WILLETTON SENIOR HIGH SCHOOL

Year 11 Physics – 2019

Nuclear Physics Test

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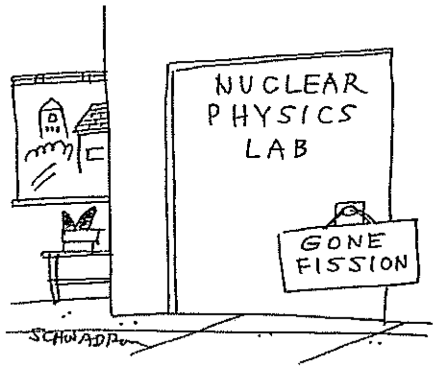
CORRECTION

Q11.b. ~~ACTIVITY~~ TIME ✓



Student name:

–MASTER–

Teacher: (Please tick one box)

Mr Boughton ☐

Mr Dopson ☐ Group 1

☐ Group 2

Mrs Munshi ☐

Dr Pitts ☐

TIME: **1 Hour**

Data sheet supplied

−½ FOR INC. UNITS

−½ FOR INC. S.FIG.

– TO MAX OF 2 MARKS.

NOTE:

1. Calculations must show clear working with answers stated to an **appropriate number of significant figures.**
2. Marks will be allocated for clear and logical setting out.
3. To help identify your answer, <u>underline</u> each answer.
4. State **assumptions** if working on open ended type questions.

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

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow X + ^{141}_{56}Ba + 3^{1}_{0}n$$

a. What are the atomic and mass numbers of the fission product **X**?

Atomic number 36 Mass number 92 (2 marks)

b. Write the element symbol for the missing fission product labelled **X**.

Kr (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)

- α ALPHA HAS A +2 CHARGE AND THUS IT IS HIGHLY IONISING AND REACTS / INTERACTS WITH A LARGE NUMBER OF SURROUNDING ATOMS
- β BETA HAS A −1 CHARGE AND TRANSFERS LESS ENERGY TO SURROUNDING ATOMS.

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 $^{A}_{Z}Rf$ $^{213}_{104}Rf$

(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:

SAME NUMBER OF PROTONS

Difference:

DIFFERENT NUMBER OF NEUTRONS

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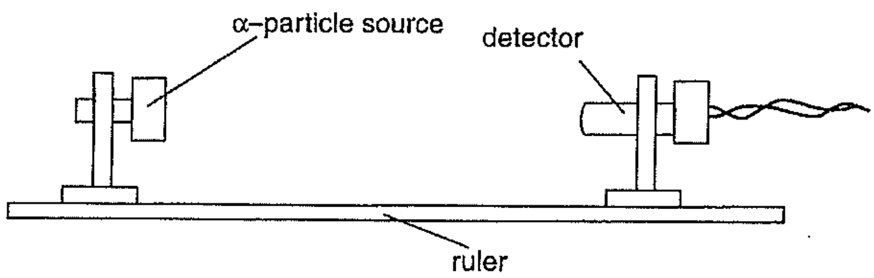
4. In an experiment to find the range of α-particles in air, the apparatus shown below was used.



The results of this experiment are 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)

BACKGROUND RADIATION

b) Estimate the count rate that is due to the source at a distance of 2 cm. (1 mark)

541 – 543 COUNTS/MIN

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

- 5 – 6cm
- THE COUNT RATE DROPS SIGNIFICANTLY BETWEEN 5 – 6 cm FROM THE SOURCE.

5. A radioactive isotope has a count of 3.85×10^3 decays in one hour. Calculate the activity of the source in Bq. (2 marks)

$$\text{ACTIVITY (Bq)} = \frac{3.85 \times 10^{3}}{60 \times 60} \; ①$$

$$= \cancel{10.694}$$

$$= \cancel{10.7\ \text{Bq}} \; ①$$

$$= 1.0694$$

$$= 1.07\ \text{Bq}$$

6. a. Define what is meant by the "binding energy" of a nucleus. (2 marks)

