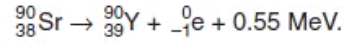


Q1.

- 6 Strontium-90 decays with the emission of a β -particle to form Yttrium-90. The reaction is represented by the equation



The decay constant is 0.025 year^{-1} .

- (a) Suggest, with a reason, which nucleus, ${}_{38}^{90}\text{Sr}$ or ${}_{39}^{90}\text{Y}$, has the greater binding energy.

.....
.....
..... [2]

- (b) Explain what is meant by the decay constant.

.....
.....
..... [2]

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(c) At the time of purchase of a Strontium-90 source, the activity is 3.7×10^6 Bq.

(i) Calculate, for this sample of strontium,

1. the initial number of atoms,

number = [3]

2. the initial mass.

mass = kg [2]

(ii) Determine the activity A of the sample 5.0 years after purchase, expressing the answer as a fraction of the initial activity A_0 . That is, calculate the ratio $\frac{A}{A_0}$.

ratio = [2]

Q2.

MEGA LECTURE

8 Fig. 8.1 shows the variation with nucleon number of the binding energy per nucleon of a nucleus.

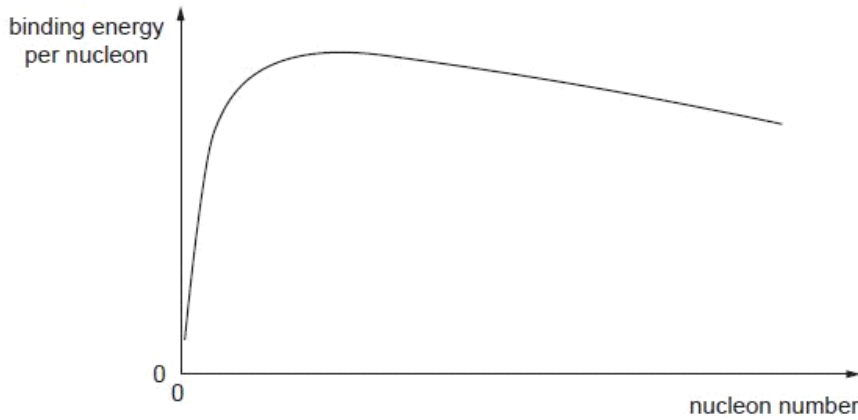
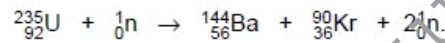


Fig. 8.1

(a) On Fig. 8.1, mark with the letter S the position of the nucleus with the greatest stability. [1]

(b) One possible fission reaction is



(i) On Fig. 8.1, mark possible positions for

1. the Uranium-235 (${}_{92}^{235}\text{U}$) nucleus (label this position U),
2. the Krypton-90 (${}_{36}^{90}\text{Kr}$) nucleus (label this position Kr). [1]

(ii) The binding energy per nucleon of each nucleus is as follows.

$${}_{92}^{235}\text{U}: 1.2191 \times 10^{-12} \text{ J}$$

$${}_{56}^{144}\text{Ba}: 1.3341 \times 10^{-12} \text{ J}$$

$${}_{36}^{90}\text{Kr}: 1.3864 \times 10^{-12} \text{ J}$$

Use these data to calculate

1. the energy release in this fission reaction (give your answer to three significant figures),

energy = J [3]

2. the mass equivalent of this energy.

mass = kg [2]

- (iii) Suggest why the neutrons were not included in your calculation in (ii).

.....
..... [1]

Q3.

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●
●
MEGA LECTURE

7 The isotope Manganese-56 decays and undergoes β -particle emission to form the stable isotope Iron-56. The half-life for this decay is 2.6 hours. Initially, at time $t = 0$, a sample of Manganese-56 has a mass of $1.4\ \mu\text{g}$ and there is no Iron-56.

Us

(a) Complete Fig. 7.1 to show the variation with time t of the mass of Iron-56 in the sample for time $t = 0$ to time $t = 11$ hours.

