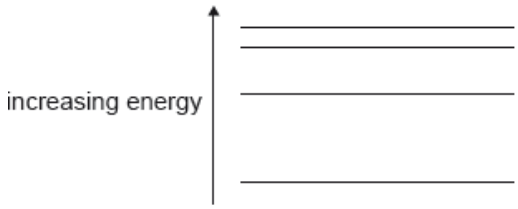
SL Paper 1

The energy-level diagram for an atom that has four energy states is shown.



What is the number of different wavelengths in the emission spectrum of this atom?

A. 1

B. 3

C. 6

D. 7

Markscheme

C

Examiners report

[N/A]

A graph of the variation of average binding energy per nucleon with nucleon number has a maximum. What is indicated by the region around the maximum?

A. The position below which radioactive decay cannot occur

B. The region in which fission is most likely to occur

C. The position where the most stable nuclides are found

D. The region in which fusion is most likely to occur

Markscheme

C

Examiners report

[N/A]

A detector, placed close to a radioactive source, detects an activity of 260 Bq. The average background activity at this location is 20 Bq. The radioactive nuclide has a half-life of 9 hours.

What activity is detected after 36 hours?

A. 15 Bq

B. 16 Bq

C. 20 Bq

D. 35 Bq

Markscheme

D

Examiners report

[N/A]

The average binding energy per nucleon of the $^{15}_{8}\mathrm{O}$ nucleus is 7.5 MeV. What is the total energy required to separate the nucleons of one nucleus of $^{15}_{8}\mathrm{O}$?

A. 53 MeV

B. 60 MeV

C. 113 MeV

D. 173 MeV

Markscheme

C

Examiners report

[N/A]

The half-life of a radioactive element is 5.0 days. A freshly-prepared sample contains 128 g of this element. After how many days will there be 16 g of this element left behind in the sample?

A. 5.0 days

B. 10 days

C. 15 days

Markscheme

C

Examiners report

[N/A]

Atomic spectra are caused when a certain particle makes transitions between energy levels.

What is this particle?

A. Electron

B. Proton

C. Neutron

D. Alpha particle

Markscheme

A

Examiners report

[N/A]

A sample contains an amount of radioactive material with a half-life of 3.5 days. After 2 weeks the fraction of the radioactive material remaining is

A. 94 %.

B. 25 %.

C. 6 %.

D. 0 %.

Markscheme

C

Examiners report

[N/A]

In a nuclear fission reaction, nucleus X splits into nucleus Y and nucleus Z. Which of the following gives a possible order of the nuclei from lowest to highest binding energy per nucleon?

A. Z → Y → X

B. Z → X → Y

C. Y → X → Z

D. X → Z → Y

Markscheme

D

Examiners report

[N/A]

Bismuth-210 $\left({}^{210}_{83}\mathrm{Bi}\right)$ is a radioactive isotope that decays as follows.

$$ {}^{210}_{83}\mathrm{Bi} \xrightarrow{\beta^-} \mathrm{X} \xrightarrow{\alpha} \mathrm{Y} $$

What are the mass number and proton number of Y?

	Mass number	Proton number
A.	206	86
B.	206	82
C.	210	82
D.	214	83

Markscheme

B

Examiners report

[N/A]

The initial number of atoms in a pure radioactive sample is *N*. The radioactive half-life of the sample is defined as the

A. time taken for one atom to undergo decay.

B. probability for $\frac{N}{2}$ atoms to undergo decay.

C. time taken for $\frac{N}{2}$ atoms to undergo decay.

D. probability that one atom will decay per unit time.

Markscheme

C

Examiners report

[N/A]

Which of the following is true about beta minus (β^-) decay?

A. An antineutrino is absorbed.

B. The charge of the daughter nuclide is less than that of the parent nuclide.

C. An antineutrino is emitted.

D. The mass number of the daughter nuclide is less than that of the parent nuclide.

Markscheme

C

Examiners report

[N/A]

Geiger and Marsden bombarded a thin gold foil with alpha particles. They observed that a small fraction of the alpha particles were deflected through angles greater than 90°. What does this observation suggest about the nucleus?

A. It is at the centre of the atom.

B. It is surrounded by orbiting electrons.

C. It is made of protons and neutrons.

D. It is a small region of the atom and is positively charged.

Markscheme

D

Examiners report

[N/A]

The nuclear reaction ${}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$ would best be described as

A. alpha decay.
B. nuclear fission.
C. nuclear fusion.
D. neutron capture.

Markscheme

C

Examiners report

What is the definition of the unified atomic mass unit?

