Physics ATAR - Year 11

Nuclear Physics Unit Test 2019

Mark: / 53

= %

Name: SOLUTIONS

Time Allowed: 50 minutes

Notes to Students:

- You must include **all** working to be awarded full marks for a question.
- Marks will be deducted for incorrect or absent units and answers stated to an incorrect number of significant figures.
- **No** graphics calculators are permitted – scientific calculators only.

Question 1 **(6 marks)**

Complete the following nuclear equations.

(a) $^{22}_{11}Na \rightarrow ^{22}_{10}Ne + \boxed{^{0}_{1}\beta^{+}} + \boxed{^{0}_{0}\upsilon}$

(1 mark)

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

(1 mark)

(c) $\boxed{^{10}_{6}C} \rightarrow ^{10}_{5}B + ^{0}_{1}\beta^{+} + \upsilon$

(1 mark)

(d) $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{91}_{36}Kr + ^{142}_{56}Ba + \boxed{3(^{1}_{0}n)}$

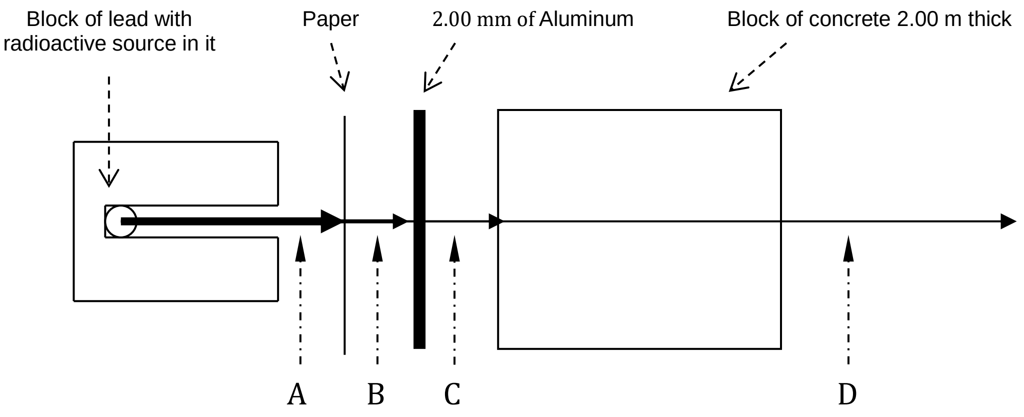
(2 marks)

(e) $\boxed{^{131m}_{54}Xe} \rightarrow ^{131}_{54}Xe + ^{0}_{0}\gamma$

(1 mark)

Question 2 **(6 marks)**

A mixture of alpha(α), beta (β), gamma (γ), and radiation are directed at close range in a vacuum towards the barriers shown in the below diagram.



(a) What type**s** of radiation are present at points A, B, C, and D?

(4 marks)

A $\alpha\ \beta\ \gamma$

B $\beta\ \gamma$

C γ

D none

(b) Justify your answer to point C.

(2 marks)

