Radioactive Decay

Question Paper

Course	HL IB Physics
Section	Nuclear & Quantum Physics
Topic	Radioactive Decay
Difficulty	Medium

To be used by all students preparing for HL IB Physics
Students of other boards may also find this useful

Question 1

Two samples P and Q of different radioactive isotopes have the same initial activity. Sample P has a third of the number of atoms as sample Q. The half-life of P is T seconds.

What is the half-life of sample Q?

A. $\frac{T}{3}$

B. $\frac{T}{3\sqrt{2}}$

C. $3T$

D. $3\sqrt{2}T$

[1 mark]

Question 2

The half-life of a radioactive isotope is 10 days. What is the approximate percentage of the sample remaining after 25 days?

A. 20

B. 19

C. 16

D. 15

[1 mark]

Question 3

A pure sample of a radioactive nuclide undergoes a decay resulting in a stable daughter nuclide. What fraction of the sample is made up of the daughter nuclide after five half-lives?

A. $\frac{1}{16}$

B. $\frac{1}{32}$

C. $\frac{15}{16}$

D. $\frac{31}{32}$

[1 mark]

Question 4

A series of radioactive decays produce both alpha particles and anti-neutrinos. Which answer option describes the nature of the energy spectrum of these two particles?

	Anti-neutrino	Alpha-particle
A.	discrete	discrete
B.	discrete	continuous
C.	continuous	discrete
D.	continuous	continuous

[1 mark]

Question 5

The decay of several unstable nuclei are observed in a radiation chamber. The following identifications are made:

I. Alpha-particles have discrete kinetic energy levels
II. Beta-particles have a continuous range of kinetic energies
III. Gamma-ray photons have discrete kinetic energy levels

These observations directly relate to two important discoveries; the use of emission spectra to identify elements and the existence of the neutrino.

Which row correctly identifies the observations that lead researchers to the discovery of emission spectra and the existence of the neutrino?

	Emission spectra	Existence of the neutrino
A.	II only	II only
B.	I and III only	II only
C.	II only	I and III only
D.	I and III only	I and II

[1 mark]

Question 6

A radioactive sample of initial activity 10.0 Bq has a half-life of 1 day.

What is the activity of the sample after 2.5 days?

A. 0.8 Bq

B. 1.2 Bq

C. 1.8 Bq

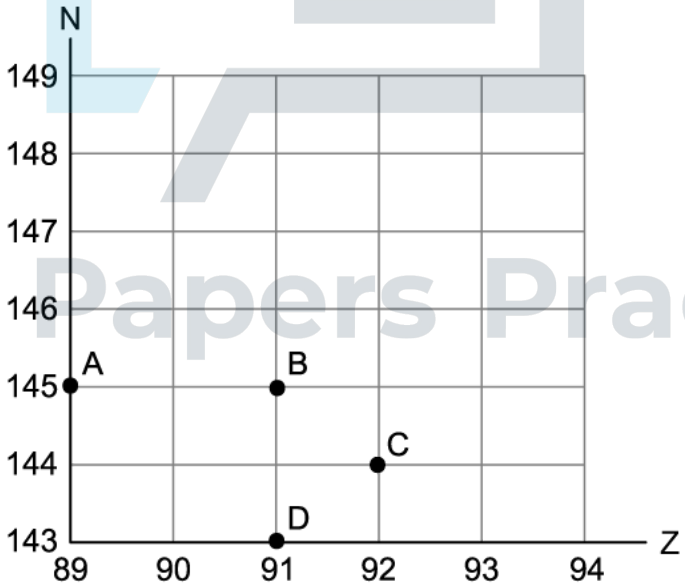
D. 7.6 Bq

[1 mark]

Question 7

$^{238}_{92}U$ decays to thorium-234 by emitting an alpha particle and two gamma rays. Thorium-234 then decays into protactinium via beta decay.

Which point on the N-Z graph below represents the position of the granddaughter nucleus, protactinium?



[1 mark]

Question 8

The half-life of carbon-14 is 6000 years.

An ancient elephant tusk has been uncovered and its age is unknown. A 20 g sample of the tusk has an activity of 1.25 Bq due to carbon-14.

A 80 g sample of tusk taken from a living elephant has an activity of 20 Bq.

Use this information to determine the age of the ancient tusk.

A. 3000 years

B. 12 000 years

C. 18 000 years

D. 24 000 years

[1 mark]

Question 9

Fluorodeoxyglucose is a compound used as a tracer in medical imaging. The isotope fluorine-18 is used, which is a positron emitter.

The way these positrons interact with electrons in the body allows PET (positron emission tomography) scanners to determine the rate of respiration certain cells are performing.