A. The mass of one atom of hydrogen.

B. $\frac{1}{12}$ of the mass of an atom of carbon-12.

C. The mass of one atom of carbon-12.

D. $\frac{1}{16}$ of the mass of an atom of oxygen-16.

Markscheme

B

Examiners report

[N/A]

Which of the following affects the rate at which a sample of a radioactive material decays?

A. The mass of the sample
B. The temperature of the sample
C. The volume of the sample
D. The pressure acting on the sample

Markscheme

A

Examiners report

[N/A]

Nucleus P decays by a sequence of emissions to form nucleus Q. One α particle and two β^- particles are emitted during the sequence. Which statement is correct?

A. Nucleus P has the same number of neutrons as nucleus Q.

B. Nucleus P is an isotope of nucleus Q.

C. Nucleus P has a greater charge than nucleus Q.

D. Nucleus P has fewer protons than nucleus Q.

Markscheme

B

Examiners report

[N/A]

Which of the following correctly identifies the three particles emitted in the decay of the nucleus $^{45}_{20}\mathrm{Ca}$ into a nucleus of $^{45}_{21}\mathrm{Sc}$?

A. $\alpha,\ \beta^-,\ \gamma$

B. $\beta^-,\ \gamma, \bar{\nu}$

C. $\alpha,\ \gamma, \bar{\nu}$

D. $\alpha,\ \beta^-, \bar{\nu}$

Markscheme

B

Examiners report

[N/A]

The rest mass of a proton is $938\ \mathrm{MeV\,c^{-2}}$. The energy of a proton at rest is

A. 0

B. $9.38 \times 10^8 \times (3 \times 10^8)^2$ J

C. 9.38×10^8 eV

D. $9.38 \times 10^8 \times (3 \times 10^8)^2$ eV

Markscheme

C

Examiners report

Many candidates appeared unfamiliar with the unit $\mathrm{MeV\,c^{-2}}$, despite the fact that the Physics Guide states that students should be familiar with this unit.

A simple model of the hydrogen atom suggests that the electron orbits the proton. What is the force that keeps the electron in orbit?

A. Electrostatic

B. Gravitational

C. Strong nuclear

D. Centripetal

Markscheme

A

Examiners report

The question asks “What is the force?”, it does not ask “What is the nature/direction of the force?”. To distinguish the two it is probably best, when teaching, to use the adverb “centripetally” rather than centripetal. So we would say “The electrostatic force acts centripetally”. In this way the candidates understand that there are many different forces, all of which can act centripetally under certain conditions.

The Geiger–Marsden experiment provides evidence for

A. the existence of discrete atomic energy levels.

B. the existence of the neutron.

C. a dense positively charged nucleus.

D. the stability of some nuclei.

Markscheme

C

Examiners report

[N/A]

Emission and absorption spectra provide evidence for

A. the nuclear model of the atom.

B. natural radioactivity.

C. the existence of isotopes.

D. the existence of atomic energy levels.

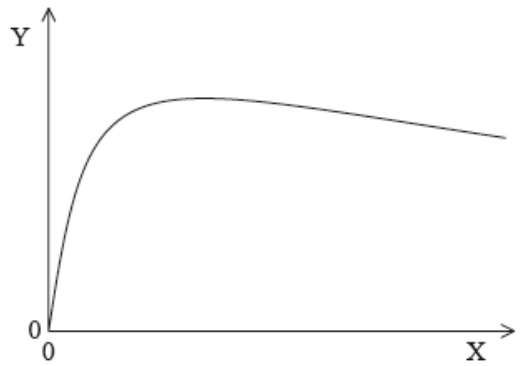
Markscheme

D

Examiners report

[N/A]

Data concerning nuclides are plotted using the axes below.



What are the axis labels for this graph?

	Y	X
A.	binding energy per nucleon	number of nucleons
B.	binding energy	number of protons
C.	number of protons	binding energy per nucleon
D.	number of nucleons	binding energy

Markscheme

A

Examiners report

[N/A]

What is the relationship between nucleon number *A*, proton number *Z* and neutron number *N*?

A. *A*=*Z*=*N*

B. *A*+*Z*=*N*

C. *A*–*Z*=*N*

D. *Z*–*A*=*N*

Markscheme

C

Examiners report

[N/A]

The nuclear reaction

$$^{2}_{1}\mathrm{H} + ^{3}_{1}\mathrm{H} \rightarrow ^{4}_{2}\mathrm{He} + ^{1}_{0}\mathrm{n}$$

is an example of

A. nuclear fission.

B. radioactive decay.

C. nuclear fusion.

D. artificial transmutation.

Markscheme

C

Examiners report

[N/A]

A radioactive isotope has a half-life of two minutes. A sample contains sixteen grams of the isotope. How much time elapses until one gram of the isotope remains?