THE AMOUNT OF ENERGY REQUIRED TO BREAK APART THE NUCLEUS

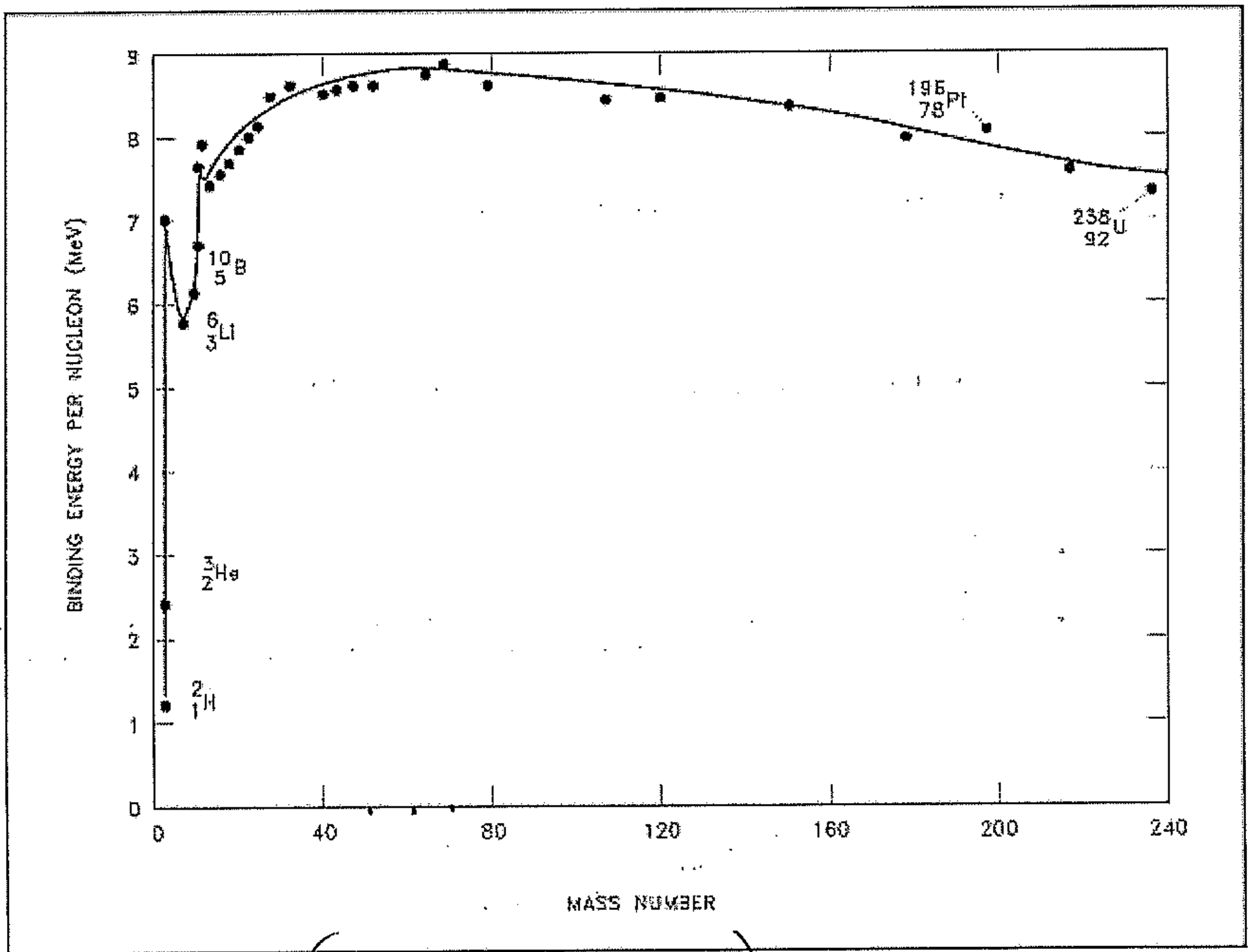
b. What is the relationship between the binding energy per nucleon of a nucleus and the stability of a nucleus? (2 marks)

HIGH B.E/NUCLEON $\propto$ STABILITY

i.e HIGH B.E/NUCLEON $\Rightarrow$ HIGH NUCLEAR STABILITY.

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

55 – 75



(COULOMBIC FORCE)

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

THE ELECTROSTATIC REPULSION BETWEEN PROTONS IS GREATER THAN THE SHORT RANGE ATTRACTIVE FORCE BETWEEN NUCLEONS.

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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)

$n = \frac{t}{t_{1/2}} = \frac{16}{4} = 4$ ① Now $A = A_0 \left(\frac{1}{2}\right)^n$

$= 60 \times (0.5)^4$ ①

$= \underline{3.75}$ kBq ①

or $60 \xrightarrow{①} 30 \xrightarrow{②} 15 \xrightarrow{③} 7.5 \xrightarrow{④} \underline{3.75}$ kBq ③

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.