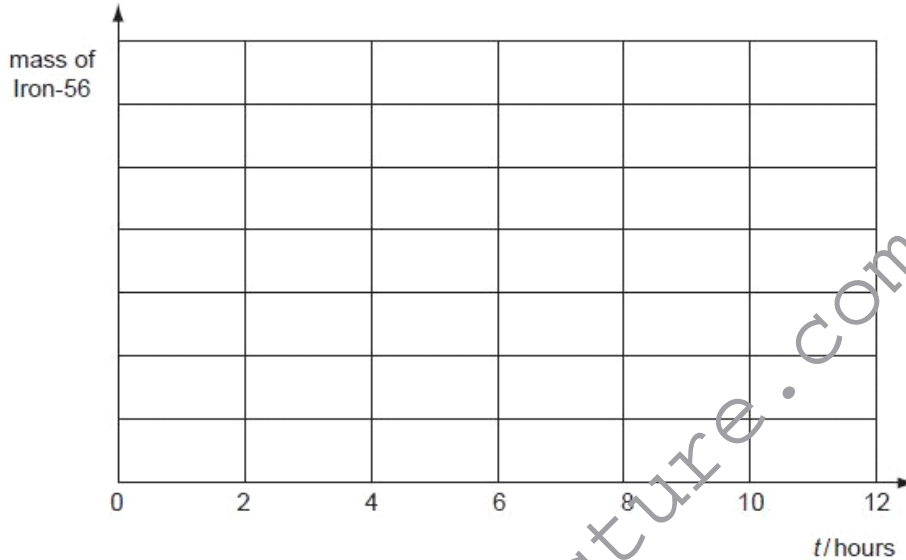


Fig. 7.1

[2]

(b) For the sample of Manganese-56, determine

(i) the initial number of Manganese-56 atoms in the sample,

number =[2]

(ii) the initial activity.

activity = Bq [3]



(c) Determine the time at which the ratio

$$\frac{\text{mass of Iron-56}}{\text{mass of Manganese-56}}$$

is equal to 9.0.

time = hours [2]

Q4.

6 (a) Define the *decay constant* of a radioactive isotope.

.....
.....
..... [2]

(b) Strontium-90 is a radioactive isotope having a half-life of 28.0 years. Strontium-90 has a density of 2.54 g cm^{-3} .

A sample of Strontium-90 has an activity of $6.4 \times 10^9 \text{ Bq}$. Calculate

(i) the decay constant λ , in s^{-1} , of Strontium-90,

$\lambda = \dots\dots\dots \text{s}^{-1}$ [2]

(ii) the mass of Strontium-90 in the sample,

mass = g [4]

(iii) the volume of the sample.

volume = cm³ [1]

(c) By reference to your answer in (b)(iii), suggest why dust that has been contaminated with Strontium-90 presents a serious health hazard.

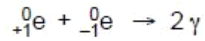
.....
.....
..... [2]

Q5.



- 8 A positron (${}^0_+1e$) is a particle that has the same mass as an electron and has a charge of $+1.6 \times 10^{-19} \text{C}$.
A positron will interact with an electron to form two γ -ray photons.

Ex



Assuming that the kinetic energy of the positron and the electron is negligible when they interact,

- (a) suggest why the two photons will move off in opposite directions with equal energies,

.....
.....
.....
.....
.....
.....
.....[3]

- (b) calculate the energy, in MeV, of one of the γ -ray photons.

energy = MeV [3]

Q6.

MEGA LECTURE

- 9 (a) A sample of a radioactive isotope contains N nuclei at time t . At time $(t + \Delta t)$, it contains $(N - \Delta N)$ nuclei of the isotope.

Examiner

For the period Δt , state, in terms of N , ΔN and Δt ,

- (i) the mean activity of the sample,

activity = [1]

- (ii) the probability of decay of a nucleus.

probability = [1]

- (b) A cobalt-60 source having a half-life of 5.27 years is calibrated and found to have an activity of 3.50×10^5 Bq. The uncertainty in the calibration is $\pm 2\%$.

Calculate the length of time, in days, after the calibration has been made, for the stated activity of 3.50×10^5 Bq to have a maximum possible error of 10%.

time = days [4]

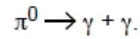
Q7.

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- 8 A π^0 meson is a sub-atomic particle.
A stationary π^0 meson, which has mass 2.4×10^{-28} kg, decays to form two γ -ray photons.
The nuclear equation for this decay is

Fi
Exam
U



- (a) Explain why the two γ -ray photons have the same energy.

.....
.....
..... [2]

- (b) Determine, for each γ -ray photon,

- (i) the energy, in joule,

energy = J [2]

- (ii) the wavelength,

wavelength = m [2]

(iii) the momentum.

