − M(He – 3)

md = [(2 × 1.67 × 10-27 + 1.67 × 10-27] − 5.00 × 10-27

md = 1 × 10-29 kg (1 mark)

Calculating the binding energy of an atom

EJ = mc2

EJ = 1 × 10-29 × (3 × 108)2

EJ = 9 × 10-13 J (1 mark)

Converting Joules to electron Volts

1 eV = 1.6 × 10-19

Hence

EeV = (1 mark)

EeV = 5.625 × 106 eV

EeV = 5.625 MeV (1 mark)

Converting to per nucleon

= 5.625 ÷ 3

= 1.875 MeV per nucleon (1 mark)

**Question 8:**

The forming of a new element during radioactive decay is called ‘transmutation’. Explain why emitting alpha and beta radiation causes a transmutation but by emitting gamma radiation does not.**[3 marks]**

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When alpha radiation is emitted, two protons and two neutrons are remove so the number of protons decreases and the atom is now a lower element on the periodic table. (1 mark)

When beta radiation is emitted, a neutron breaks down into a proton and a beta particle. The atom now has an additional proton so is now a higher element on the periodic table. (1 mark)

Gamma radiation, on the other hand, is an electromagnetic wave and a form of energy. A change in energy doesn’t affect the number of protons so the atom stays the same element. (1 mark)

**Question 9:**

When Pu-238 (atomic number 94) is bombarded with a neutron, fission occurs to form Sn-128 (atomic number 50), Ru-108 (atomic number 44) and some neutrons.

a) Complete the nuclear equation showing the number of neutrons released. **[1 mark]**

3

b) How much binding energy is released per reaction in Joules using the information on your data sheet and the information below. **[3 marks]**

* Pu-238 = 396.82 × 10-27 kg
* Sn-128 = 212.33 × 10-27 kg
* Ru-108 = 179.13 × 10-27 kg

Calculating the binding energy of an atom

mPu-238 + mn = mSn-128 + mRu-108 + 3 × mn + mbinding energy

396.82 × 10-27 + 1.68 × 10-27 = 212.33 × 10-27 +179.13 × 10-27 + 3 × 1.68 × 10-27 +mbinding energy

398.5 × 10-27 = 396.5 × 10-27 +mbinding energy (1 mark)

Hence mbinding energy =398.5 × 10-27 − 396.5 × 10-27

mbinding energy = 2 × 10-27  (1 mark)

E = mc2

= 2.00 × 10-27 × (3 × 108)2

= 1.80 × 10-10 J (1 mark)

**Question 10:**

If Am-259 (atomic number 95) is bombarded with a two neutrons, it becomes metastable and transmutates to a stable daughter element over the course of 241 years. During this process it undergoes 15 alpha decays and 15 beta decays. What is the daughter element? **[3 marks]**

(1 mark for neutron addition)

(1 mark for alpha and beta subtraction)

(1 mark for )

261 = A + 15 × 4 + 15 × 0, A = 201

95 = Z + 15 × 2 + 15 × -1, Z = 80

**Question 11:**

A radiation source and a detector can be used to measure the thickness of very thin aluminium foil during manufacture. Select, from the table, a suitable radioisotope to be used as a radiation source for this industrial process.

|  |  |  |
| --- | --- | --- |
| **Radioisotope** | **Most Useful Radiation Emitted** | Half-Life |
| Americium-241  Cesium-137  Cobalt-60  Iodine-131  Radium-223  Strontium-90 | alpha  gamma  gamma  beta  alpha  beta | 432 years  30 years  5.27 days  8.04 days  11.4 years  29 years |

Strontium-90 (½ mark for Iodine – 131)

Choice: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ **[1 mark]**

Reason for choice: **[4 marks]**

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Beta only radiation that can pass through aluminium but be affected by the thickness would be beta. (1 mark)

Alpha wouldn’t pass through any thickness (1 mark) and gamma is unaffected by thin aluminium. (1 mark)

Beta safe for humans so use one with longest half-life to reduce cost therefore use strontium-90. (1 mark)

**Question 12:**

A miner in a uranium mine is unaware that he is breathing in Radon-222 gas, an alpha emitter. The gas has a very long half life with an activity of 3.40kBq which will be unchanged during his time in the mine. Each decay of the isotope releases 3.8 x 10-12 J of energy into the body and that the radioisotope is not eliminated from the body as it settles into the tissue of his lung. After a month the gas is discovered and the mine closed (assume a month is 30 days). NOTE: 1 Bq = 1 decay

a) Calculate the total energy the miner absorbed into his lungs during this time. **[2 marks]**

energy = (activity) × (energy per decay) × (time in seconds)

= 3.4 x 103 × 3.8 × 10-12 × 30 × 24 × 60 × 60 (1 mark)

= 3.4 x 103 × 3.8 × 10-12 × 2592000

= 0.03349 J

= 0.033 J (1 mark)

b) Calculate the absorbed dose he received in one month if he has a mass of 75 kg. (If you were unable to obtain a value for (a) above use 0.035 J) **[2 marks]**

absorbed dose = (1 mark)

absorbed dose = 4.47 × 10-4 Gy or J kg-1 (1 mark)

(Alternative answer: 4.67 × 10-4 Gy)

c) Calculate the dose equivalent if the alpha radiation has a quality factor of 20. **[2 marks]**

dose equivalent = absorbed dose × 20 (1 mark)

= 4.47 × 10-4 × 20

= 8.93 × 10-3 Sv (1 mark)

(alternative answer from (b) above 9.33 × 10-3 Sv)

d) Looking at the table below, should the miner be concerned about his exposure? Explain.

**[2 marks]**

|  |  |
| --- | --- |
| **Dose Equivalent (Sv)** | **Body damage** |
| 0.25 | Reduction in white blood cell count |
| 1 | Possible nausea, vomiting. |
| 4 | Nausea, diarrhoea, drop in blood cell count. |
| 5 | Loss of hair, 50% die. |
| 10 | Severe damage to central nervous system, death within days |

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

No (1 mark)

This is a very small amount so will cause no harm (1 mark)

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**Question 13:**

Determine the half-life of the substance from the graph.

15 days

Half-life = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ **[1 mark]**

30 days

Second Half – life = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ **[1 mark]**

45 days

Third Half – life = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ **[1 mark]**

Is this graph a correct representation of a typical radioactive decay. Explain why.

**[3 marks]**

Yes (1 mark)

Line direction and curve suggest decay. (1 mark)

Half-life is 15 days and 60kBq, half-life of the first half-life is 30 days and 30kBq and third half-life is 45 days and 15kBq, which abides by the exponential equation for half-lifes. (1 mark)

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