Fluorine-18 decays into an isotope of oxygen.

Which equation below represents the correct nuclear equation for this decay?

A. ${}^{18}_{9}F \rightarrow {}^{18}_{8}O + {}^{0}_{+1}\beta + \upsilon_e$

B. ${}^{18}_{9}F \rightarrow {}^{18}_{8}O + {}^{0}_{-1}\beta + \overline{\upsilon_e}$

C. ${}^{18}_{9}F \rightarrow {}^{18}_{9}O + {}^{0}_{+1}\beta + \upsilon_e$

D. ${}^{18}_{9}F \rightarrow {}^{18}_{8}O + {}^{0}_{+1}\beta + \overline{\upsilon_e}$

[1 mark]

Question 10

Protactinium-231 ($^{231}_{91}Pa$) is a radioactive element, it decays by alpha radiation and then beta-minus decay as shown below:

$$^{231}_{91}Pa \rightarrow A + \alpha \rightarrow B + \beta^{-} + \overline{\upsilon}_{e}$$

What proton number and mass number will element **B** have?

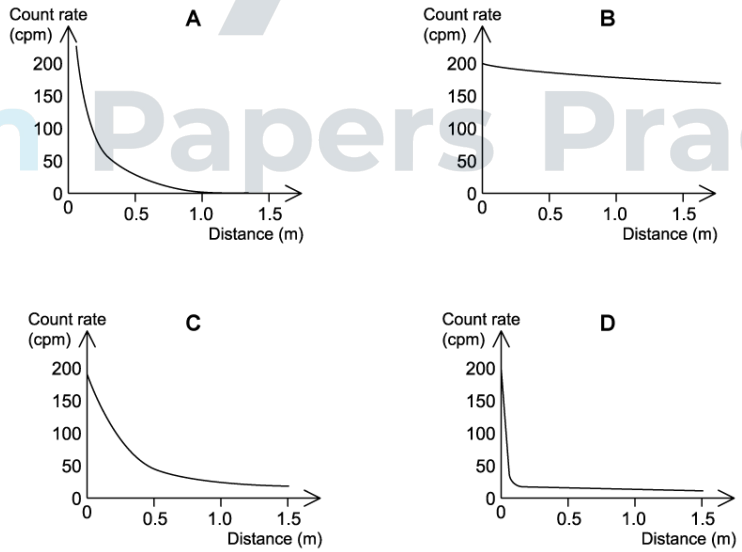
	Proton Number	Mass Number
A.	89	229
B.	90	229
C.	89	227
D.	90	227

[1 mark]

Question 11

A radioactive source is known to emit β radiation. A Geiger-Muller tube is used to measure the count rate at increasing distances from the source.

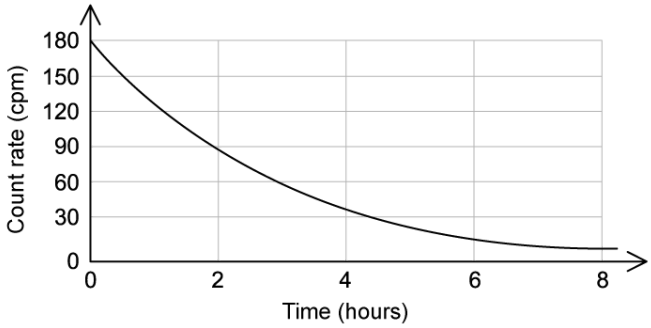
Which graph correctly represents the variation in count rate over these distances for β radiation?



[1 mark]

Question 12

Unstable nuclei make up 10% of a sample's mass. The count rate of the sample is measured over a time period of 8 hours.



After some time has passed, the percentage of the sample which is unstable reduces to 2.5%. What is the count rate of the source at this time?

A. 90 cpm

B. 60 cpm

C. 45 cpm

D. 30 cpm

[1 mark]

Question 13

A source is known to be radioactive but the type of radiation being emitted is unknown.

A Geiger-Müller tube is placed close to the source and different materials are placed between the two. A table of the count rates recorded for each material is shown below. The background count rate is 15 counts per minute.

Material	Count rate recorded / counts per minute
Paper	528
Nothing	1064
Thick lead	17
Aluminium	524

What types of radiation are being emitted by the source?

A. α, β and γ

B. α only

C. β and γ

D. α and γ

[1 mark]

Question 14

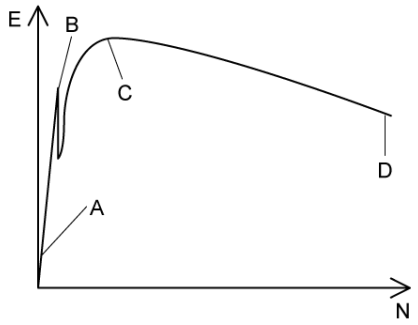
Three of the four isotopes below are the same element. Which isotope represents a different element?

