MOMENTUM

IB Physics HL

Nuclear physics - Set 1

E.4-E.5 | First assessment 2025 | Higher Level

Independent examination-style practice material

10 original problems

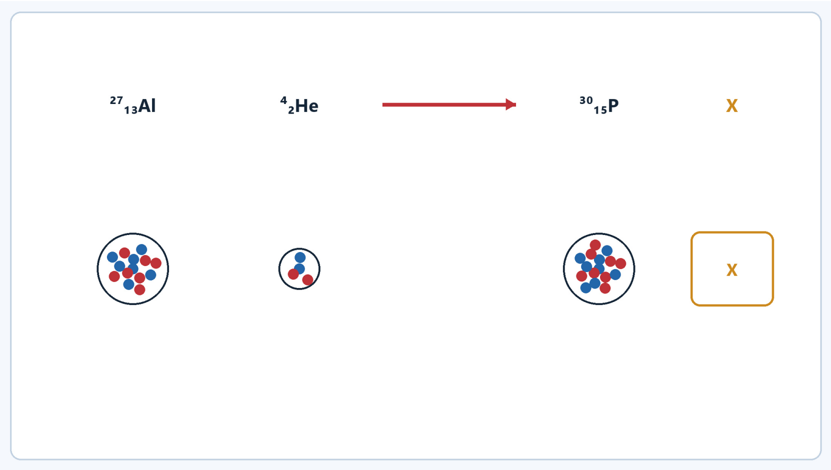
TASK 01

[5]

Balancing a nuclear reaction

Paper 2 style | IB code E.4

Complete the reaction: aluminium-27 plus an alpha particle produces phosphorus-30 and particle X.



(a) Determine the mass number and atomic number of X. [2]

(b) Identify X. [1]

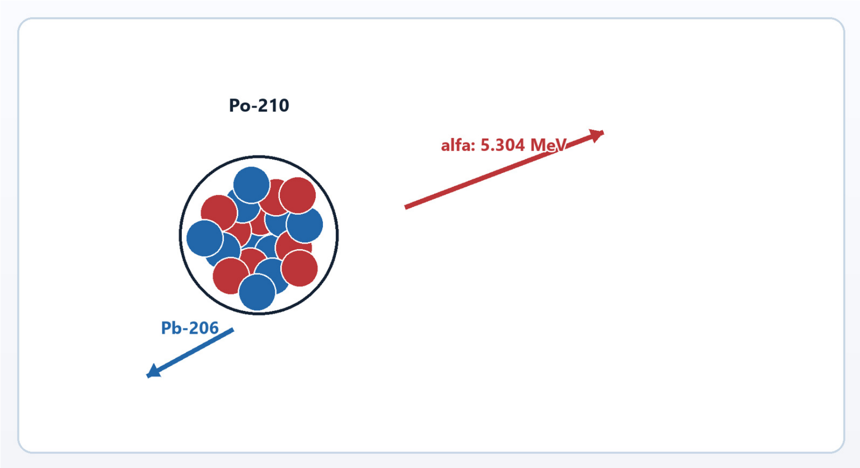
(c) State the two conservation rules used. [2]

TASK 02
[5]

Energy sharing in alpha decay

Paper 2 style | IB code E.4

Stationary polonium-210 decays into lead-206 and an alpha particle, releasing 5.407 MeV. Treat masses as proportional to mass numbers.