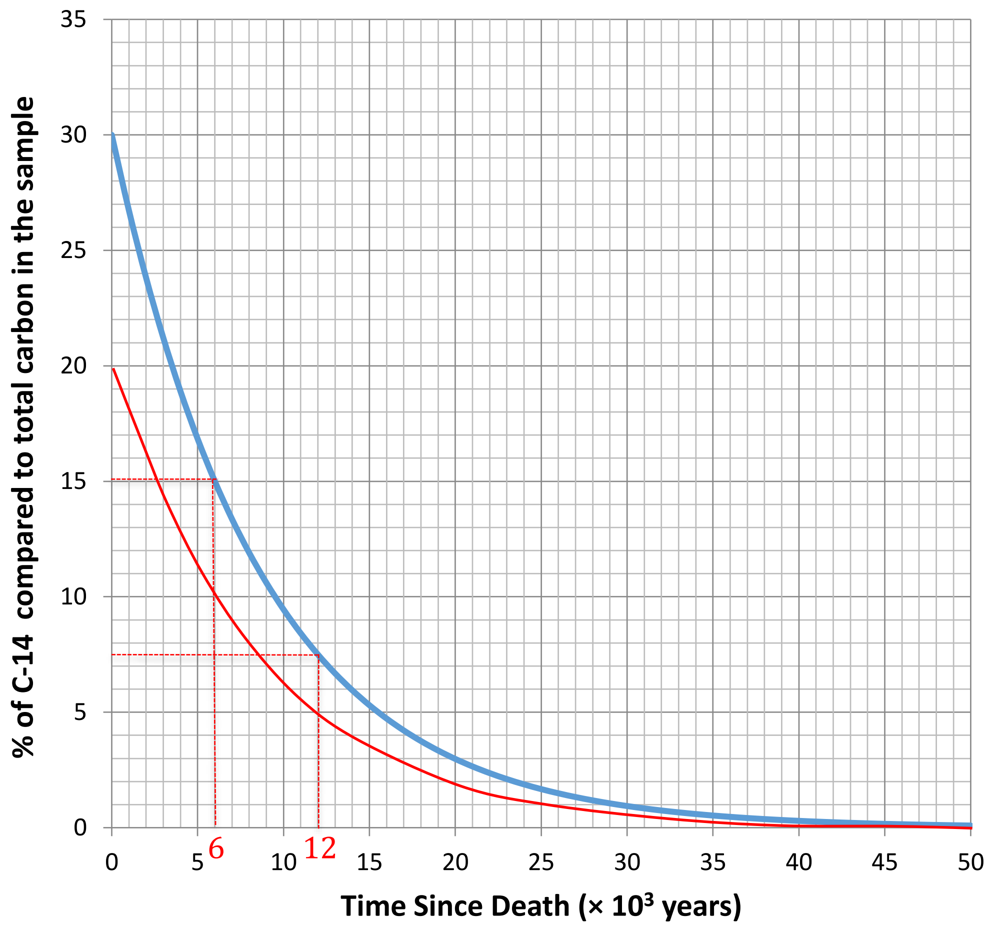
- Paper has captured α and aluminium would have captured β
- Meaning only γ would be detected at point C

Question 3 **(11 marks)**

Radio carbon dating is a useful technique for establishing the date of death of organic matter. Two pieces of information are required;

- the half-life of carbon-14
- the ratio of carbon-14 to non-radioactive forms of carbon the organic matter contained while it was alive.

The fraction of carbon-14 compared to total carbon for a sample as a function of time is shown below.



(a) State the percentage of carbon in this organic matter that was not radioactive while the organism was alive.

(1 marks)

70%

(b) Determine the half-life of carbon-14 as indicated by the graph. Show evidence of how you determined your answer on the graph.

(2 marks)

- Working on graph shown
- $t_{1/2} = 6.0 \times 10^3$ years

(c) Determine, by use of a calculation, the number of half-lives of carbon-14 has undergone in the sample after 12,000 years. (If you could not complete (b), use $t_{1/2}$ = 3,000 years)

(2 marks)

$n = t / t_{1/2}$ ½

= 12000 / 6000 ½

= 2 1

n = 4 (if use $t_{1/2}$ = 3,000 years)

(d) The graph scale reveals the percentage of carbon-14 becomes negligible at 40 thousand years since time of death. Determine, by use of a calculation, what the likely percentage of carbon-14 is after 40 thousand years has passed. (If you could not complete (b), use $t_{1/2}$ = 3,000 years)

(4 marks)

$n = t / t_{1/2}$ ½

= 40,000 / 6000 ½

= 6.67 1

$A = A_0(1/2)^n$ ½

$= 30\%(1/2)^{6.67}$ ½

= 0.295 % 1

n = 13.3

A = 0.00297%
(if use $t_{1/2}$ = 3,000 years)

(e) On the graph, sketch the curve showing the percentage of carbon-14 for a sample that had 20% carbon-14 prior to its death.

(2 marks)

1 mark for A_0 starting at 20
1 mark for Activity at 2/3 of original curve at key points (t = 6, 12, 20 years)

Question 4 **(9 marks)**

The nuclear fission of uranium-235 within nuclear fuel rods has a range of possible products. While the average mass of a fission fragment is 118, it is unlikely to find fragments of this mass since the uranium nucleus usually splits unevenly. The most common fission result is barium-137 and krypton-95 in addition to some neutrons. The mass of reactants and products of this common reaction are found in the table.

