Physics ATAR - Year 11

Nuclear Physics Unit Test 2018

Mark: /58

= %

Teachers Initials:________

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 **(4 marks)**

The following isotopes are used extensively for various medical purposes.

(a) State the chemical symbol for element 43.

Tc

(b) State the number of neutrons in Co-58.

58 - 27 = 31

(c) State the mass number of the element that results from beta negative decay of I-131.

$^{131}_{53}I \rightarrow {}^{131}_{54}Xe + {}^{0}_{-1}\beta + \bar{v}$ Beta negative decay does not affect mass number so 131

(d) State the nuclide formed from neutron capture by boron-10.

$^{10}_{4}B + {}^{1}_{0}n \rightarrow {}^{11}_{4}B$ so Boron-11

Question 2 **(7 marks)**

An Hg-196 nucleus is bombarded by a neutron producing Au-195 and an unknown product particle.

(a) Determine **and name** the unknown product particle by writing the nuclear equation. (3 marks)

$^{196}_{80}Hg + {}^{1}_{0}n \rightarrow {}^{195}_{79}Au + {}^{2}_{1}H$ so Deuterium

(b) Determine the half-life of gold-195 if it takes 9.30 x 10^2 days for 1.60 x 10^{-4} g of gold-195 to decay to 2.50 x10^{-6} g. (4 marks)

$$\frac{A}{A_0} = \frac{2.50 \times 10^{-6}}{1.60 \times 10^{-4}} = \frac{1}{64} = \frac{1}{2^6}$$

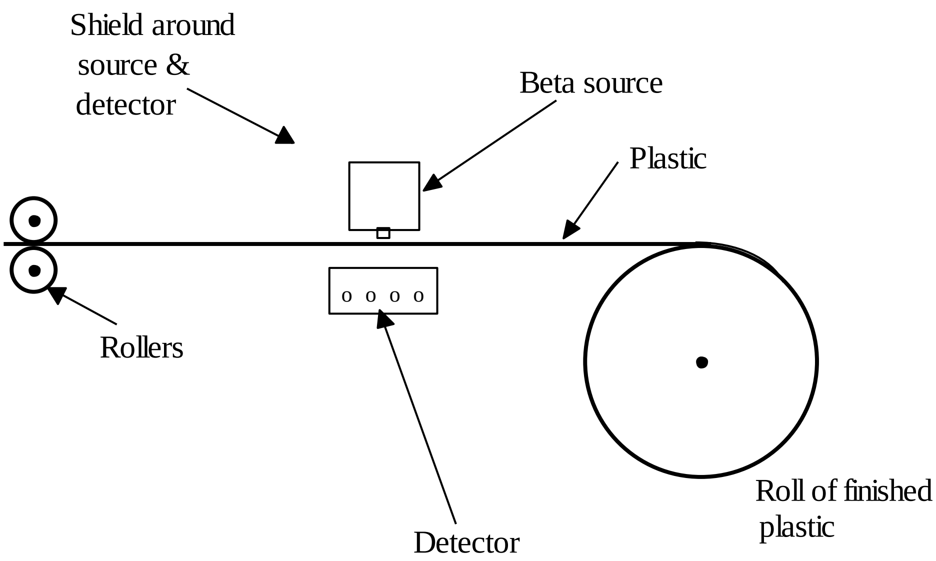
n = 6

$$t_{1/2} = \frac{t}{n} = \frac{930}{6}$$

$$t_{1/2} = 155 \; days$$

Question 3 **(10 marks)**

In a factory that manufactures plastic the thickness of the plastic is monitored by a thickness recorder. The plastic passes between a **beta negative** particle source and a detector as shown in the diagram below. When the roller maintains an ideal pressure on the plastic, a reading of between 85-95 Bq is detected. The table below shows the readings on the detector (in counts per second) during one production run.



time interval (minutes)	0 - 2	2 - 4	4 - 6	6 - 8	8 -10	10 - 12	12 - 14	14 - 16	16 - 18	18 - 20
Counts/s	89	90	88	89	91	170	172	172	168	169

(a) Explain the possible cause for the reading that occurs between the 10-12 minute interval compared to the 8-10 minute interval.

