Physics
Christ Church Grammar School

Science Department
Year 11 2020

ATAR PHYSICS
UNIT 1 – Nuclear Physics
TEST 2020

Student Name:

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Teacher: JRM PCW CJO SA
(Please circle)

Time allowed for this paper
Working time for paper: 50 minutes.

Instructions to candidates:

- You must include **all** working to be awarded full marks for a question.
- Marks may be deducted if diagrams are not drawn neatly with a ruler and to scale (if specified).
- Marks will be deducted for incorrect or absent units.
- **No** graphics calculators are permitted – scientific calculators only.

Mark:	/ 54
=	%

Question 1 **(10 marks)**

When a neutron hits a Boron-10 nucleus, the Boron absorbs the neutron and emits an alpha particle.

(a) Write the nuclear equation for the absorption reaction.

(2 marks)

Description	Marks
${}^{10}_{5}B + {}^{1}_{0}n \rightarrow {}^{4}_{2}\alpha + {}^{7}_{3}Li$	2

(b) Name the element formed in the reaction.

(1 mark)

Description	Marks
Lithium 7	1

(c) Calculate the binding energy per nucleon of a Boron-10 nucleus.

(5 marks)

Particle	**Atomic mass (u)**
Proton	1.007276
Neutron	1.008665
Electron	0.0005486
Hydrogen	1.007825
Boron 10	10.012938

Description	Marks
5 x 0.0005486 5 x 1.008665 5 x 1.007276	1
Total Mass = 10.08245u	1
MD = 10.08425 – 10.012938 = 0.069512	1
BE = MD x 931 = 64.7 MeV	1
BE/N = BE/10 = 6.47 MeV / nucleon (3 S F)	1

(d) Explain how a nucleus stays together even though the sub-atomic particles within the nucleus repel each other.

(2 marks)

Description	Marks
The nucleus is held together by the strong nuclear force	1
This force holds all nucleons together and overcomes the electrostatic repulsion of the protons	1

Question 2 **(19 marks)**

When Uranium-235 is bombarded with a neutron, it becomes Uranium-236 before decaying. One of the decay reactions creates Barium-144 and Krypton-89.

(a) Balance the equation below.

(1 mark)

$$^{236}_{92}U \rightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + energy + \_\_\_\_\_\_\_\_\_\_$$

Description	Marks
$3\,^{1}_{0}n$	1

(b) Calculate the energy released from each decay event.

(5 marks)

Particle	**Atomic mass (u)**
Proton	1.007276
Neutron	1.008665
Electron	0.0005486
Hydrogen	1.007825
Uranium 236	236.04557
Barium 144	143.92295
Krypton 89	88.91763

Description	Marks
236.04557 → 143.92295 + 88.91763 + 3 x 1.008665	1
MD = 236.04557 – 235.86653	1
MD = 0.17904u (5 DP)	1
E = MD x 931 = 0.17904 x 931	1
E = 167. MeV (3 SF)	1

(c) With reference to the equation above, explain how a chain reaction can occur.

(3 marks)

Description	Marks
For each decay to occur, an atom of U-235 must be bombarded with a neutron	1
Each decay produces 3 additional neutrons	1
For each decay, 3 other decays can occur	1

(d) Explain the function of coolant in a Nuclear reactor.

(2 marks)

Description	Marks
Coolant is used to remove heat from the reactor core	1
It transports this heat (energy) to a generator to make electricity	1

(e) Explain the function of a moderator in a Nuclear reactor.

(2 marks)

Description	Marks
A moderator will slow down the neutrons that are ejected from a decay	1
Slower moving neutrons are more likely to be accepted into a fuel atom to cause a decay	1

Current Nuclear reactors are all based on fission reactions. Various countries around the world are working hard to create reactors which are based on fusion reactions.

(a) State and explain two benefits of a fusion reactor compared to a fission reactor.