Particle	Mass (u)
Uranium-235	235.043930
Barium-137	136.905827
Krypton-95	94.939844
Neutron	1.008665

(a) Write the nuclear reaction showing the most commonly occurring fission of uranium-235. (3 marks)

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{95}_{36}Kr + ^{137}_{56}Ba + 4^{1}_{0}n$$

-1 mark per error
arithmetic
name of particle
expression of 4 neutrons

(b) Calculate the mass defect of this fission reaction. (2 marks)

m.d. = m(U-235) + m(n) - [m(Ba-137) + m(Kr-95) + 4 x m(n)]

= 235.043930 + 1.008665 – [136.905827 + 94.939844 + 4x 1.008665] (1)

= 0.172264 u (6.d.p) (1)

(c) Calculate the energy released by a single fission event in joules. (3 marks)

E = m.d. x 931

= 0.172264 x 931

= 160 MeV (1) x 1.60×10^{-13} (½) = 2.56×10^{-11} J (3.s.f) (1)

(d) State the form that this energy is released as. (1 mark)

Kinetic Energy

Question 5 **(5 marks)**

The aluminum - 27 atom has an atomic mass of 26.981538 u. Calculate the binding energy per nucleon of the aluminum - 27 atom in eV.

Name	Mass of atom (u)
Proton	1.007 276
Neutron	1.008 665
Electron	0.000 548 58
Hydrogen	1.007 825

m.d. $= 13 \times m(^1_1H) + 14 \times m(n) - m(\text{Al-27})$

$= 13 \times (1.007825) + 14 \times (1.008665) - 26.981538$ (1)

$= 0.241497$ u (6.d.p) (1)

BE = m.d. x 931 (1)

= 0.241497 x 931 (½)

= 225 MeV (½)

BE/nuc = 225 / 27

= 8.33 MeV/nucleon (1)

Question 6 **(16 marks)**

Organic items imported into Australia can be bombarded with ionising radiation at customs if there is a risk of foreign flora or fauna being brought unintentionally. Consider a large wooden statue similar to the one shown.

(a) State and explain which form of ionising radiation would be most suited to destroying any organic material contained in the statue.

(3 marks)

- gamma radiation
- has the highest penetrating ability of all ionising radiation
- and would be able to penetrate the entire statue.

A 3.50 kg statue receives a full-body exposure of ionizing radiation with a Quality Factor of x1.50 and an activity of 12.4 TBq for a time of 15.0 minutes.

(b) Assuming that 24.0% of the radiation is absorbed by the statue, calculate the number of ionizing particles absorbed by the statue in this time.

(3 marks)

n = Rate x time x 0.24 (1)

= 12.4 $x10^{12}$ x (15x60) x 0.24 (1)

= 2.68 $x10^{15}$ particles. (1)

Each ionising particle imparts 5.40 $x10^{5}$ eV to the molecules in the statue

(c) Calculate the energy in Joules that the molecule receives per ionizing particle.

(2 marks)

E (J) = E(eV) x 1.60 $x10^{-19}$

= 5.40$x10^{5}$ x 1.60 $x10^{-19}$ (1)

= 8.64 $x10^{-14}$ J (1)

(d) Calculate the absorbed dose and dose equivalent for the wooden statue. (If you could not complete (b) use n = 1.00 $x10^{15}$)

(4 marks)

A.D. = $\frac{Energy}{mass}$ (½)

= $\frac{8.64\times10^{-14}(2.68\times10^{15})}{3.50}$ (½)

= 66.2 Gy (1)

D.E. = A.D. x Q.F (½)

= 66.2 x 1.50 (½)

= 99.3 Sv (1)

If n = 1.00 $x10^{15}$ used A.D = 24.7 Gy, D.E. 37.0 Sv

(e) State and explain two precautions that workers at customs would employ to prevent any unwanted personal health issues.

(4 marks)

1.
- shielding from device.
- Gamma rays require ~2m of concrete or many cm of lead to absorb the ionising radiation and prevent the workers from receiving an absorbed dose.

2.
- Distance
- Workers would distance themselves from the device when in operation as the intensity is inversely proportional to distance squared

3.
- Time
- Energy absorbed is proportional to the time of exposure, workers should not be present for long while the device is operating.

4.
- Use Radiation monitoring device (dose badge or Geiger counte)
- So employees can be aware of a radioactivity.

END OF TEST