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QUESTION WORKBOOK

Nuclear reactors and safety

Nuclear physics · Year 13

AQA 3.8.1.7, 3.8.1.8 · OCR A 6.4.4(h), 6.4.4(i)

18 questions · 55 marks

NAVY SCREEN EDITION

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SECTION A · Warm-up

A1 State the function of the moderator in a thermal nuclear reactor. [2]

A2 State the function of the control rods in a nuclear reactor. [2]

A3 State the function of the coolant in a nuclear reactor. [2]

A4 Give one example of a material used as the moderator and one example of a material used in the control rods of a thermal nuclear reactor. [2]

A5 State two properties needed by the coolant of a nuclear reactor. [2]

SECTION B · Standard

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B1 Explain, in terms of collisions, why the moderator in a thermal reactor is made from atoms of low mass. [3]

B2 Explain how control rods are used to keep a reactor operating at a steady rate. [3]

B3 Describe how the moderator, the control rods and the coolant work together in a thermal nuclear reactor. [4]

B4 Explain what is meant by critical mass in the context of a working reactor. [3]

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B5 In a reactor running at a steady power, each fission releases on average 2.5 neutrons. Determine the average number of neutrons per fission that must be absorbed by the control rods, or lost in other ways, without causing fission. [2]

B6 Beryllium-9 can be used as a moderator. In a head-on elastic collision with a stationary nucleus of mass M, a neutron of mass m keeps a fraction $((M - m)/(M + m))^2$ of its kinetic energy. Taking $M = 9m$ for beryllium-9, calculate the fraction of its kinetic energy a neutron keeps in one head-on collision, and state one property, other than low nuclear mass, that a moderator material must have. [3]

B7 After a reactor has been shut down, the fuel rods must be cooled for a long time. Explain why the fuel continues to release thermal energy even though the chain reaction has stopped. [3]

SECTION C · Stretch

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C1 Use the elastic collision model to explain why water or graphite, rather than a material with heavy nuclei, is chosen as a moderator. [4]

C2 Describe the main safety features of a nuclear reactor and how high-level radioactive waste is handled. [4]

C3 Explain why spent nuclear fuel must be handled remotely and stored for a long time. [3]

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C4 In a head-on elastic collision with a stationary deuterium nucleus, of mass 2m where m is the neutron mass, a neutron keeps a fraction $((M - m)/(M + m))^2$ of its kinetic energy. Show that this fraction is 1/9, and go on to determine the number of successive head-on collisions needed to reduce a neutron's kinetic energy from 1.0 MeV to below 1.0 eV. [4]

C5 A campaign leaflet claims that a nuclear power station could explode like a nuclear bomb. Deduce whether the claim is justified. [3]

C6 A country with ageing coal-fired power stations is deciding whether to replace them with nuclear power stations. Discuss the benefits and the risks that should be weighed in this decision, giving physical reasons, and state a conclusion. [6]

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