(4 marks)

Description	Marks
No dangerous nuclear waste	1
Fusion is typically creating elements with low mass numbers that are stable	1
Greater energy released per fusion number of nucleons/mass	1
About 10 times greater energy released	1
Difficult to have a meltdown	1
Very high temperatures must be maintained and there is no chain reaction	1
Fuel in not being enriched	1
No possibility of making fission bombs from products	1

(b) State the major obstacle needed to overcome in order to create a fusion reactor.

(2 marks)

Description	Marks
To create a fusion reaction, a large amount of energy is needed	1
The hydrogen particles must have sufficient kinetic energy to collide and fuse	1

Question 3 **(6 marks)**

An old wooden spear is found in outback Australia. The ratio of C-14 to C-12 is measured and calculated to be only 12.5% of the current atmospheric ratio. The half life of C-14 is 5370 years.

(a) Calculate the age of the spear.

(3 marks)

Description	Marks
$2^n = \frac{100}{12.5} = 8$	1
N = 3	1
T = n x t1/2 = 3 x 5370 = 16,100 years (3 S F)	1

(b) Carbon dating ceases to be reliable after 10 half lives. If the initial activity of the sample is 3.20 decays per minute, calculate the activity of the sample when carbon dating is no longer reliable.

(3 marks)

Description	Marks
$A = \frac{A_0}{2^n}$	1
A = 3.20 / 2^{10}	1
A = 0.00313 Decays per minute.	1

Question 4 **(19 marks)**

Nuclear medical specialists will often use radioactive iodine to diagnose different illness. The isotope Iodine-123 is typically used. Iodine will undergo gamma decay during this time. A patient that undergoes this type of diagnostic procedure receives 105 J of energy. The patient has a mass of 67.0 kg.

(a) Calculate the absorbed dose and dose equivalent of this procedure.

(4 marks)

Description	Marks
AD = E/m	1
AD = 105/67 = 1.57Gy	1
DE = AD x QF	1
DE = 1.57 x 1 = 1.57Sv	1

(b) Explain why Iodine-123 was likely selected for this procedure.

(3 marks)

Description	Marks
Gamma has a lower ability to ionise hence less destructive to other cells	1
Gamma has greater penetrating ability than alpha or beta	1
Short half life to reduce exposure time	1
Ability to concentrate at thyroid (if for thyroid cancer)	1

(c) State and explain two ways the medical team can reduce or eliminate the effects of radiation on their own body.

(4 marks)

Description	Marks
Shielding from radiation	1
Staff can wear lead aprons or stand behind dense walls (concrete). These materials stop the radiation	1
OR:	
Increase distance from source	1
Radiation can only travel a set distance in air.	1
OR:	
Limit time of exposure	1
Decrease the amount of energy (gamma radiation) absorbed	1

Using the Iodine-123 procedure, the doctors have found that the tumour has a mass of 48.0 g and is situated in the thyroid. As a treatment, they have decided to insert a radioactive implant that contains a sample of an alpha emitter with a very long half life. This implant will be placed next to the tumour and will be removed when the tumour has received sufficient radiation. The activity of the sample is 62.0 kBq and each event releases 22.4 MeV of energy. Doctors have calculated that the tumour needs to receive an equivalent dose of 80.0 Sv.

(d) Calculate how long the implant must remain in the patients body in order that the tumour receive the required dose.

(6 marks)

Description	Marks
Equations as below	1
AD = ED/QF = 80.0/20 = 4.00 Gy	1
E = AD x m = 4.0 x 0.048 = 0.192 J	1
E = 22.4 x 10^{6} x 1.60 x 10^{-19} = 3.58 x 10^{-12} J	1
Events = 0.192 / 3.58 x 10^{-12} = 5.36 x 10^{10}	1
Time = 5.36 x 10^{10} / 62.0 x 10^{3} = 864032 s OR 240 hr OR 10.0 days	1

(e) State two assumptions that you have made in the calculation above.

(2 marks)

Description	Marks
Activity remains constant	1
Tumour receives 100% of radiation	1

END OF TEST