Ex

momentum = N s [2]

Q8.

8 Americium-241 is an artificially produced radioactive element that emits α -particles. A sample of americium-241 of mass $5.1 \mu\text{g}$ is found to have an activity of $5.9 \times 10^5 \text{ Bq}$.

For
Exam
Use

(a) Determine, for this sample of americium-241,

(i) the number of nuclei,

number = [2]

(ii) the decay constant,

decay constant = s^{-1} [2]

MEGA LECTURE

(iii) the half-life, in years.

half-life = years [2]

(b) Another radioactive element has a half-life of approximately 4 hours. Suggest why measurement of the mass and activity of a sample of this element is not appropriate for the determination of its half-life.

.....
..... [1]

Q9.

8 (a) The variation with nucleon number A of the binding energy per nucleon B_E of nuclei is shown in Fig. 8.1.

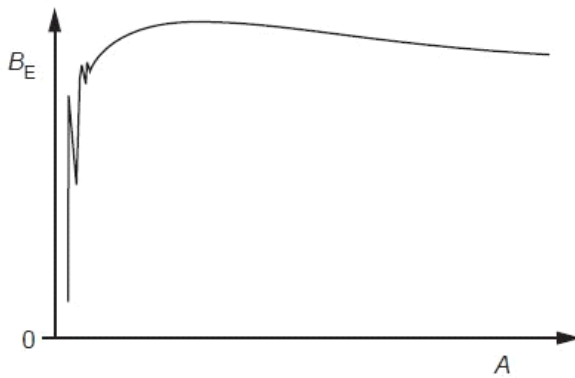


Fig. 8.1

On Fig. 8.1, mark the approximate positions of

- (i) iron-56 (label this point Fe), [1]
- (ii) zirconium-97 (label this point Zr), [1]
- (iii) hydrogen-2 (label this point H). [1]

(b) (i) State what is meant by *nuclear fission*.

.....
.....
..... [2]

(ii) By reference to Fig. 8.1, explain how fission is energetically possible.

.....
.....
..... [2]

Q10.

8 (a) State what is meant by the *binding energy* of a nucleus.

.....
.....
..... [2]

(b) Show that the energy equivalence of 1.0u is 930MeV.

[3]

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(c) Data for the masses of some particles and nuclei are given in Fig. 8.1.

	mass/u
proton	1.0073
neutron	1.0087
deuterium (${}^2_1\text{H}$)	2.0141
zirconium (${}^{97}_{40}\text{Zr}$)	97.0980

Fig. 8.1

Use data from Fig. 8.1 and information from (b) to determine, in MeV,

(i) the binding energy of deuterium,

binding energy = MeV [2]

(ii) the binding energy **per nucleon** of zirconium.

binding energy per nucleon = MeV [3]

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Us

Q11.

MEGA LECTURE

9 (a) (i) State what is meant by the *decay constant* of a radioactive isotope.

For
Exami
Us

.....
.....
..... [2]

(ii) Show that the decay constant λ and the half-life $t_{\frac{1}{2}}$ of an isotope are related by the expression

$$\lambda t_{\frac{1}{2}} = 0.693.$$

[3]

(b) In order to determine the half-life of a sample of a radioactive isotope, a student measures the count rate near to the sample, as illustrated in Fig. 9.1.

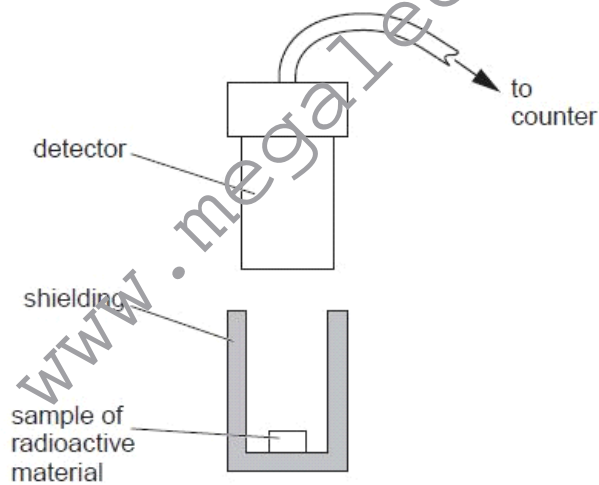


Fig. 9.1



Initially, the measured count rate is 538 per minute. After a time of 8.0 hours, the measured count rate is 228 per minute.