(a) Explain why the products have equal momentum magnitudes. [1]

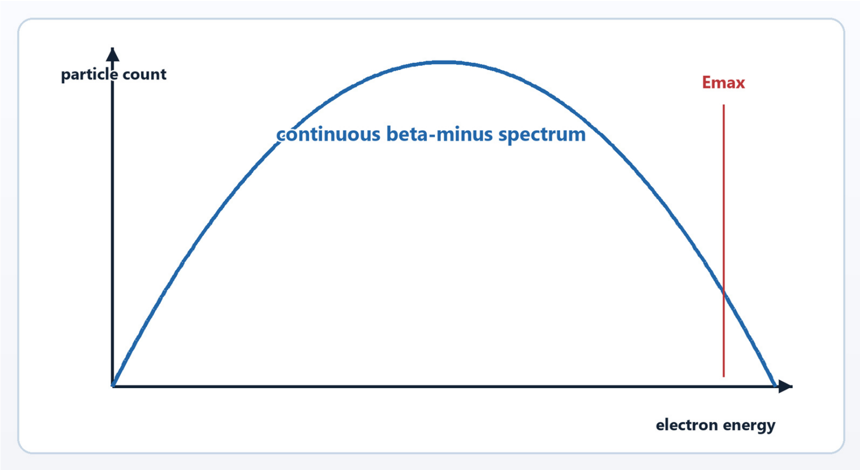
(b) Determine the kinetic energy of each product. [4]

TASK 03
[6]

The continuous beta spectrum

Paper 2 style | IB code E.4

Carbon-14 undergoes beta-minus decay to nitrogen-14.



(a) Write the complete decay equation, including the neutral lepton. [2]

(b) Explain why emitted electrons have a continuous range of energies. [3]

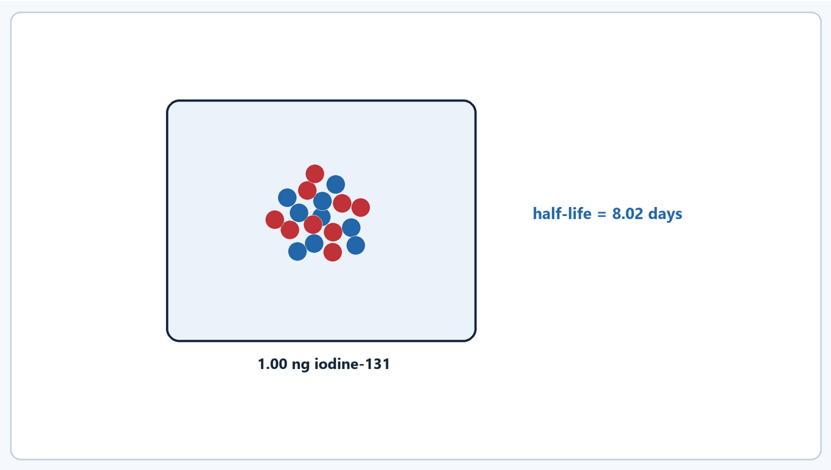
(c) State the change in atomic number and mass number. [1]

TASK 04
[6]

Activity of iodine-131

Paper 2 style | IB code E.4

A sample contains 1.00 ng of pure iodine-131. Its half-life is 8.02 days. Use N_A = 6.022e23 mol^{-1}.



(a) Determine the number of nuclei. [2]

(b) Determine the decay constant. [2]

(c) Determine the initial activity. [2]

TASK 05
[5]

Radiocarbon dating

Paper 2 style | IB code E.4

The carbon-14 activity per unit mass in an organic sample is 25.0% of that in living material. Carbon-14 half-life is 5730 years.

(a) Determine the age of the sample. [2]

(b) A measurement gives 26.0% with uncertainty 1.0 percentage point. Estimate the age range. [3]