A. 6 minutes

B. 8 minutes

C. 10 minutes

D. 12 minutes

Markscheme

B

Examiners report

[N/A]

When an alpha particle collides with a nucleus of nitrogen-14 $\left({}^{14}_{7}\mathrm{N}\right)$, a nucleus X can be produced together with a proton. What is X?

A. ${}^{18}_{8}\mathrm{X}$

B. ${}^{17}_{8}\mathrm{X}$

C. ${}^{18}_{9}\mathrm{X}$

D. ${}^{17}_{9}\mathrm{X}$

Markscheme

B

Examiners report

[N/A]

The binding energy per nucleon of ${}^{11}_{4}Be$ is 6 MeV. What is the energy required to separate the nucleons of this nucleus?

A. 24 MeV

B. 42 MeV

C. 66 MeV

D. 90 MeV

Markscheme

Examiners report

[N/A]

Which of the following is true in respect of both the Coulomb interaction and the strong interaction between nucleons in an atom?

	Coulomb interaction exists between	Strong interaction exists between
A.	protons only	neutrons only
B.	both protons and neutrons	neutrons only
C.	protons only	both protons and neutrons
D.	both protons and neutrons	both protons and neutrons

Markscheme

C

Examiners report

[N/A]

A radioactive sample has activity A_0 at t=0. What will be the activity of the sample after two half-lives?

A. zero
B. $\frac{A_0}{4}$
C. less than $\frac{A_0}{4}$ if the sample is kept at high pressure
D. greater than $\frac{A_0}{4}$ if the sample is kept at high temperature

Markscheme

B

Examiners report

Element X decays through a series of alpha (α) and beta minus (β^-) emissions. Which series of emissions results in an isotope of X?

A. 1α and 2β^-

B. 1α and 4β^-

C. 2α and 2β^-

D. 2α and 3β^-

Markscheme

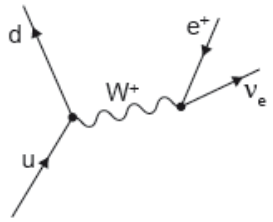
A

Examiners report

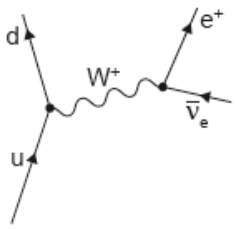
[N/A]

Which Feynman diagram shows beta-plus (β^+) decay?

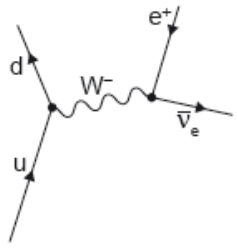
A.



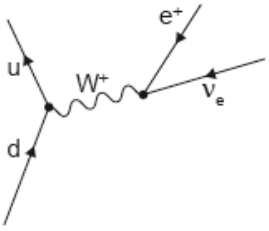
B.



C.



D.



Markscheme

A

Examiners report

[N/A]

A radio-isotope has an activity of 400 Bq and a half-life of 8 days. After 32 days the activity of the sample is

A. 200 Bq.

B. 100 Bq.

C. 50 Bq.

D. 25 Bq.

Markscheme

D

Examiners report

[N/A]

As quarks separate from each other within a hadron, the interaction between them becomes larger. What is the nature of this interaction?

A. Electrostatic
B. Gravitational
C. Strong nuclear
D. Weak nuclear

Markscheme

C

Examiners report

[N/A]

Three of the fundamental forces between particles are

I. strong nuclear

II. weak nuclear

III. electromagnetic.

What forces are experienced by an electron?

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Markscheme

C

Examiners report

Which of the following lists three fundamental forces in increasing order of strength?

A. electromagnetic, gravity, strong nuclear
B. weak nuclear, gravity, strong nuclear
C. gravity, weak nuclear, electromagnetic
D. electromagnetic, strong nuclear, gravity

Markscheme

C

Examiners report

[N/A]

The relationship between proton number Z, neutron number N and nucleon number A is

A. $A = Z - N$.
B. $Z = A + N$.
C. $N = A - Z$.
D. $N = A + Z$.

Markscheme

C

Examiners report

[N/A]

The mass defect for deuterium is 4×10^{-30} kg. What is the binding energy of deuterium?

A. 4×10^{-7} eV
B. 8×10^{-2} eV
C. 2×10^{6} eV
D. 2×10^{12} eV

Markscheme

C

Examiners report

[N/A]

What is the energy equivalent to the mass of one proton?