(2 marks)

- The thickness of the plastic has become thinner or has run out because the detector is receiving increased levels of radiation as there is less material blocking the radiation

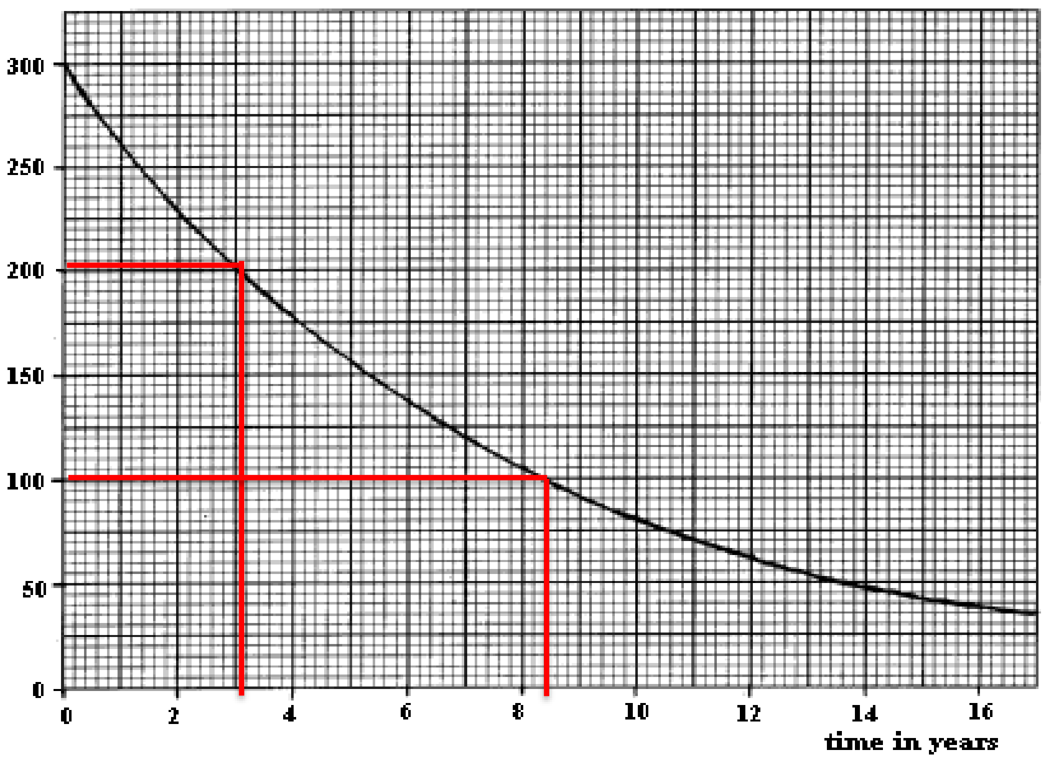
(b) The beta source and detector are covered by shields. Explain what the shielding should be made of to provide the **MINIMUM** necessary protection for workers who are near the beta source.

(3 marks)

- The shielding would need to be at least a thin sheet of aluminium several mm thick
- as this is sufficient to stop penetration of beta minus radiation
- which has medium penetration ability

The radioactive decay curve for the beta particle source that was used in the thickness detector is shown below.

Activity (Bq)



(c) Use the graph to determine the half-life of the beta source. Include lines on the graph to clearly how you determined the average half-life.

(3 marks)

$t_{1/2} = 8.3 - 3.0\ years$

5.3 years

or other correct combination

1 mark lines, 1 mark working, 1 mark answer

(d) Explain whether an alpha emitter would be a more suitable radiation source to be used in the thickness detector.

(2 marks)

No
Alpha particles have low penetrating ability and will be stopped by the plastic sheet

Question 4 **(15 marks)**

The Crab nebula is a remnant of a supernova seen in AD 1054. A supernova is the violent explosion of a star. A possible energy releasing process in a supernova is represented by the following equation.

$${}^{13}_{6}C + {}^{4}_{2}He \rightarrow {}^{b}_{a}X + {}^{0}_{1}Y + 3.5488 \times 10^{-13}\text{J}$$

(a) Name this type of nuclear reaction.

(1 mark)

This is a nuclear fusion reaction

(b) Name the element represented by 'X'.

(2 marks)

${}^{13}_{6}C + {}^{4}_{2}He \rightarrow {}^{17}_{7}X + {}^{0}_{1}Y$ X represents Nitrogen-17

(c) Name particle represented by 'Y'.

(1 mark)

Y represents a positron

(d) Determine the mass equivalent in kilogram of the energy released in this nuclear reaction.