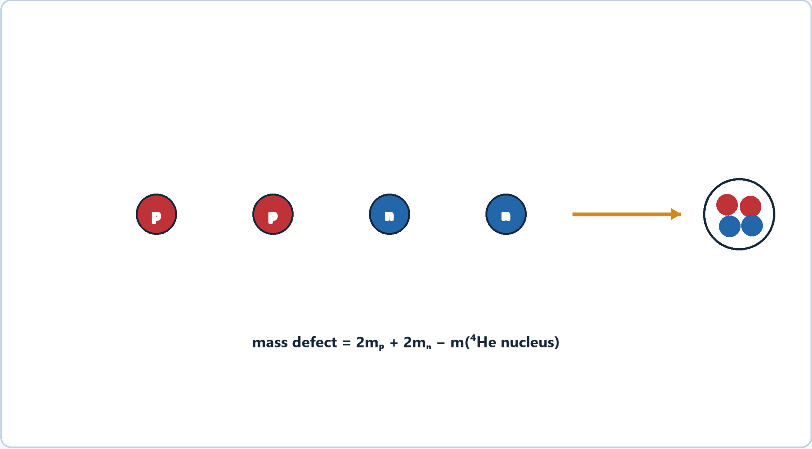
TASK 06

[5]

Mass defect of helium-4

Paper 2 style | IB code E.4

Use proton mass 1.007276 u, neutron mass 1.008665 u and helium-4 nucleus mass 4.001506 u. Use 1 u c^2 = 931.5 MeV.



(a) Determine the mass defect. [2]

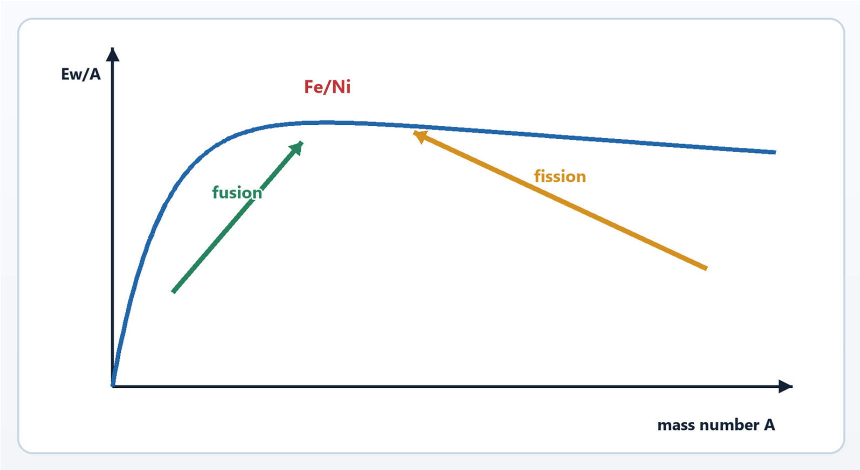
(b) Determine the binding energy and binding energy per nucleon. [3]

TASK 07
[5]

Interpreting the binding-energy curve

Paper 2 style | IB code E.4

The graph shows binding energy per nucleon against nucleon number.



(a) Identify the region of greatest nuclear stability. [1]

(b) Explain why fusion of light nuclei can release energy. [2]

(c) Explain why fission of very heavy nuclei can release energy. [2]

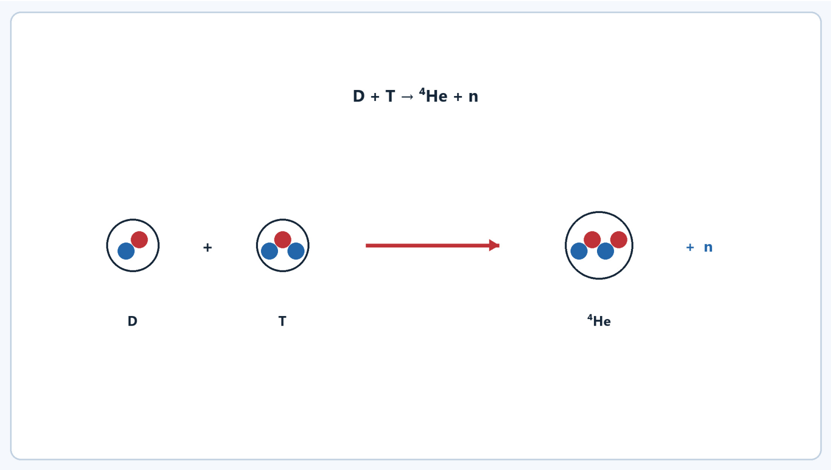
TASK 08

[5]

Energy from deuterium-tritium fusion

Paper 2 style | IB code E.5

For D + T -> He-4 + n, use atomic masses 2.014102 u, 3.016049 u, 4.002603 u and neutron mass 1.008665 u.