A. $9.38 \times (3 \times 10^8)^2 \times 10^6$ J

B. $9.38 \times (3 \times 10^8)^2 \times 1.6 \times 10^{-19}$ J

C. $\frac{9.38 \times 10^8}{1.6 \times 10^{-19}}$ J

D. $9.38 \times 10^8 \times 1.6 \times 10^{-19}$ J

Markscheme

D

Examiners report

[N/A]

A simple model of an atom has five energy levels. What is the maximum number of different frequencies in the emission spectrum of that atom?

A. 4

B. 6

C. 10

D. 25

Markscheme

C

Examiners report

[N/A]

In the Geiger–Marsden experiment α-particles are scattered by gold nuclei. The experimental results provide evidence that

A. α-particles have discrete amounts of kinetic energy.

B. most of the mass and positive charge of an atom is concentrated in a small volume.

C. the nucleus contains protons and neutrons.

D. gold atoms have a high binding energy per nucleon.

Markscheme

B

Examiners report

[N/A]

The binding energy per nucleon of a $^{3}_{1}\mathrm{H}$ nucleus is 3 MeV. What is the minimum energy needed to

completely separate the nucleons of $^{3}_{1}\mathrm{H}$?

A. 12 MeV
B. 9 MeV
C. 6 MeV
D. 3 MeV

Markscheme

B

Examiners report

Two pure samples of radioactive nuclides X and Y have the same initial number of atoms. The half-life of X is $T_{\frac{1}{2}}$.

After a time equal to 4 half-lives of X the ratio $\frac{\text{number of atoms of X}}{\text{number of atoms of Y}}$ is $\frac{1}{8}$.

What is the half-life of Y?

A. $0.25T_{\frac{1}{2}}$

B. $0.5T_{\frac{1}{2}}$

C. $3T_{\frac{1}{2}}$

D. $4T_{\frac{1}{2}}$

Markscheme

Examiners report

[N/A]

The number of neutrons and the number of protons in a nucleus of an atom of the isotope of uranium $^{235}_{92}\mathrm{U}$ are

	Neutrons	Protons
A.	92	143
B.	143	92
C.	235	92
D.	92	235

Markscheme

B

Examiners report

[N/A]

What is the definition of the unified atomic mass unit?

A. $\frac{1}{12}$ the mass of a neutral atom of carbon-12

B. The mass of a neutral atom of hydrogen-1

C. $\frac{1}{12}$ the mass of a nucleus of carbon-12

D. The mass of a nucleus of hydrogen-1

Markscheme

A

Examiners report

[N/A]

Which particle is acted on by both the strong nuclear force and the Coulomb force?

A. Antineutrino
B. Electron
C. Neutron
D. Proton

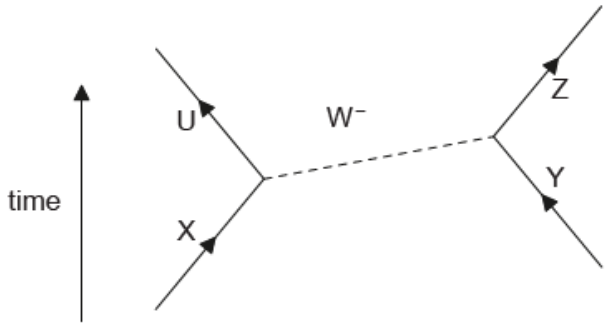
Markscheme

D

Examiners report

[N/A]

The Feynman diagram shows a particle interaction involving a W^- boson.



Which particles are interacting?

A. U and Y

B. W^- boson and Y

C. X and Y

D. U and X

Markscheme

C

Examiners report

[N/A]

A nucleus of the isotope plutonium-238 $\left(^{238}\mathrm{P}\right)$ decays into a nucleus of uranium by emitting an alpha particle. What is the nucleon number of the uranium nucleus?

A. 234
B. 236
C. 238

D. 240

Markscheme

A

Examiners report

[N/A]

The nuclear reaction equation for the decay of a nucleus of thorium-231 (Th-231) to a nucleus of protactinium-231 (Pa-231) is shown below.

$$^{231}_{90}\mathrm{Th} \rightarrow {}^{231}_{91}\mathrm{Pa} + \beta^{-} + x$$

The particle *x* is a/an

A. proton.
B. antineutrino.
C. neutron.
D. electron.

Markscheme

B

Examiners report

Which of the following is the correct definition of the binding energy of a nucleus?

