MOMENTUM

IB Physics HL

Nuclear physics - Set 1 - Markscheme

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

Independent examination-style practice material

10 original problems

Task 01 - Balancing a nuclear reaction

Paper 2 style | IB code E.4 | Total [5]

Part	Marking guidance	Marks
(a)	Mass number: 27+4 = 30+A_X gives A_X=1. Charge: 13+2 = 15+Z_X gives Z_X=0.	**2**
(b)	X is a neutron.	**1**
(c)	Conservation of nucleon number and electric charge.	**2**

Task 02 - Energy sharing in alpha decay

Paper 2 style | IB code E.4 | Total [5]

Part	Marking guidance	Marks
(a)	Initial momentum is zero, so the two product momenta are equal and opposite.	**1**
(b)	For equal p, K is inversely proportional to mass. K_alpha/K_Pb = 206/4; gives K_alpha = 5.304 MeV and K_Pb = 0.103 MeV.	**4**

Task 03 - The continuous beta spectrum

Paper 2 style | IB code E.4 | Total [6]

Part	Marking guidance	Marks
(a)	C-14 -> N-14 + electron + electron antineutrino.	**2**
(b)	The fixed decay energy is shared variably between electron, antineutrino and nuclear recoil.	**3**
(c)	Atomic number increases by one; mass number is unchanged.	**1**

Task 04 - Activity of iodine-131

Paper 2 style | IB code E.4 | Total [6]

Part	Marking guidance	Marks
(a)	N = (1.00e-9/131)N_A = 4.60e12.	**2**
(b)	lambda = ln2/(8.02x86400) = 1.00e-6 s^{-1}.	**2**
(c)	A = lambda N = 4.60e6 Bq.	**2**

Task 05 - Radiocarbon dating

Paper 2 style | IB code E.4 | Total [5]

Part	Marking guidance	Marks
(a)	0.250 = (1/2)^2, so age = 2(5730) = 11460 years.	**2**
(b)	Uses t = -T_half ln(f)/ln2 for f=0.25 and 0.27, giving approximately 10.8 to 11.5 thousand years.	**3**

Task 06 - Mass defect of helium-4

Paper 2 style | IB code E.4 | Total [5]

Part	Marking guidance	Marks
(a)	Delta m = 2m_p+2m_n-m_nucleus = 0.030376 u.	**2**
(b)	Binding energy = 28.30 MeV and per nucleon = 7.07 MeV.	**3**

Task 07 - Interpreting the binding-energy curve

Paper 2 style | IB code E.4 | Total [5]

Part	Marking guidance	Marks
(a)	The maximum is near iron/nickel, A about 56 to 62.	**1**
(b)	Fusion products have greater binding energy per nucleon, so total mass decreases and energy is released.	**2**
(c)	Medium-mass fission products are more tightly bound per nucleon than the original heavy nucleus.	**2**

Task 08 - Energy from deuterium-tritium fusion

Paper 2 style | IB code E.5 | Total [5]

Part	Marking guidance	Marks
(a)	Delta m = 0.018883 u.	**2**
(b)	Q = Delta m c^2 = 17.59 MeV.	**2**
(c)	A sufficiently high temperature and confinement time/density are required to overcome Coulomb repulsion.	**1**

Task 09 - Energy from uranium-235 fission

Paper 2 style | IB code E.5 | Total [6]

Part	Marking guidance	Marks
(a)	N = N_A/235 = 2.56e21.	**2**
(b)	E = N(200 MeV) = 8.21e10 J.	**3**
(c)	E = 22.8 MWh.	**1**

Task 10 - Criticality in a chain reaction

Paper 2 style | IB code E.5 | Total [7]

Part	Marking guidance	Marks
(a)	N50/N0 = 1.01^50 = 1.64.	**2**
(b)	N50/N0 = 0.98^50 = 0.364.	**2**
(c)	k>1 is supercritical, k<1 is subcritical, and steady critical operation requires k=1.	**3**