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 ✓

Choice: Sr-90 (1 mark)

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

- β CAN PENETRATE THE FOIL AND THE ACTIVITY PASSING THROUGH IS SENSITIVE TO CHANGE IN THICKN
- A 29 YEAR HALF LIFE IS GOOD AS THE ACTIVITY IS HIGH OVER A LONG PERIOD OF TIME AND THE SOURCE DOES NOT HAVE TO BE CHANGED FREQUENTLY.

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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 40.0 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)

LIVING 16 d/m/g

DEAD $\frac{160}{40} \Rightarrow 4$ d/m/g (1)

$16 \xrightarrow{1} 8 \xrightarrow{2} 4 = 2$ H.L (1)

AGE $\approx 2 \times 5730$

$= 11,460$ YR

$= 1.146 \times 10^4$

$= 1.15 \times 10^4$ YRS (1)

OR

$A = A_o e^{-kt}$

$k = \frac{\ln 2}{H.L} = \frac{\ln 2}{5730} = 0.000120968$ (1)

$4 = 16 e^{-0.000120968 t}$ (1)

$\ln 0.25 = -0.000120968 t$

$\therefore t = \frac{-1.386294}{-0.000120968}$

$= 11,460$ YRS

$= 1.15 \times 10^4$ YRS (1)

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 3.70kBq, which will be unchanged during his time in the mine. Each decay of the isotope releases 3.40×10^{-12} 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 is 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)

$E_{TOT} = 30 \times 8 \times 3600 \times 3.40 \times 10^{-12} \times 3.7 \times 10^3$ (1)

$= 0.01086912$

$= 1.09 \times 10^{-2}$ J (1)

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b. Calculate the absorbed dose he received in one month if he has a mass of 78.0 kg and the actual energy absorbed by the tissue is 0.0983 J

(2 marks)

$$A.D = \frac{E}{m}$$

$$= \frac{9.83 \times 10^{-2}}{78} \quad 1$$

$$= 1.2602 \times 10^{-3}$$

$$= \underline{1.26} \times 10^{-3} \text{ Gy or } \underline{1.26 \text{ mGy}}$$

$$\text{J kg}^{-1} \quad 1$$

c. Calculate the dose equivalent if the alpha radiation has a quality factor of 20.

(2 marks)

$$D.E = A.D \times QF$$

$$= 1.2602 \times 10^{-3} \times 20 \quad 1$$

$$= 2.5204 \times 10^{-2}$$

$$= \underline{2.52} \times 10^{-2} \text{ Sv} \quad 1$$

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

YES. ½

½

THE ALPHA SOURCE IS HIGHLY IONISING

½

AND IT REMAINS TRAPPED IN THE BODY

½

FOR A VERY LONG PERIOD OF TIME (LONG EXPOSURE).