A. The product of the binding energy per nucleon and the nucleon number

B. The minimum work required to completely separate the nucleons from each other

C. The energy that keeps the nucleus together

D. The energy released during the emission of an alpha particle

Markscheme

B

Examiners report

[N/A]

For which quantity can the unit $MeVc^{-2}$ be used?

A. Mass
B. Momentum
C. Kinetic energy
D. Binding energy

Markscheme

A

Examiners report

This proved to be a difficult question, with many candidates opting for response D. This is possibly down to the fact that they encountered these units in the topic on binding energy so they have made an incorrect connection. Often such questions can be approached by elimination. By being aware that responses C and D both involved energy, they were unlikely to be the correct answer. The physics data book also has the masses of particles expressed in the same units.

For which reason were quarks first introduced?

A. To explain the existence of isotopes
B. To describe nuclear emission and absorption spectra
C. To account for patterns in properties of elementary particles
D. To account for the missing energy and momentum in beta decay

Markscheme

C

Examiners report

[N/A]

The reaction $p^+ + n^0 \rightarrow p^+ + \pi^0$ does not occur because it violates the conservation law of

A. electric charge.

B. baryon number.

C. lepton number.

D. strangeness.

Markscheme

B

Examiners report

[N/A]

Which statement about atomic spectra is **not** true?

A. They provide evidence for discrete energy levels in atoms.

B. Emission and absorption lines of equal frequency correspond to transitions between the same two energy levels.

C. Absorption lines arise when electrons gain energy.

D. Emission lines always correspond to the visible part of the electromagnetic spectrum.

Markscheme

D

Examiners report

[N/A]

The half-life of a particular radioactive isotope is 8 days. The initial activity of a pure sample of the isotope is A.

Which of the following is the time taken for the activity of the isotope to change by $\frac{7}{8}A$?

A. 7 days
B. 24 days
C. 32 days
D. 56 days

Markscheme

B

Examiners report

Which of the following provides evidence for the existence of atomic energy levels?

A. Absorption spectra

B. Nuclear fission

C. The Geiger–Marsden experiment

D. Radioactive decay

Markscheme

A

Examiners report

[N/A]

Which statement correctly describes the process of nuclear fusion?

A. The joining together of two small atoms to create a larger atom.

B. The splitting up of a large atom to create two smaller atoms.

C. The joining together of two small nuclei to create a larger nucleus.

D. The splitting up of a large nucleus to create two smaller nuclei.

Markscheme

C

Examiners report

[N/A]

The nuclear equation below is an example of the transmutation of mercury into gold.

$$^{2}_{1}\mathrm{H} + ^{199}_{80}\mathrm{Hg} \rightarrow ^{197}_{79}\mathrm{Au} + \mathrm{X}$$

The particle **X** is a

A. gamma-ray photon.

B. helium nucleus.

C. proton.

D. neutron.

Markscheme

B

Examiners report

Nuclei of the isotope nitrogen-14 are bombarded with neutrons and as a result nuclei of an isotope of carbon are produced. The nuclear reaction equation for this process may be written as

$$^{14}_{7}\mathrm{N} + \mathrm{neutron} \rightarrow {}^{A}_{6}\mathrm{C} + \mathrm{proton}$$

What is the nucleon number *A* of the isotope of carbon?

A. 12

B. 13

C. 14

D. 15

Markscheme

C

Examiners report

Many candidates opted for B, presumably assuming that a neutron had no mass.

In a particular atom, the nucleon number is the total number of

A. protons.
B. neutrons.
C. electrons.
D. protons and neutrons.

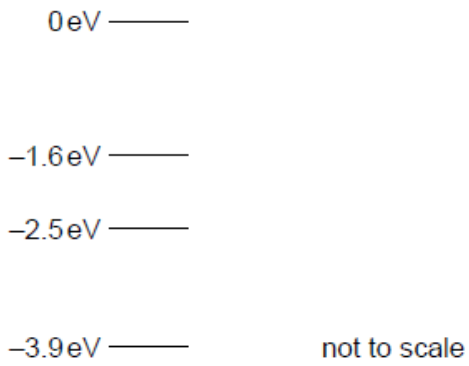
Markscheme

D

Examiners report

[N/A]

Photons of energy 2.3eV are incident on a low-pressure vapour. The energy levels of the atoms in the vapour are shown



What energy transition will occur when a photon is absorbed by the vapour?