(a) Determine the reaction mass difference. [2]

(b) Determine the energy released. [2]

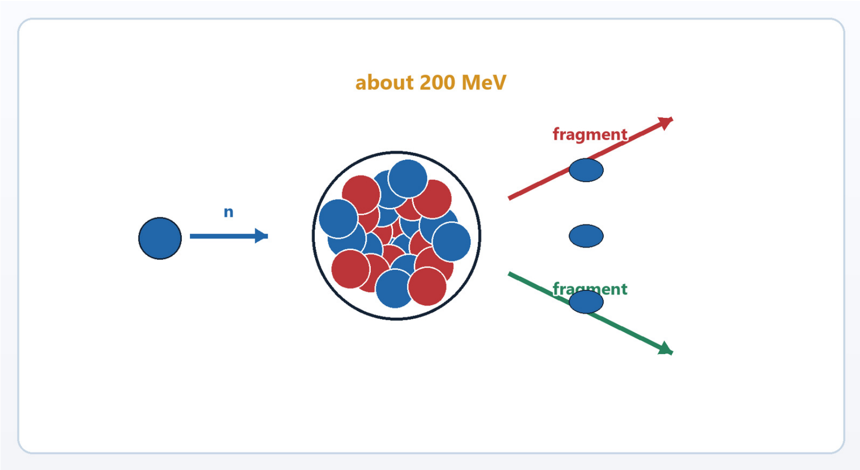
(c) State one condition required for a sustained fusion reaction. [1]

TASK 09
[6]

Energy from uranium-235 fission

Paper 2 style | IB code E.5

One uranium-235 fission releases on average 200 MeV. A sample contains 1.00 g of pure uranium-235.



(a) Determine the number of nuclei. [2]

(b) Determine the total energy if all nuclei fission. [3]

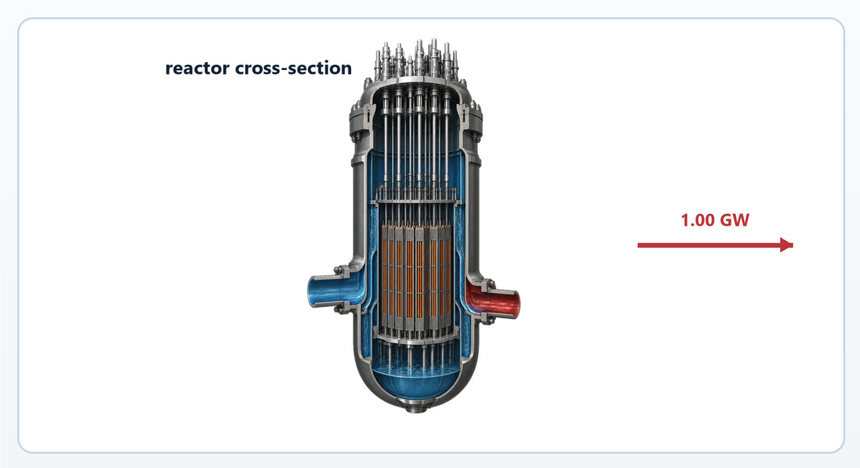
(c) Express the energy in MWh. [1]

TASK 10
[7]

Criticality in a chain reaction

Paper 2 style | IB code E.5

In a simplified reactor model, each neutron generation contains k times as many neutrons as the preceding generation.



(a) Determine N50/N0 for k = 1.01. [2]

(b) Determine N50/N0 for k = 0.98. [2]

(c) Interpret both cases and state the condition for critical operation. [3]