AQA

A Level

A Level Physics

Nuclear Physics 2

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]

ii. A human weighing 700 N. [2]

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

(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]

2. Nuclear transformations are capable of producing and consuming large quantities of energy. 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: 7

(a) Define binding energy. [1]

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

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

(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]

3. Nuclear fission reactors now provide the majority of numerous countries' electricity. This question tackles the reactions that occur inside these facilities.

Total for Question 3: 10

(a) 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]

(b) Nuclear fission reactions in a reactor can only continue if the number of nuclei involved in the reaction does not decrease. This is achieved by using a particular amount of uranium fuel. Why is the arrangement of the fuel important? [2]

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

(d) Low-level waste accounts for 90% of the waste (by volume) generated by nuclear power plants. In contrast, high-level waste represents only 3%. Give an example of each and briefly explain how each is treated and disposed of. [3]