A. –3.9eV to –1.6eV

B. –1.6eV to 0eV

C. –1.6eV to –3.9eV

D. 0eV to –1.6eV

Markscheme

A

Examiners report

[N/A]

When compared with beta particles and gamma-ray photons, alpha particles have the greatest

A. mass.

B. penetrating power.

C. range in air.

D. speed.

Markscheme

A

Examiners report

[N/A]

In a neutral atom there are n_e electrons, n_p protons and n_n neutrons. What is the mass number of the nuclide?

A. $n_p + n_e + n_n$

B. $n_p + n_n$

C. $n_n + n_p - n_e$

D. $n_n - n_e$

Markscheme

B

Examiners report

[N/A]

A freshly prepared sample contains 4.0 μg of iodine-131. After 24 days, 0.5μg of iodine-131 remain. The best estimate of the half-life of iodine-131 is

A. 8 days.
B. 12 days.
C. 24 days.
D. 72 days.

Markscheme

A

Examiners report

[N/A]

A nucleus of californium (Cf) contains 98 protons and 154 neutrons. Which of the following correctly identifies this nucleus of californium?

A. $^{98}_{252}\mathrm{Cf}$

B. $^{154}_{98}\mathrm{Cf}$

C. $^{252}_{98}\mathrm{Cf}$

D. $^{350}_{154}\mathrm{Cf}$

Markscheme

C

Examiners report

[N/A]

Which of the following gives the correct number of protons and neutrons in a nucleus of carbon-14 $\left({}^{14}_{6}\mathrm{C}\right)$.

	Protons	Neutrons
A.	8	6
B.	6	8
C.	14	6
D.	6	14

Markscheme

B

Examiners report

[N/A]

A nucleus of phosphorus (P) decays to a nucleus of silicon (Si) with the emission of particle X and particle Y.

$$ {}^{30}_{15}\mathrm{P} \rightarrow {}^{30}_{14}\mathrm{Si} + \mathrm{X} + \mathrm{Y} $$

What are X and Y?

	X	Y
A.	antineutrino	positron
B.	antineutrino	electron
C.	neutrino	electron
D.	neutrino	positron

Markscheme

D

Examiners report

[N/A]

In nuclear fission, a nucleus of element X absorbs a neutron (n) to give a nucleus of element Y and a nucleus of element Z.

$$X + n \rightarrow Y + Z + 2n$$

What is $\frac{\text{magnitude of the binding energy per nucleon of Y}}{\text{magnitude of the binding energy per nucleon of X}}$ and $\frac{\text{total binding energy of Y and Z}}{\text{total binding energy of X}}$?

	$\frac{\text{Magnitude of the binding energy per nucleon of Y}}{\text{Magnitude of the binding energy per nucleon of X}}$	$\frac{\text{Total binding energy of Y and Z}}{\text{Total binding energy of X}}$
A.	greater than 1	greater than 1
B.	less than 1	greater than 1
C.	greater than 1	less than 1
D.	less than1	less than 1

Markscheme

A

Examiners report

[N/A]

A student suggests the following nuclear reaction between deuterium ${}^{2}_{1}\mathrm{H}$ and tritium ${}^{3}_{1}\mathrm{H}$

$${}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow n\mathrm{X} + m\mathrm{Y}$$

where *n* and *m* are integers. What are X and Y?

	X	Y
A.	electron	neutron
B.	electron	proton
C.	alpha particle	neutron
D.	alpha particle	proton

Markscheme

C

Examiners report

A few comments from the G2 forms suggested that B was indeed possible with $n = 3$ and $m = 5$. This is, however, only a mathematical possibility and there is no evidence that candidates were distracted. Over 80% of the HL candidates and 60% of the SL candidates selected the correct response, recognising the reaction as fusion.

What gives the total change in nuclear mass and the change in nuclear binding energy as a result of a nuclear fusion reaction?

	Nuclear mass	Nuclear binding energy
A.	decreases	decreases
B.	decreases	increases
C.	increases	decreases
D.	increases	increases

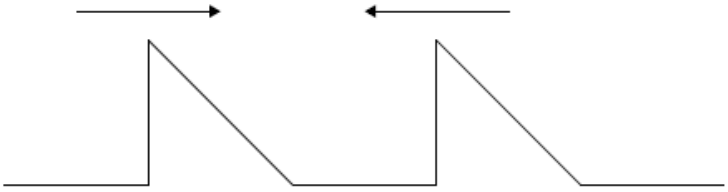
Markscheme

B

Examiners report

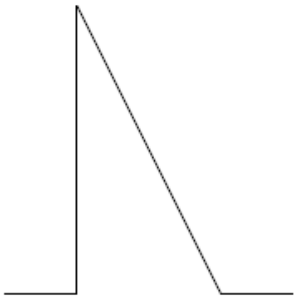
[N/A]

Two pulses are travelling towards each other.

