Western Australian Certificate of Education
ATAR course examination, 2019

Question/Answer Booklet

11 PHYSICS

Test 6 - Nuclear Physics

Name SOLUTIONS

Student Number: In figures

Mark: $\overline{}$ 39 In words

Time allowed for this paper

Reading time before commencing work: five minutes
Working time for paper: fifty minutes

Materials required/recommended for this paper

To be provided by the supervisor

This Question/Answer Booklet
Formulae and Data Booklet

To be provided by the candidate

Standard items: pens, (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: non-programmable calculators satisfying the conditions set by the School Curriculum and Standards Authority for this course

Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Short Answers					
Section Two: Problem-solving	7	7	50	39	100
Section Three: Comprehension					
				Total	100

Instructions to candidates

1. The rules for the conduct of examinations at Holy Cross College are detailed in the College Examination Policy. Sitting this examination implies that you agree to abide by these rules.

2. Write your answers in this Question/Answer Booklet.

3. Working or reasoning should be clearly shown when calculating or estimating answers.

4. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

5. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

   - Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
   - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

6. Answers to questions involving calculations should be ***evaluated and given in decimal form.*** It is suggested that you quote all answers to ***three significant figures***, with the exception of questions for which estimates are required. Despite an incorrect final result, credit may be obtained for method and working, providing these are ***clearly and legibly set out***.

7. Questions containing the instruction "estimate" may give insufficient numerical data for their solution. Students should provide appropriate figures to enable an approximate solution to be obtained. Give final answers to a maximum of two significant figures and include appropriate units where applicable.

8. Note that when an answer is a vector quantity, it must be given with magnitude and direction.

9. In all calculations, units must be consistent throughout your working.

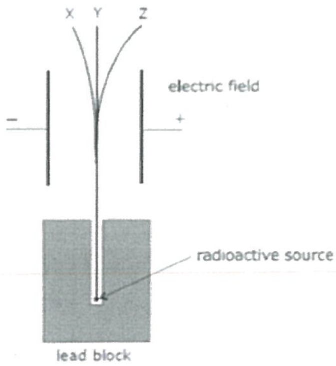
1. Complete the following nuclear equations. (3 marks)

(a) ${}^{4}_{2}He + {}^{14}_{7}N \longrightarrow {}^{17}_{8}O + \underline{{}^{1}_{1}p}$ (1)

(b) $\underline{{}^{1}_{1}p} + {}^{7}_{3}Li \longrightarrow {}^{4}_{2}He + {}^{4}_{2}He$ (1)

(c) ${}^{18}_{8}O + {}^{1}_{1}p \longrightarrow \underline{{}^{15}_{7}N} + {}^{4}_{2}He$ (1)

2. The diagram illustrates that three types of radiation are emitted from a radioactive source.



(a) Name the radiations labelled in the diagram. (2 marks)

X: alpha particle

Y: gamma ray (1) [X and Z correct - 1 mark]

Z: beta particle

(b) Which one is the most ionising? Explain your answer. (2 marks)

- Alpha particle. (1)
- Big and slow moving so it removes electrons easily from atoms. (1)

(c) Which one is the most penetrating? Explain your answer. (2 marks)

- Gamma ray (1)
- Pure energy and no mass (not a particle) so it can penetrate materials easily. (1)

(d) Describe one use for a radioactive source. Include an explanation of why it is used this way. (2 marks)

- Use appropriate. (1)
- Relates use to the properties of the radiation. (1)

3. (a) Explain what is meant by the term ***half-life***. (1 mark)

- Time taken for half of the radioactive atoms in a sample to decay.

(b) 2.40×10^3 disintegrations per second are detected from a sample of Ra-224. If the half-life of Ra-224 is 3.40 days, what will be the count rate after 11.0 days? (4 marks)

$$n = \frac{11.0}{3.40} \quad (1)$$

$$= 3.23 \text{ half-lives} \quad (1)$$

$$N = N_0 \frac{1}{2^n}$$

$$= \frac{2.40 \times 10^3}{2^{3.23}} \quad (1)$$

$$= \underline{256 \text{ disintegrations/second}} \quad (1)$$

4. The mass of a Ne-20 atom is 19.992440u. Calculate its:

(a) mass defect. (3 marks)

Data $^{1}_{1}p = 1.007285\ u$ $^{1}_{0}n = 1.008665\ u$ $^{0}_{-1}e = 0.000549\ u$

$10 \times p = 10 \times 1.007285u = 10.07285u$

$10 \times n = 10 \times 1.008665u = 10.08665u$

$10 \times e = 10 \times 0.000549u = 0.00549u$

$20.16499u$ (1)

Mass defect $= 20.16499u - 19.992440u$

$= 0.17255u$ (1)

$= \underline{161\ MeV}$ (1)

(b) binding energy per nucleon (in MeV). (2 marks)

$B.E. = \frac{161}{20}$ (1)

$= \underline{8.05\ MeV/nucleon}$ (1)

5. One of the fusion reactions in the Sun is:

$$^{3}_{2}He + ^{3}_{2}He \longrightarrow ^{4}_{2}He + ^{1}_{1}H + ^{1}_{1}H$$

The atomic masses are:

$^{1}_{1}H$	1.007825u
$^{3}_{2}He$	3.016029u
$^{4}_{2}He$	4.002603u

Calculate the amount of energy released in the reaction in Joules (J). (5 marks)

Mass (reactants) = 2(3.016029 u) = 6.032058u (1)

Mass (products) = 4.002603u + 2(1.007825u)

= 6.018253u (1)

Mass difference = 6.032058 u − 6.018253u

= 0.013805u (1)

= 12.85 MeV (1)

= $\underline{2.06 \times 10^{-12} J}$ (1)

6. A 90.0 kg person receives an equivalent dose of 9.00×10^{2} mSv after exposure to slow neutrons.

(a) Explain what is meant by the term ***quality factor***. Use alpha and beta radiation to help explain the difference. (3 marks)

- The amount of cell damage caused by a radiation compared to an equal dose of γ rays. (1)

e.g. α particles are big and slow so they ionise very easily. ∴ Q.F. = 20 (1)

β particles are small and fast and don't ionise atoms easily. ∴ QF = 1 (1)

(b) Determine the absorbed dose received by the person. (2 marks)

$$E.D. = A.D. \times Q.F.$$

$$\Rightarrow \quad AD = \frac{0.900}{3} \quad (1)$$

$$= \underline{0.300 \text{ Gy}} \quad (1)$$

(c) Calculate the amount of energy received by the person from the radiation. (2 marks)

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

$$\Rightarrow \quad E = (0.300)(90.0) \quad (1)$$

$$= \underline{27.0 \text{ J}} \quad (1)$$

7. (a) Describe the difference between fission and fusion. Include in your answer which elements typically undergo each type of reaction. (3 marks)

FISSION: splitting of a heavy nucleus into smaller daughter nuclei $(1\frac{1}{2})$

FUSION: joining of two light nuclei at high temperatures to form a heavier nucleus. $(1\frac{1}{2})$

(b) Using U-235 as an example, explain what is meant by the term ***chain reaction***. a simple diagram may help your explanation. (2 marks)

- U-235 can fission (split) to produce two smaller nuclei, releasing 2-3 neutrons. (1)
- These neutrons can then split neighbouring nuclei, releasing more neutrons that can continue the process. (1)

(c) What is meant by the term ***critical mass***? (1 mark)

- The mass of fissile material required to have an uncontrolled chain reaction. (1)