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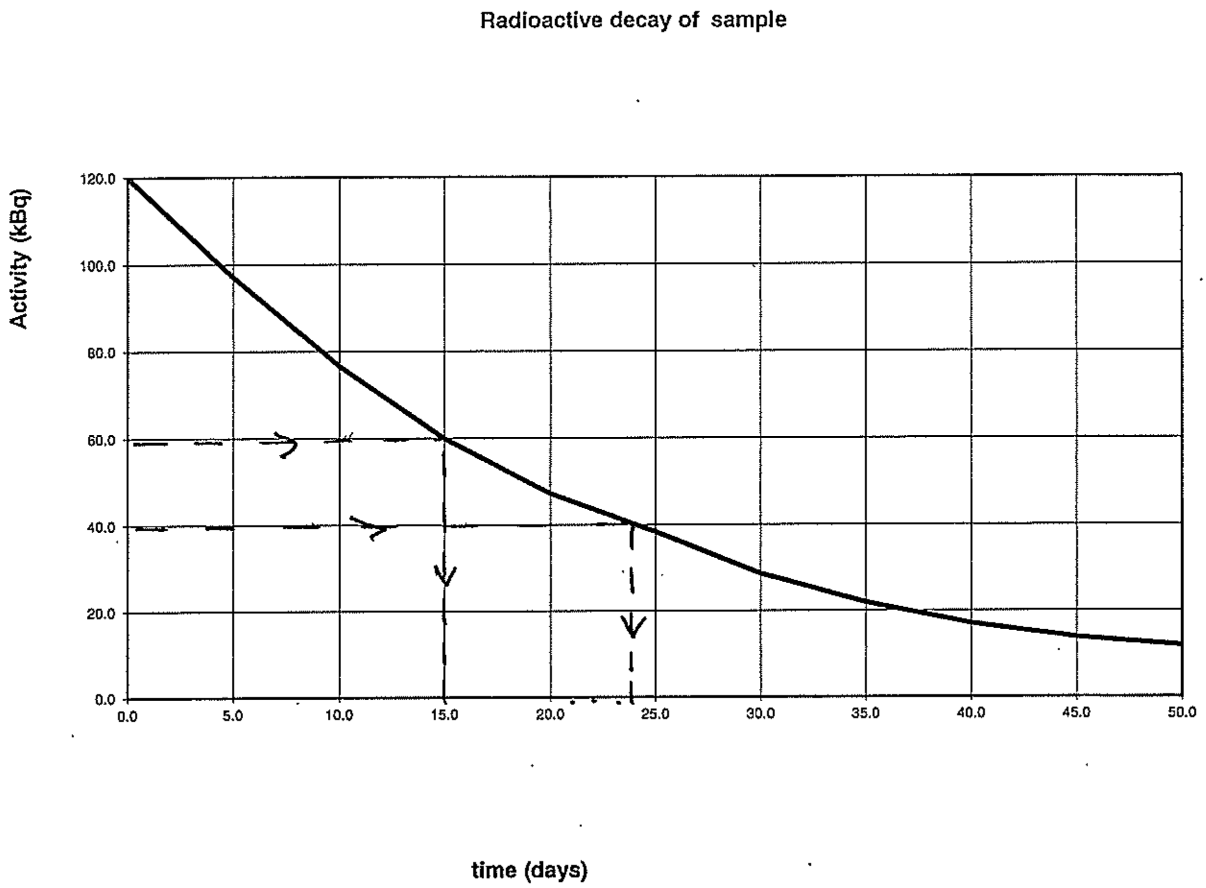
11. a. Determine the half-life of a radioactive sample from the graph below.



Half-life = 15 DAYS ~~(-½) IF NO CONSTRUCTION LINES~~ (1 mark)

b. Use the graph to determine the time when the activity is 40.0 kBq.
Show construction lines on the graph.

~~Activity~~ TIME = 23 – 24 DAYS. (-½) IF NO CONSTRUCTION LINES. ✓ (1 mark)

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12. Boron undergoes fission via thermal neutron capture to produce lithium-7, an alpha particle and energy in the reaction (6 marks)

$$\underbrace{{}^{1}_{0}n + {}^{10}_{5}B}_{m_r} \rightarrow \underbrace{{}^{7}_{3}Li + {}^{4}_{2}He}_{m_p}$$

KEY POINTS
- (−1) FOR EACH MAJOR ERROR
- (−1) IF CARRYING OUT A ROUNDED SUB TOTAL.

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

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-4 atom	4.002 603 u
Mass of a neutron	1.008 665 u

FOR MASS REACTANTS

$m_r = 1(1.008665) + 10.012939$
$= 11.021604u$ (½)

FOR MASS PRODUCTS

$m_p = 7.016005 + 4.002603$
$= 11.018608u$ (½)

FOR MASS DEFECT (u)

$\Delta m = m_r - m_p$
$= 11.021604 - 11.018608$
$= 0.002996u$ (1)
$(2.996 \times 10^{-3} u)$
$= 3.00 \times 10^{-3} u$

MASS DEFECT (kg)

$0.002996 \times 1.66 \times 10^{-27}$
$= 4.97336 \times 10^{-30}$ kg
$= 4.97 \times 10^{-30}$ kg

B.E (MeV)

$0.002996u \times 931 = 2.789276$
$= 2.79$ MeV

B.E (J)

MeV ⇒ J OR $E = mc^2$

$2.789276 \times 1.6 \times 10^{-13}$
$= 4.4628 \times 10^{-13}$
$= 4.46 \times 10^{-13}$ J

⇒ $4.97336 \times 10^{-3} \times (3 \times 10^{8})$
$= 4.476 \times 10^{-13}$
$= 4.48 \times 10^{-13}$ J

ACCEPT EITHER

Mass defect	0.002996 (3.00×10^{-3})	u (1)
Mass defect	4.97×10^{-30}	kg (1)
Binding energy	$4.46 - 4.48 \times 10^{-13}$	J (1)
Binding energy	2.79 − 2.80	MeV (1)