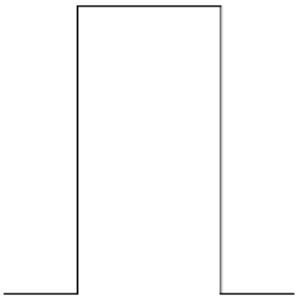


What is a possible pulse shape when the pulses overlap?

A.

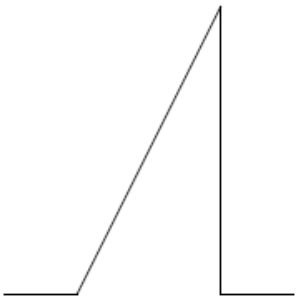


B.



C.

D.



Markscheme

A

Examiners report

[N/A]

An electron is accelerated through a potential difference of 100 V. Which of the following gives the correct gain in kinetic energy of the electron in both joule and electronvolt?

	Joule / J	Electronvolt / eV
A.	100	100
B.	1.6×10^{-17}	100
C.	100	1.6×10^{-17}
D.	1.6×10^{-17}	1.6×10^{-17}

Markscheme

B

Examiners report

[N/A]

Which nucleons in a nucleus are involved in the Coulomb interaction and the strong short-range nuclear interaction?

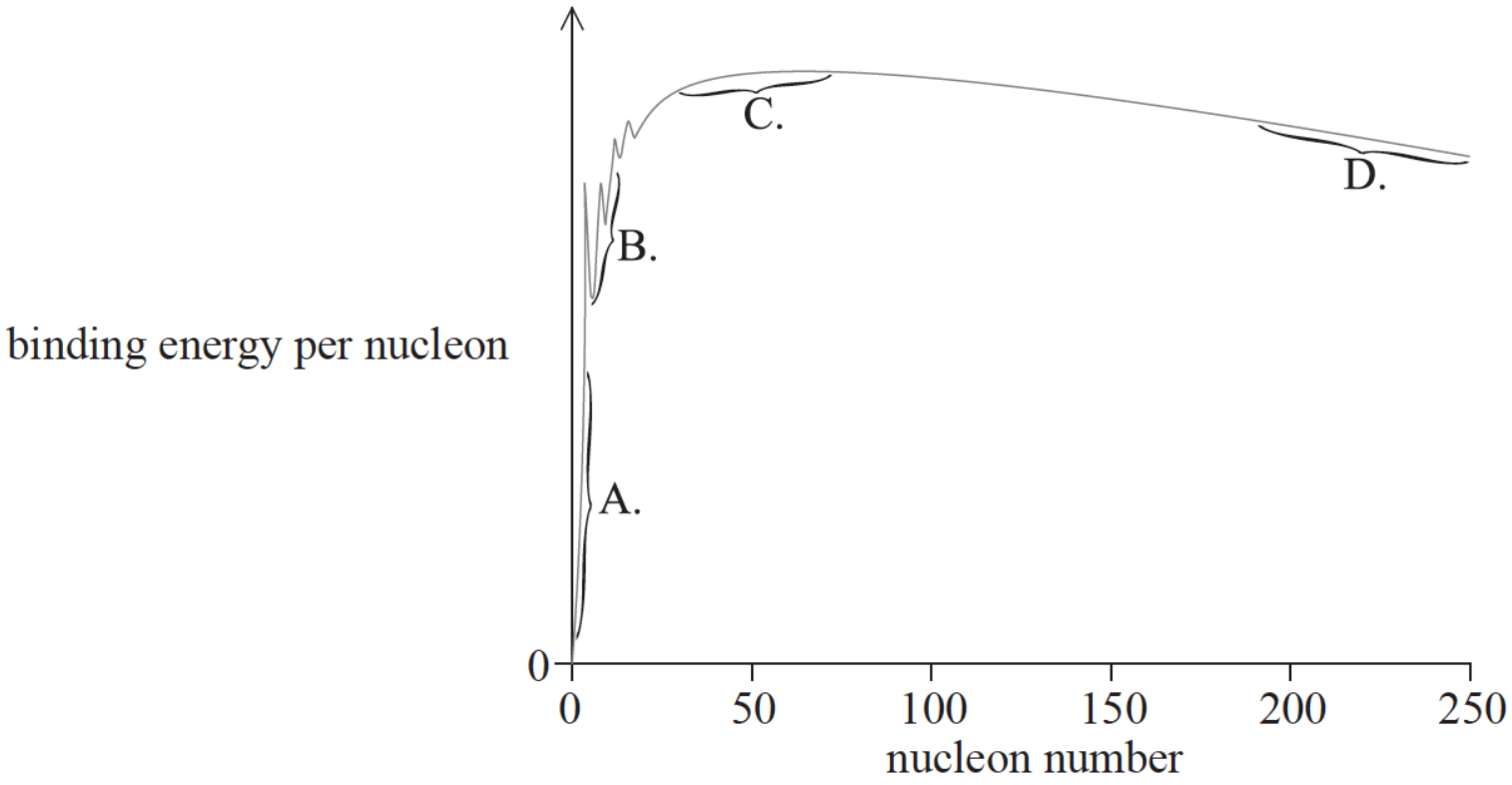
	Coulomb interaction	Strong short-range interaction
A.	protons	protons, neutrons
B.	protons	neutrons
C.	protons	protons
D.	protons, neutrons	neutrons

