

Exercise walk-through

18.2

Fission (full E.4)

International Baccalaureate · IB Diploma · Physics · SL

Fission · 2.1

Reasoning

In nuclear fission a heavy nucleus splits into lighter nuclei. Proton number and nucleon number balance in a nuclear equation. The total rest mass can decrease; the difference corresponds to released energy through $E = \Delta mc^2$. fission: Splitting of a heavy nucleus into lighter nuclei; chain reaction: A sequence in which products initiate further events.

Fission · 3.1

Reasoning

Separate conservation of nucleon number from conservation of total energy. Released neutrons may initiate further fissions, escape or be absorbed. A controlled reactor and an uncontrolled chain reaction have different neutron-management conditions. Balance a supplied nuclear equation, use the specified mass data and identify the system. Analyse models or published reactor data; this is not a school attempt to produce fission or handle reactor materials.

Fission · 5.1

Reasoning

Mass number is not a precise mass in kilograms. Balanced integer labels alone do not calculate the released energy. Radioactive decay and neutron-induced fission are not interchangeable descriptions. Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Exercises 2.1-2.3

2.1 Distinguish spontaneous fission from neutron-induced fission. [2]

2.2 State the role of the moderator in a nuclear reactor. [2]

2.3 State two properties of fission products that make them hazardous. [2]

Exercises 2.1-2.3

2.1 Distinguish spontaneous fission from neutron-induced fission. [2]

2.1 Spontaneous: the nucleus splits by itself, no incoming particle; induced: an absorbed neutron triggers the split.

2.2 State the role of the moderator in a nuclear reactor. [2]

2.2 To slow fast neutrons to thermal speeds by collisions; slow neutrons are far more likely to cause further U-235 fissions.

2.3 State two properties of fission products that make them hazardous. [2]

2.3 Any two: they are radioactive; neutron-rich, undergoing further beta decay; intensely ionizing with long half-lives; generate decay heat.

Exercises 2.4·3.2

2.4 State the function of control rods.

[1]

3.1 Complete and balance: ${}_{92}^{235}\text{U} + {}_0^1n \rightarrow {}_{56}^{141}\text{Ba} + {}_{36}^{92}\text{Kr} + \dots$ State how many neutrons are released, and explain how this number makes a chain reaction possible.

[3]

3.2 A fission reaction has a mass difference of 0.21 u . Calculate the energy released in MeV and in joules.

[3]

Exercises 2.4·3.2

2.4 State the function of control rods. [1]

2.4 Absorb neutrons to control – hold or damp – the reaction rate.

3.1 Complete and balance: ${}_{92}^{235}\text{U} + {}_0^1n \rightarrow {}_{56}^{141}\text{Ba} + {}_{36}^{92}\text{Kr} + \dots$ State how many neutrons are released, and explain how this number makes a chain reaction possible. [3]

3.1 Three neutrons: $+ 3{}_0^1n$; A : $236 = 141 + 92 + 3$ and Z : $92 = 56 + 36$ balance; at least one of the three can trigger the next fission, so the reaction can sustain – and if more than one does, grow.

3.2 A fission reaction has a mass difference of 0.21 u . Calculate the energy released in MeV and in joules. [3]

3.2 $E = 0.21 \times 931.5 = 196\text{ MeV} \approx 200\text{ MeV}$; in joules: $196 \times 1.6 \times 10^{-13} = 3.1 \times 10^{-11}\text{ J}$.

Exercises 3.3-3.4

3.3 Explain why fission fragments are radioactive even though the parent uranium is only weakly so, and describe one long-term management option for them. [4]

3.4 A reactor runs at a thermal power of 2.0×10^9 W. Using $E = 2.8 \times 10^{-11}$ J per fission, calculate the number of fissions per second, and the mass of U-235 consumed per day if every nucleus fissions ($235 \text{ u} = 3.9 \times 10^{-25}$ kg). [4]

Exercises 3.3-3.4

3.3 Explain why fission fragments are radioactive even though the parent uranium is only weakly so, and describe one long-term management option for them. [4]

3.3 The fragments inherit uranium's neutron-to-proton ratio while sitting at medium mass numbers, where stability demands fewer neutrons – they are neutron-rich and beta-decay repeatedly; long-term option: after years of cooled pool storage, seal the waste in corrosion-resistant containers inside deep geological repositories, stable for the tens of thousands of years the longest half-lives demand.

3.4 A reactor runs at a thermal power of 2.0×10^9 W. Using $E = 2.8 \times 10^{-11}$ J per fission, calculate the number of fissions per second, and the mass of U-235 consumed per day if every nucleus fissions ($235 \text{ u} = 3.9 \times 10^{-25}$ kg). [4]

3.4 Fissions per second = $P/E = (2.0 \times 10^9)/(2.8 \times 10^{-11}) = 7.1 \times 10^{19} \text{ s}^{-1}$; per day: $\times 86400 = 6.2 \times 10^{24}$ fissions; mass = $6.2 \times 10^{24} \times 3.9 \times 10^{-25} = 2.4 \text{ kg}$.