For
Examin
Use

Use these data to estimate the half-life of the isotope.

half-life = hours [3]

- (c) The accepted value of the half-life of the isotope in (b) is 5.8 hours.
The difference between this value for the half-life and that calculated in (b) cannot be explained by reference to faulty equipment.

Suggest two possible reasons for this difference.

1.

.....

2.

.....

[2]

Q12.

MEGA LECTURE

8 The element strontium has at least 16 isotopes. One of these isotopes is strontium-89. This isotope has a half-life of 52 days.

Exa
1

(a) State what is meant by *isotopes*.

.....
.....
..... [2]

(b) Calculate the probability per second of decay of a nucleus of strontium-89.

probability = s⁻¹ [3]

(c) A laboratory prepares a strontium-89 source. The activity of this source is measured 21 days after preparation of the source and is found to be 7.4×10^6 Bq.

Determine, for the strontium-89 source at the time that it was prepared,

(i) the activity,

activity = Bq [2]

(ii) the mass of strontium-89.

mass = g [2]

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Q13.

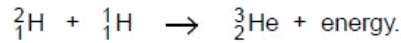
8 (a) State what is meant by a *nuclear fusion reaction*.

.....

 [2]

Ex
L

(b) One nuclear reaction that takes place in the core of the Sun is represented by the equation



Data for the nuclei are given in Fig. 8.1.

	mass/u
proton ${}^1_1\text{H}$	1.00728
deuterium ${}^2_1\text{H}$	2.01410
helium ${}^3_2\text{He}$	3.01605

Fig. 8.1

(i) Calculate the energy, in joules, released in this reaction.

energy = J [3]

(ii) The temperature in the core of the Sun is approximately $1.6 \times 10^7\text{K}$.
 Suggest why such a high temperature is necessary for this reaction to take place.

.....

 [2]

Q14.


MEGA LECTURE

- 8 (a) Explain why the mass of an α -particle is less than the total mass of two individual protons and two individual neutrons.

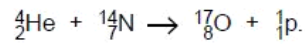
For
Examiner
Use

.....

.....

..... [2]

- (b) An equation for one possible nuclear reaction is



Data for the masses of the nuclei are given in Fig. 8.1.

		mass / u
proton	${}^1_1\text{p}$	1.00728
helium-4	${}^4_2\text{He}$	4.00260
nitrogen-14	${}^{14}_7\text{N}$	14.00307
oxygen-17	${}^{17}_8\text{O}$	16.99913

Fig. 8.1

- (i) Calculate the mass change, in u, associated with this reaction.

mass change = u [2]

- (ii) Calculate the energy, in J, associated with the mass change in (i).

energy = J [2]



(iii) Suggest and explain why, for this reaction to occur, the helium-4 nucleus must have a minimum speed.

Ex
L

.....
.....
..... [2]

Q15.

8 (a) Define the term radioactive *decay constant*.

Use

.....
.....
.....[2]

(b) State the relation between the activity A of a sample of a radioactive isotope containing N atoms and the decay constant λ of the isotope.

.....[1]

(c) Radon is a radioactive gas with half-life 56 s. For health reasons, the maximum permissible level of radon in air in a building is set at 1 radon atom for every 1.5×10^{21} molecules of air. 1 mol of air in the building is contained in 0.024 m^3 .

Calculate, for this building,

(i) the number of molecules of air in 1.0 m^3 ,

number =



(ii) the maximum permissible number of radon atoms in 1.0 m^3 of air,

number =

(iii) the maximum permissible activity of radon per cubic metre of air.

activity = Bq
[5]

Q16.

6 The isotopes Radium-224 ($^{224}_{88}\text{Ra}$) and Radium-226 ($^{226}_{88}\text{Ra}$) both undergo spontaneous α -particle decay. The energy of the α -particles emitted from Radium-224 is 5.68 MeV and from Radium-226, 4.78 MeV.

(a) (i) State what is meant by the *decay constant* of a radioactive nucleus.

.....
.....
..... [2]

(ii) Suggest, with a reason, which of the two isotopes has the larger decay constant.