(3 marks)

$$E = \Delta mc^2$$

$$\frac{E}{c^2} = m = \frac{3.5488 \text{ x } 10^{-13}}{9.00 \times 10^{16}}$$

m = 3.94 x 10^{-30} kg

(e) Use the data listed in the table (on right) and the value determined in part **(d)** to calculate the mass of element X (assume it is at rest).
(If you do not have an answer to part d use 3.10×10^{-27} kg)

(3 marks)

Name	Mass of atom (kg)
Carbon-13	21.5912×10^{-27}
Helium-4	6.6460×10^{-27}
Y	1.6748×10^{-27}

mass of reactants - mass of products = mass defect

$(21.5912 \times 10^{-27} + 6.6460 \times 10^{-27}) - (X + 1.6748 \times 10^{-27}) = 3.9431 \times 10^{-30}$

$= 28.2372 \times 10^{-27} - 1.6748 \times 10^{-27} - 3.9431 \times 10^{-30}) = X$

$X = 26.5585 \times 10^{-27}$ kg (4 d.p)

[Alternate answer
$= 28.2372 \times 10^{-27} - 1.6748 \times 10^{-27} - 3.10 \times 10^{-27}) = X = 2.35 \times 10^{-26}$ kg (2.d.)]

(f) The Carbon-13 atom has an atomic mass of 13.003355 u. Calculate the binding energy per nucleon of the carbon -13 atom in eV.

(5 marks)

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

BE = (6 x 1.007825 + 7 x 1.008665) - 13.003355

BE = 13.107605 -13.003355

BE =0.10425 u x 931 = 9.71×10^{7} eV

BE/nucleon = $(9.71 \times 10^{7}$ eV)/13

$= 7.47 \times 10^{6}$ eV/nucleon

Question 5 **(12 marks)**

A 90.0 kg person accidentally inhales a mass of tritium that has an activity of 1.30 x 10^{10} Bq and a half-life of 12.3 years.

Assume that the tritium spreads uniformly throughout the body and that each decay leads on average to the absorption of 5.00 keV of energy from the electrons emitted in the decay.

(a) Write a nuclear reaction for the decay of the tritium.

(2 marks)

$${}^{3}_{1}H \rightarrow {}^{0}_{-1}e + {}^{3}_{2}He + \bar{\upsilon} + energy$$

(b) Determine the energy emitted in joules from the decay of tritium for a period of one second.

(3 marks)

E = Activity x Energy/event x time

= (1.30 x 10^{10}) x (5.00 x 10^{3} x 1.60 x 10^{-19}) x 1

= 1.04 x 10^{-5} J/s

(c) Assuming a constant rate of decay, determine the absorbed dose for the person over a period of one week.

(4 marks)

A.D. = Energy absorbed/mass

A.D. = 1.04 x 10^{-5} x (7 x 24 x 60 x 60) / 90.0

A.D. = (6.28992)/90.0

A.D. = 6.99 x10^{-2} Gy

(d) Would it be reasonable to use tritium as a radioisotope in medical treatment or diagnosis? Explain your reasoning.

(3 marks)

- No
- It would be hard for the body to absorb a form of hydrogen gas for diagnositic purposes
- The half life of the tritium is also too long for a radioactive isotope to be in the body emitting Beta negative particles

Question 6 **(10 marks)**

When a uranium-235 nucleus absorbs a neutron, many fission products are possible. One such reaction in a nuclear power plant results in the formation of lanthanum-148 (La), bromine-85 (Br) and neutrons.

(a) Write an equation for this reaction and identify the number of neutrons produced.

(2 marks)

$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{148}_{57}La + ^{85}_{35}Br + 3^{1}_{0}n$ + energy so 3 neutrons produced

(b) Describe how the neutrons released in this reaction differ from those that took part in the initial fission reaction.

(2 marks)?

- Uranium-235 can only absorb slow neutrons
- but the neutrons produced will have much greater speed when the nucleus splits

Many of the products of fission reactions are radioactive but are not able to be used in the reactor. This waste is taken from the site and stored permanently in a safe and secure place where its activity can be monitored. The measured activity from some radioactive waste when it was first removed from the reactor was 128 Bq above the background count of 2.00 Bq.

(c) Explain what is meant by the term ‘background count’ and give an example of a source that contributes to it.

(2 marks)

- The background count is radiation that comes from natural sources in the environment
- e.g. cosmic rays, rocks, atomic testing, nuclear sources, etc

(d) If the average half-life of the waste in part (c) is taken as being 7.50 x 10^4 years, calculate how long it will take for its activity to reach the same level as the background count.

(4 marks)

$A = A_0(1/2)^n$; $2 = 128(1/2)^n$

n = 6.00 half-lives

Age = n x $t_{1/2}$ = 6.00 x 7.50 x10^4 yrs

= 4.50 x 10^5 years

END OF TEST