Edexcel, OCR

A Level

A Level Physics

Nuclear Physics (Answers)

Name:

M M E

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Total Marks: /30

1. The equivalence of mass and energy, quantified by Einstein's famous equation $E = mc^2$, underpins all nuclear reactions.

Total for Question 1: 13

(a) Calculate the energy equivalent of the following:

i. The mass of an electron. [2]

Solution: 8.20×10^{-14} J

ii. A human weighing 700 N. [2]

Solution: 6.42×10^{18} J

(b) Calculate the final mass when a ${}^{4}_{2}\mathrm{He}$ nucleus is taken from rest to having kinetic energy of 5.0 MeV. Will this change be an increase or a decrease? [4]

Solution: 6.7×10^{-27} Kg
An increase.

(c) Calculate the minimum photon energy required for pair production, giving your answer in units of MeV. Give an example of when pair production is useful. [5]

Solution: 1.02 MeV
It is an absorption mechanism for x-rays. Without absorption there would be no contrast in a medical x-ray image.

2. Nuclear transformations are capable of producing and consuming large quantities. This is exploited in nuclear reactors. In this question you will calculate the energies associated with transformations and consider the implications of this for nuclear fusion and fission.

Total for Question 2: 17

(a) Define binding energy. [1]

Solution: The binding energy of a nucleus is the minimum energy required to completely separate it into its constituent protons and neutrons.

(b) How is binding energy of a particle related to its mass defect? [1]

Solution: binding energy of a nucleus = mass defect of nucleus $\times c^2$

(c) State the SI unit of mass defect and binding energy. [1]

Solution: Kg and J.

(d) A $^{7}_{3}$Li nucleus has a mass of 7.016 u. Calculate the binding energy per nucleon, giving your answer in units of eV. [4]

Solution: 5.4 MeV

(e) Sketch a graph to show the variation of the binding energy per nucleon with the nucleon number. Annotate your graph to show the position of ^{56}Fe and the directions of fusion and fission reactions. [4]

Solution: Shape: sharp increase for nucleon numbers from 1-50; gently decreasing tail slope thereafter.
Peak at 56 i.e. Fe
Scales: 0-10 MeV vs 0-250 is appropriate.

(f) Briefly explain how the sun produces energy. [3]

Solution: The only way to achieve fusion is to bring nuclei into close enough proximity such that the strong force attracts them to coalesce. The sun achieves this by being very dense. Small nuclei are fused to form larger ones: the hydrogen burning cycle, whereby two protons fuse to form deuterium, which then fuses with another proton to form helium, produces about 5 MeV each time and happens very frequently.

(g) What is the role of the control rods in a nuclear fission reactor? [1]

Solution: To ensure that precisely one slow neutron survives each fission reaction.

(h) State two requirements for a subterranean nuclear waste repository. [2]

Solution: e.g. geologically stable, secure from attack, self-sufficient.