.....
.....
.....
..... [3]

(b) Radium-224 has a half-life of 3.6 days.

(i) Calculate the decay constant of Radium-224, stating the unit in which it is measured.

decay constant =[2]

(ii) Determine the activity of a sample of Radium-224 of mass 2.24 mg .

activity = Bq [4]

(c) Calculate the number of half-lives that must elapse before the activity of a sample of a radioactive isotope is reduced to one tenth of its initial value.

Use

number of half-lives =[2]

Q17.

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●
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MEGA LECTURE

7 Fig. 7.1 illustrates the variation with nucleon number A of the binding energy per nucleon E of nuclei.

USE

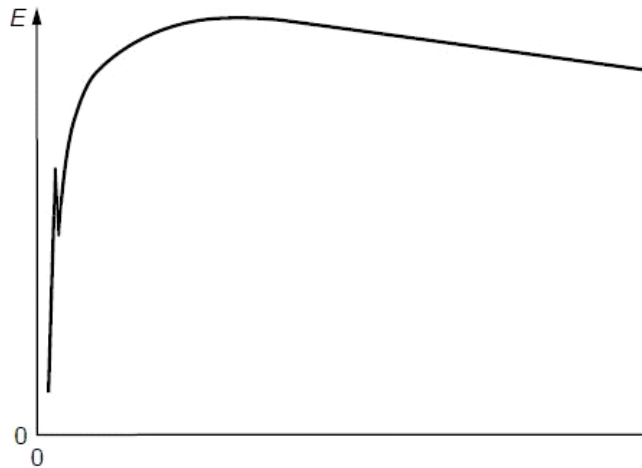


Fig. 7.1

(a) (i) Explain what is meant by the *binding energy* of a nucleus.

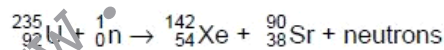
.....

.....

..... [2]

(ii) On Fig. 7.1, mark with the letter S the region of the graph representing nuclei having the greatest stability. [1]

(b) Uranium-235 may undergo fission when bombarded by a neutron to produce Xenon-142 and Strontium-90 as shown below.



(i) Determine the number of neutrons produced in this fission reaction.

number = [1]

(ii) Data for binding energies per nucleon are given in Fig. 7.2.

isotope	binding energy per nucleon / MeV
Uranium-235	7.59
Xenon-142	8.37
Strontium-90	8.72

Fig. 7.2

Calculate

1. the energy, in MeV, released in this fission reaction,

energy = MeV [3]

2. the mass equivalent of this energy.

mass = kg [3]

Q18.

MEGA LECTURE

8 Uranium-234 is radioactive and emits α -particles at what appears to be a constant rate.

A sample of Uranium-234 of mass $2.65 \mu\text{g}$ is found to have an activity of 604 Bq .

(a) Calculate, for this sample of Uranium-234,

(i) the number of nuclei,

number = [2]

(ii) the decay constant,

decay constant = s^{-1} [2]

(iii) the half-life in years

half-life = years [2]

MEGA LECTURE

(b) Suggest why the activity of the Uranium-234 appears to be constant.

.....
..... [1]

(c) Suggest why a measurement of the mass and the activity of a radioactive isotope is not an accurate means of determining its half-life if the half-life is approximately one hour.

.....
..... [1]

U₁

Q19.

7 (a) Explain what is meant by the *binding energy* of a nucleus.

.....
..... [1]

(b) Fig. 7.1 shows the variation with nucleon number (mass number) A of the binding energy per nucleon E_B of nuclei.

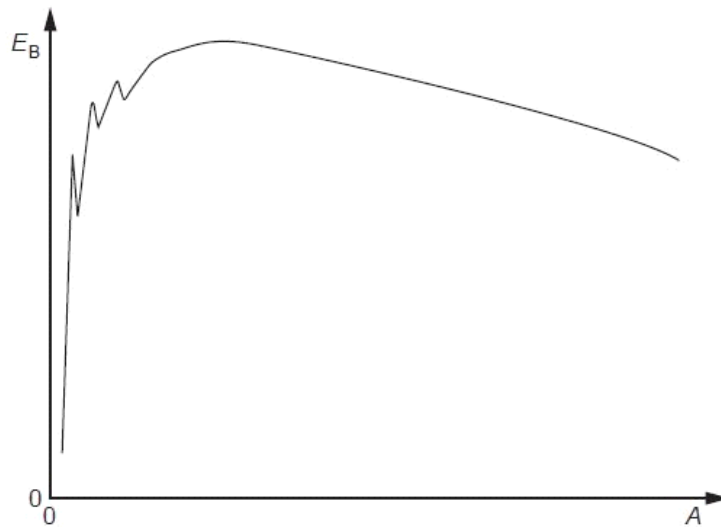
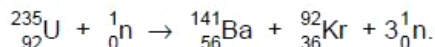


