**COMET BAY COLLEGE**

**Physics - Unit 1 – Task 2**

**Nuclear Energy Test**

**Name: SOLUTIONS Total Marks /52**

**Question 1:**

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.

**Palladium**

1. Write the element name for the missing daughter product labelled X. \_\_\_\_\_\_\_\_\_\_\_\_ (1 mark)
2. What is the atomic and mass numbers of the daughter product X:

**116**

1. Mass number \_\_\_\_\_\_\_\_\_\_ (1 mark)

**46**

1. Atomic number \_\_\_\_\_\_\_\_\_\_\_ (1 mark)

**Question 2:**

In terms of the properties of alpha and beta radiation, explain why alpha radiation cannot penetrate paper but beta radiation can. (4 marks)

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**Alpha is a positive large, heavy particle that is slow moving. (1 mark)**

**When it hits another particle, it is attracted to the negative electrons and quickly stopped as it hits the particle. (1 mark)**

**Beta is a negative electron, small size and mass which moves very fast. (1 mark)**

**Rebounds off other particles due outer negative electrons so travels further. (1 mark)**

**Or similar**

**Question 3:**

A radioactive isotope has a count of 8.85 x 103 decays per 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)**

**= 2046 Bq (1 mark)**

**Question 4:**

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)**

**Or similar**

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**Question 5:**

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 4.99 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] – 4.99 × 10-27**

**md = 2 × 10-29 kg (1 mark)**

**Calculating the binding energy of an atom**

**EJ = mc2**

**EJ = 2 × 10-29 × (3 × 108)2**

**EJ = 1.8 × 10-12 J (1 mark)**

**Converting Joules to electron Volts**

**1 eV = 1.6 × 10-19**

**Hence**

**EeV = (1 mark)**

**EeV = 1.125 × 107 eV**

**EeV = 11.25 MeV (1 mark)**

**Converting to per nucleon**

**EeV = 11.25 ÷ 3**

**= 3.75 MeV per nucleon (1 mark)**

**Question 6:**

A pure sample of radioactive gold is known to have a count of 42.0 kBq, however it also has a half-life occurring every 3 days. The sample analysed in the laboratory has a reading of 2.5 kBq. How many days has the sample being sitting there before being analysed, assuming it was initially pure? (5 marks)

**A0 = 42.0 kBq**

**A = 2.5 kBq**

**Half-life = 3.00 days**

**A = A0 (0.5)n**

**2.5 = 42.0 (0.5)n (1 mark)**

**= (1 mark rearranging)**

**16.8 = 2n**

**log 16.8 = n log 2 (1 mark logs or trial and error)**

**n = 4.07 half lifes (1 mark)**

**days = 3 x 4.07 = 12.2 days (1 mark)**

**days = 3 x 5 = 15 days (also accepted, since half-life is not exact)**

**trial and error method also accepted**

**Question 7:**

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)**

1. Choice: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (1 mark)
2. 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)**

**Or similar**

**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)

**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)**

**Or similar**

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**Question 9:**

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

**15 days**

1. Half-life = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (1 mark)

**30 days**

1. Second Half – life = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (1 mark)

**45 days**

1. Third Half – life = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (1 mark)
2. 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)**

**Or similar**

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

**Question 10:**

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 3.40 kBq 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

1. 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)**

1. 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)**

1. Calculate the dose equivalent of the alpha radiation. (2 marks)

**dose equivalent = absorbed dose × quality factor**

**= 4.47 × 10-4 × 20 (1 mark)**

**= 8.93 × 10-3 Sv (1 mark)**

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

1. 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 |

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**No (1 mark)**

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

**Question 11:**

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.

1. Complete the nuclear equation showing the number of neutrons released. (1 mark)

3

1. How much binding energy is released per reaction in Joules using the information on your data sheet and the information below? (6 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**

**(1 mark) (1 mark)**

**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 mark)**

**= 1.80 × 10-10 J (1 mark)**