Markscheme

A

Examiners report

The graph shows the relationship between binding energy per nucleon and nucleon number. In which region are nuclei most stable?



Markscheme

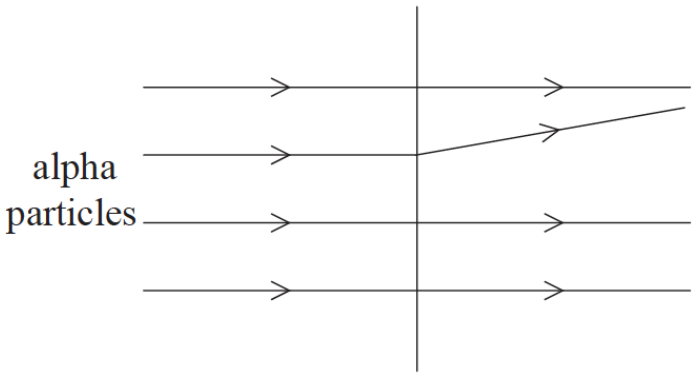
C

Examiners report

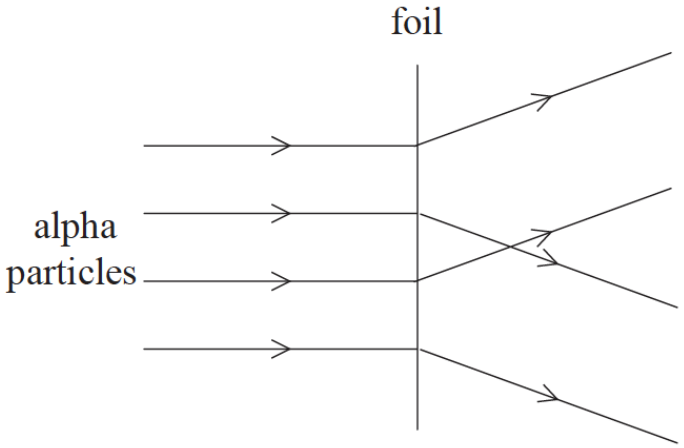
[N/A]

In the Geiger–Marsden experiment alpha particles were directed at a thin gold foil. Which of the following shows how the majority of the alpha particles behaved after reaching the foil?

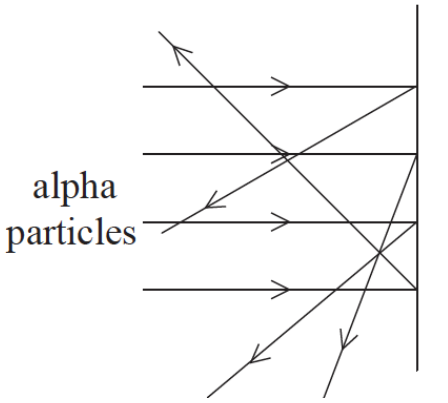
A.



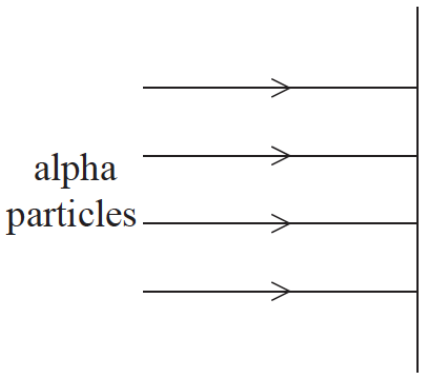
B.



C.



D.



Markscheme

A

Examiners report

Response B with many particles being significantly deflected was a common choice of candidates at both levels; A shows the clear majority of particles passing through the foil undeflected.