Fig. 7.1

U₂



One particular fission reaction may be represented by the nuclear equation



- (i) On Fig. 7.1, label the approximate positions of
1. the uranium (${}_{92}^{235}\text{U}$) nucleus with the symbol U,
 2. the barium (${}_{56}^{141}\text{Ba}$) nucleus with the symbol Ba,
 3. the krypton (${}_{36}^{92}\text{Kr}$) nucleus with the symbol Kr. [2]
- (ii) The neutron that is absorbed by the uranium nucleus has very little kinetic energy. Explain why this fission reaction is energetically possible.

.....

.....

..... [2]

- (c) Barium-141 has a half-life of 18 minutes. The half-life of Krypton-92 is 3.0 s. In the fission reaction of a mass of Uranium-235, equal numbers of barium and krypton nuclei are produced. Estimate the time taken after the fission of the sample of uranium for the ratio

$$\frac{\text{number of Barium-141 nuclei}}{\text{number of Krypton-92 nuclei}}$$

to be approximately equal to 8.

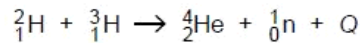
time = s [3]

Q20.


MEGA LECTURE

- 8 The controlled reaction between deuterium (${}^2_1\text{H}$) and tritium (${}^3_1\text{H}$) has involved ongoing research for many years. The reaction may be summarised as

For
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where $Q = 17.7\text{MeV}$.

Binding energies per nucleon are shown in Fig. 8.1.

	binding energy per nucleon /MeV
${}^2_1\text{H}$	1.12
${}^1_0\text{n}$	–
${}^4_2\text{He}$	7.07

Fig. 8.1

- (a) Suggest why binding energy per nucleon for the neutron is not quoted.

.....
 [1]

- (b) Calculate the mass defect, in kg, of a helium ${}^4_2\text{He}$ nucleus.

mass defect = kg [3]

- (c) (i) State the name of the type of reaction illustrated by this nuclear equation.

..... [1]

- (ii) Determine the binding energy per nucleon, in MeV, of tritium (${}^3_1\text{H}$).

binding energy per nucleon = MeV [3]

Q21.

- 8 (a) State what is meant by the *decay constant* of a radioactive isotope.

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Exam
Ur

.....
.....
..... [2]

- (b) Show that the decay constant λ is related to the half-life $t_{\frac{1}{2}}$ by the expression

$$\lambda t_{\frac{1}{2}} = 0.693.$$

[3]

- (c) Cobalt-60 is a radioactive isotope with a half-life of 5.26 years (1.66×10^8 s).

A cobalt-60 source for use in a school laboratory has an activity of 1.8×10^5 Bq.

Calculate the mass of cobalt-60 in the source.

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mass = g [3]

Q22.



8 In some power stations, nuclear fission is used as a source of energy.

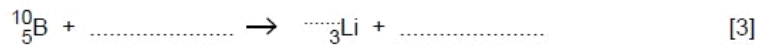
For
Examiner's
Use

(a) State what is meant by *nuclear fission*.

.....

 [2]

(b) The nuclear fission reaction produces neutrons. In the power station, the neutrons may be absorbed by rods made of boron-10. Complete the nuclear equation for the absorption of a single neutron by a boron-10 nucleus with the emission of an α -particle.



(c) Suggest why, when neutrons are absorbed in the boron rods, the rods become hot as a result of this nuclear reaction.

.....

 [3]

Q23.

8 The isotope phosphorus-33 (${}_{15}^{33}\text{P}$) undergoes β -decay to form sulfur-33 (${}_{16}^{33}\text{S}$), which is stable. The half-life of phosphorus-33 is 24.8 days.

For
Exam
Use

(a) (i) Define radioactive *half-life*.

.....