	Nucleon number	Neutron number
A.	233	141
B.	235	143
C.	238	146
D.	239	146

[1 mark]

Question 15

The image below shows a simplified version of the binding energy per nucleon *E* of nuclei versus the nucleon number *N*. Which of the following positions represents nuclei that are the most stable?



[1 mark]

Question 16

The rest mass of a nucleus of Boron-11 ($^{11}_{5}B$) can be considered as m_B. The rest-masses of a neutron and proton can be considered as m_N and m_P respectively. Which of the following equations is the correct representation for the binding energy of Boron-11?

A. $(5m_P + 6m_N - m_B)c^2$

B. $(5m_P + 6m_N + m_B)c^2$

C. $(5m_P + 11m_N - m_B)c^2$

D. $(6m_P + 5m_N - m_B)c^2$

[1 mark]

Question 17

The binding energy per nucleon is 7.98 MeV for an atom of $^{16}_{8}O$. Approximately how much energy would be needed to completely separate the nucleons of this atom?

A. 33.2 MeV

B. 63.9 MeV

C. 88.5 MeV

D. 127.7 MeV

[1 mark]

Question 18

The mass defect for Helium-4 is 5.04×10^{-29} kg. What is the binding energy of Helium-4 closest to?

A. 0.02 MeV

B. 28 MeV

C. 190 MeV

D. 1225 MeV

[1 mark]

Question 19

Two identical nuclei of mass *m* fuse to form a single heavier nucleus (with no other products) with mass *M*. Which of the following statements is correct?

A. $m = M$

B. $2m = M$

C. $2m > M$

D. $2m < M$

[1 mark]

Question 20

Nitrogen-14 can be transformed into Oxygen-17 by bombardment with high energy alpha particles, as described in the nuclear reaction equation below:

$$^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}H$$

The total rest mass of the reactants is 18.006 u and total rest mass of the products is 18.007 u.

Which of the following statements about this reaction is **correct**?

A. A mass of 0.001 u has been converted to about 1 MeV of energy

B. The kinetic energy of the products exceeds the kinetic energy of the reactants by about 1 MeV

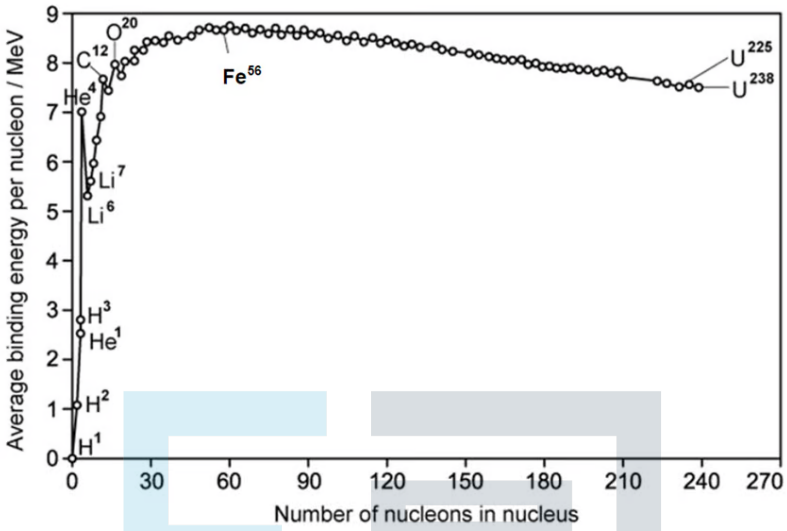
C. The kinetic energy of the reactants exceeds the kinetic energy of the products by about 1 MeV

D. The mass defect of this reaction is 0.002 u

[1 mark]

Question 21

The graph below shows how the average binding energy per nucleon varies with nucleon number for stable nuclei.



Approximately how much energy is released when the nucleus ${}^{181}_{70}\mathrm{X}$ forms?

A. 7.90 MeV

B. 1430 MeV

C. 533 MeV

D. 888 MeV

[1 mark]

Question 22

Which statement about nuclear binding energy is correct?

A. It is the energy equivalent of the mass of the neutrons in a nucleus

B. It is the energy required to separate nucleons in a nucleus

C. It is the energy required to overcome the electrostatic force between nucleons in the nucleus

D. It is the energy required to remove a single nucleon from a nucleus

[1 mark]