Cecil Andrews College

Year 11 Physics 2023

Nuclear Physics Test

Time: 1 Hour

Formula sheet supplied.

Mark: /45

Instructions:

1. Calculations must show clear working out, and answers much be given to three significant figures
2. Marks will be allocated for clear and logical setting out
3. Underline your answer
4. State assumptions for open ended questions

1. During a fission reaction, uranium-235 is bombarded by a neutron, then splits into two fission products and emits three neutron. Part of the nuclear equation is shown below.

1. What are the atomic and mass numbers of the fission product, X?

Atomic number: \_\_\_\_\_\_\_\_\_ Mass number: \_\_\_\_\_\_\_\_\_\_ (2 marks)

1. Write the element symbol for the missing fission product, labelled X

Element: \_\_\_\_\_\_\_\_ (1 mark)

2. In terms of the properties of alpha and beta radiation, explain why alpha radiation cannot penetrate paper, but beta radiation can. (2 marks)

|  |
| --- |
|  |
|  |
|  |
|  |
|  |

3. A new element with a nucleus containing 104 protons and 109 neutrons has been discovered. It has been named Rutherfordium and given the elemental symbol Rf.

a. Complete the atomic formula for Rutherfordium in the form : \_\_\_\_\_\_\_\_\_\_\_\_

(1 mark)

b. Two isotopes of Rutherfordium have been observed. State **one** similarity and **one** difference of the nucleus for the two isotopes. (2 marks)

Similarity:

|  |
| --- |
|  |

Difference:

|  |
| --- |
|  |

4. In an experiment to find the range of -particles in air, the apparatus shown below was used.

Diagram

Description automatically generated

The results of this experiment were shown below.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Count rate**  **Counts/min** | 681 | 562 | 441 | 382 | 317 | 20 | 19 | 21 | 19 |
| **Distance from source to detector**  **(cm)** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

a. State what causes the count rate 9 cm from the source. (1 mark)

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

b. Estimate the count rate that is due to the source at a distance of 2 cm. (2 marks)

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

c. Suggest a value for the maximum distance that -particles can travel from the source. Justify your answer. (2 marks)

|  |
| --- |
|  |

5. A radioactive Isotope has a count of decays in one hour. Calculate the activity of the source in Bq. Note that 1 Bq = 1 decay per second. (2 marks)

6. a. Describe what is meant by the “binding energy” of a nucleus. (2 marks)

|  |
| --- |
|  |
|  |
|  |

b. What is the relationship between the binding energy per nucleon (B/A) of a nucleus and the stability of a nucleus? (2 marks)

|  |
| --- |
|  |

c. Use the graph below to approximately determine the mass number, A, of the most stable element. (1 mark)

Graphical user interface, application, table

Description automatically generated

d. Why do some nuclei undergo radioactive decay? (1 mark)

|  |
| --- |
|  |
|  |

7. If the original activity of a radioactive sample is 60.0 kBq and it has a half-life of 4.00 days, what will be the theoretical activity after 16.0 days? Show all working to arrive at your answer. (3 marks)

|  |  |  |
| --- | --- | --- |
| **Radioisotope** | **Most useful radiation emitted** | **Half-life** |
| Americium-241 | Alpha | 432 years |
| Cesium-137 | Gamma | 30 years |
| Cobalt-60 | Gamma | 5.27 days |
| Iodine-131 | Beta | 8.04 days |
| Radium-223 | Alpha | 11.4 years |
| Strontium-90 | beta | 29 years |

8. A radiation source and a detector can be used to measure the thickness of very thin aluminium foil during the manufacturing process. Select from the table below **the most suitable** radioisotope to be used as a radiation source.

Choice: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (1 mark)

State two reasons for your choice of isotope. (2 marks)

|  |
| --- |
|  |
|  |
|  |
|  |

9. When a plant or animal dies it stops taking in carbon-14 and radioactive decay begins to decrease the amount of carbon-14 in the tissues. The age of the deceased organism can then be predicted by measuring the activity of carbon-14 left in the remnants.

A 40 g sample of carbon from a skeleton has a carbon-14 decay rate of 160 decays per minute. Considering the activity of carbon-14 in a living organism is 16.0 decays minute-1 g-1 and the half-life of carbon-14 is 5730 years, what is the approximate age of the skeleton?

(3 marks)

10. A miner works in a uranium mine is unaware that he is breathing in radon-222 gas, which unfortunately is an alpha-emitter. The gas has a very long half-life with an activity of 3.70 kBq, which will be unchanged during his time in the mine. Each decay of the isotope releases J of energy into the body and the radioisotope is not eliminated from the body, as it will settle into the tissue of his lungs. After a month, the dangerous radon gas is detected and the mine closed (assume one month is 30 days and the workday is 8 hours).

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

b. Calculate the absorbed does he received in one month if he has a mass of 78 kg and the actual energy absorbed by the tissue is 0.0983 J. (2 marks)

c. Calculate the dose equivalent if the alpha radiation has a weight factor of 20. (2 marks)

d. Should the miner be concerned about his exposure? Explain. (2 marks)

|  |
| --- |
|  |
|  |
|  |
|  |
|  |
|  |
|  |

11. a. Determine the half-life of a radioactive sample from the graph below.

Chart, line chart

Description automatically generated

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

b. Use the graph to determine when the activity is 40 kBq.

Time = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (1 mark)

12. Boron undergoes fission via thermal neutron capture to produce lithium-7, an alpha particle and energy in the reaction

Using the data below, calculate the mass defect (in u and kg) and the binding energy (in J and MeV) for this reaction. (6 marks)

|  |  |
| --- | --- |
| Mass of a neutral boron atom | 10.012 939 u |
| Mass of a neutral lithium-7 atom | 7.016 005 u |
| Mass of a neutral Helium atom | 4.002 603 u |
| Mass of a neutron | 1.008 665 u |

|  |  |  |
| --- | --- | --- |
| Mass defect |  | u |
| Mass defect |  | kg |
| Binding energy |  | J |
| Binding energy |  | MeV |