 [2]

(ii) Show that the decay constant of phosphorus-33 is $3.23 \times 10^{-7} \text{ s}^{-1}$.

[1]

(b) A pure sample of phosphorus-33 has an initial activity of 3.7×10^6 Bq.

Calculate

(i) the initial number of phosphorus-33 nuclei in the sample,

number = [2]

(ii) the number of phosphorus-33 nuclei remaining in the sample after 30 days.

number = [2]

(c) After 30 days, the sample in (b) will contain phosphorus-33 and sulfur-33 nuclei.
Use your answers in (b) to calculate the ratio

$$\frac{\text{number of phosphorus-33 nuclei after 30 days}}{\text{number of sulfur-33 nuclei after 30 days}}$$

ratio = [2]

For
Examiner's
Use

Q24.



8 Radon-222 is a radioactive element having a half-life of 3.82 days.

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Use

Radon-222, when found in atmospheric air, can present a health hazard. Safety measures should be taken when the activity of radon-222 exceeds 200 Bq per cubic metre of air.

(a) (i) Define radioactive *decay constant*.

.....
.....
..... [2]

(ii) Show that the decay constant of radon-222 is $2.1 \times 10^{-6} \text{ s}^{-1}$.

[1]

(b) A volume of 1.0 m^3 of atmospheric air contains 2.5×10^{25} molecules.

Calculate the ratio

$$\frac{\text{number of air molecules in } 1.0 \text{ m}^3 \text{ of atmospheric air}}{\text{number of radon-222 atoms in } 1.0 \text{ m}^3 \text{ of atmospheric air}}$$

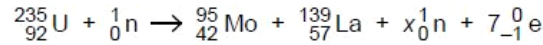
for the minimum activity of radon-222 at which safety measures should be taken.

ratio = [3]

Q25.

- 8 When a neutron is captured by a uranium-235 nucleus, the outcome may be represented by the nuclear equation shown below.

For
Examiner:
Use



- (a) (i) Use the equation to determine the value of x .

$x = \dots\dots\dots$ [1]

- (ii) State the name of the particle represented by the symbol ${}_{-1}^0\text{e}$.

$\dots\dots\dots$ [1]

- (b) Some data for the nuclei in the reaction are given in Fig. 8.1.

	mass / u	binding energy per nucleon / MeV
uranium-235 (${}_{92}^{235}\text{U}$)	235.123	
molybdenum-95 (${}_{42}^{95}\text{Mo}$)	94.945	8.09
lanthanum-139 (${}_{57}^{139}\text{La}$)	138.955	7.92
proton (${}_1^1\text{p}$)	1.007	
neutron (${}_0^1\text{n}$)	1.009	

Fig. 8.1

Use data from Fig. 8.1 to

- (i) determine the binding energy, in u, of a nucleus of uranium-235,

binding energy = $\dots\dots\dots$ u [3]



(ii) show that the binding energy per nucleon of a nucleus of uranium-235 is 7.18 MeV.

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Use

[3]

(c) The kinetic energy of the neutron before the reaction is negligible.
Use data from (b) to calculate the total energy, in MeV, released in this reaction.

energy = MeV [2]

Q26.

8 (a) State what is meant by *nuclear binding energy*.

For
Examiner's
Use

.....

 [2]

(b) The variation with nucleon number A of the binding energy per nucleon B_E is shown in Fig. 8.1.

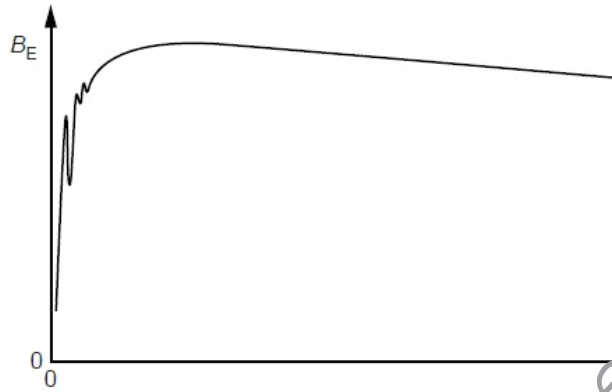
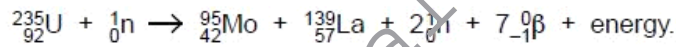


Fig. 8.1

When uranium-235 (${}^{235}_{92}\text{U}$) absorbs a slow-moving neutron, one possible nuclear reaction is



(i) State the name of this type of nuclear reaction.

