Cambridge Assessment International Education

Cambridge International AS & A Level

12: Nuclear physics – Topic questions

The questions in this document have been compiled from a number of past papers, as indicated in the table below.

Use these questions to formatively assess your learners' understanding of this topic.

Question	Year	Series	Paper number
12	2017	June	41
12	2017	March	42
13	2016	March	42

The mark scheme for each question is provided at the end of the document.

12 One possible nuclear reaction that takes place in a nuclear reactor is given by the equation

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \rightarrow ^{95}_{42}\text{Mo} + ^{139}_{57}\text{La} + 2^{1}_{0}\text{n} + x\,^{0}_{-1}\text{e}$$

Data for the nuclei and particles are given in Fig. 12.1.

nucleus or particle	mass / u
$^{235}_{92}\text{U}$	235.123
$^{95}_{42}\text{Mo}$	94.945
$^{139}_{57}\text{La}$	138.955
$^{1}_{0}\text{n}$	1.00863
$^{0}_{-1}\text{e}$	5.49×10^{-4}

Fig. 12.1

(a) Determine, for this nuclear reaction, the value of x.

x = ...[1]

(b) **(i)** Show that the energy equivalent to 1.00 u is 934 MeV.

[3]

(ii) Calculate the energy, in MeV, released in this reaction. Give your answer to three significant figures.

energy = ... MeV [3]

(c) Suggest the forms of energy into which the energy calculated in **(b)(ii)** is transformed.

.....

.....

.....

.....[2]

[Total: 9]

12 **(a)** Define the *binding energy* of a nucleus.

.....

.....

.....[2]

(b) A stationary nucleus of uranium-238 ($^{238}_{92}U$) decays to form a nucleus of thorium-234 ($^{234}_{90}Th$). An α-particle and a gamma-ray photon are emitted. The equation representing the decay is

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He + {}^{0}_{0}\gamma$$

The masses of the nuclei are given in Fig. 12.1.

nucleus	mass / u
uranium-238	238.05076
thorium-234	234.04357
helium-4	4.00260

Fig. 12.1

(i) State the relationship between the binding energies of the nuclei that is consistent with this reaction being energetically possible.

.....

.....[1]

(ii) Calculate, for this reaction,

1. the change, in u, of the mass,

change of mass = ...u [1]

2. the total energy, in J, released.

energy = ...J [2]

(iii) State and explain whether the energy of the gamma-ray photon is equal to the energy released in the reaction.

.....

.....

.....[2]

[Total: 8]

13 Beryllium-7 ($^{7}_{4}$Be) is produced in the upper atmosphere and then sinks down onto the Earth's surface. Nuclei of beryllium-7 decay with a half-life of 53.3 days to form stable nuclei.

The activity of a sample of beryllium-7 on a tree leaf is 39 mBq.

(a) Show that the decay constant of beryllium-7 is $1.5 \times 10^{-7}\,s^{-1}$.

[1]

(b) Determine the mass of the beryllium-7 on the leaf.

mass = ... kg [3]

(c) The leaf is covered so that no further beryllium-7 is added to the existing sample from the atmosphere.

Calculate the time that must elapse before the activity of the sample is reduced to 2.0 mBq.

time = ... s [2]

[Total: 6]

Question	Answer	Marks
12 (a)	$x = 7$	**1**
12 (b) (i)	$E = mc^2$	**1**
	$= 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$ $= 1.494 \times 10^{-10}$ J	**1**
	division by 1.6×10^{-13} clear to give 934 MeV	**1**
12 (b) (ii)	$\Delta m = (235.123 + 1.00863) - (94.945 + 138.955 + 2 \times 1.00863 + 7 \times 5.49 \times 10^{-4})$ **or** $\Delta m = 235.123 - (94.945 + 138.955 + 1 \times 1.00863 + 7 \times 5.49 \times 10^{-4})$	**1**
	= 0.21053 u	**1**
	energy = 0.21053 × 934 = 197 MeV	**1**
12 (c)	kinetic energy of nuclei/particles/products/fragments	**1**
	γ–ray photon energy	**1**
		Total: 9
12 (a)	*either*	
	(minimum) energy required / work done to separate the nucleons (in a nucleus)	**1**
	to infinity	**1**
	or	
	energy released when nucleons come together (to form a nucleus)	**(1)**
	from infinity	**(1)**
12 (b) (i)	(total) binding energy of thorium and helium (nuclei) greater than binding energy of uranium (nucleus)	**1**
12 (b) (ii)1	change in mass = 238.05076 – (234.04357 + 4.00260) = 4.59×10^{-3} u	**1**
12 (b) (ii)2	*either*	
	$E = mc^2$ $= 4.59 \times 10^{-3} \times 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$	**1**
	$= 6.9 \times 10^{-13}$J	**1**
	or	
	1u = 931 MeV $E = 4.59 \times 10^{-3} \times 931 \times 10^6 \times 1.6 \times 10^{-19}$	**(1)**
	$= 6.8 \times 10^{-13}$J	**(1)**
12 (b) (iii)	Th nucleus / He nucleus / product nucleus has kinetic energy	**1**
	energy of gamma photon must be less than energy released	**1**
		Total: 8

Question	Answer	Marks
13 (a)	$\lambda = \ln 2 / T_{½}$ $= \ln 2 / (53.3 \times 24 \times 60 \times 60) = 1.5 \times 10^{-7}\ s^{-1}$	**1**
13 (b)	$A = \lambda N$	**1**
	$N = 39 \times 10^{-3} / 1.5 \times 10^{-7} = 2.6 \times 10^{5}$ $m = (2.6 \times 10^{5} / 6.0 \times 10^{23}) \times 7 \times 10^{-3}$ or $2.6 \times 10^{5} \times 1.66 \times 10^{-27} \times 7$	**1**
	$= 3.0 \times 10^{-21}$kg	**1**
13 (c)	$2 / 39 = \exp(-1.5 \times 10^{-7} \times t)$ or $2 / 39 = (1 / 2)^{[t / (53.3 \times 24 \times 3600)]}$	**1**
	$t = 2.0 \times 10^{7}$ s	**1**
		Total: 6

Notes about the mark scheme are available separately.