..... [1]

(ii) On Fig. 8.1, mark the position of

1. the uranium-235 nucleus (label this position U), [1]
2. the molybdenum-95 (${}^{95}_{42}\text{Mo}$) nucleus (label this position Mo), [1]
3. the lanthanum-139 (${}^{139}_{57}\text{La}$) nucleus (label this position La). [1]



(iii) The masses of some particles and nuclei are given in Fig. 8.2.

For
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Use

	mass/u
β -particle	5.5×10^{-4}
neutron	1.009
proton	1.007
uranium-235	235.123
molybdenum-95	94.945
lanthanum-139	138.955

Fig. 8.2

Calculate, for this reaction,

- the change, in u, of the rest mass,

change in mass = u [2]

- the energy released, in MeV, to three significant figures.

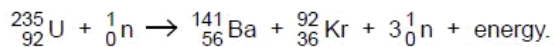
energy = MeV [3]

Q27.



MEGA LECTURE

8 One possible nuclear fission reaction is



Barium-141 (${}_{56}^{141}\text{Ba}$) and krypton-92 (${}_{36}^{92}\text{Kr}$) are both β -emitters.
 Barium-141 has a half-life of 18 minutes and a decay constant of $6.4 \times 10^{-4} \text{ s}^{-1}$.
 The half-life of krypton-92 is 3.0 seconds.

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Use

(a) State what is meant by *decay constant*.

.....

 [2]

(b) A mass of 1.2g of uranium-235 undergoes this nuclear reaction in a very short time (a few nanoseconds).

(i) Calculate the number of barium-141 nuclei that are present immediately after the reaction has been completed.

number = [2]

(ii) Using your answer in (b)(i) calculate the total activity of the barium-141 and the krypton-92 a time of 1.0 hours after the fission reaction has taken place.

activity = Bq [4]

Q28.



10 (a) Explain what is meant by the *binding energy* of a nucleus.

.....

 [2]

(b) Data for the masses of some particles are given in Fig. 10.1.

	mass/u
proton	1.00728
neutron	1.00867
tritium (${}^3_1\text{H}$) nucleus	3.01551
polonium (${}^{210}_{84}\text{Po}$) nucleus	209.93722

Fig. 10.1

The energy equivalent of 1.0 u is 930 MeV.

(i) Calculate the binding energy, in MeV, of a tritium (${}^3_1\text{H}$) nucleus.

binding energy = MeV [3]

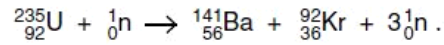
(ii) The total mass of the separate nucleons that make up a polonium-210 (${}^{210}_{84}\text{Po}$) nucleus is 211.70394 u.

Calculate the binding energy per nucleon of polonium-210.

binding energy per nucleon = MeV [3]



(c) One possible fission reaction is



By reference to binding energy, explain, without any calculation, why this fission reaction is energetically possible.

.....
.....
..... [2]

Q29.

9 Some water becomes contaminated with radioactive iodine-131 (${}_{53}^{131}\text{I}$).
The activity of the iodine-131 in 1.0 kg of this water is 460 Bq.
The half-life of iodine-131 is 8.1 days.

(a) Define radioactive *half-life*.

.....
.....
..... [2]

(b) (i) Calculate the number of iodine-131 atoms in 1.0 kg of this water.

number = [3]

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(ii) An amount of 1.0 mol of water has a mass of 18g.

Calculate the ratio

$$\frac{\text{number of molecules of water in 1.0 kg of water}}{\text{number of atoms of iodine-131 in 1.0 kg of contaminated water}}$$

ratio = [2]

(c) An acceptable limit for the activity of iodine-131 in water has been set as 170Bqkg^{-1} .

Calculate the time, in days, for the activity of the contaminated water to be reduced to this acceptable level.

time = days [3]

Q30.



9 One likely means by which nuclear fusion may be achieved on a practical scale is the D-T reaction.

(a) State what is meant by *nuclear fusion*.

.....
 [1]

(b) In the D-T reaction, a deuterium (${}^2_1\text{H}$) nucleus fuses with a tritium (${}^3_1\text{H}$) nucleus to form a helium-4 (${}^4_2\text{He}$) nucleus. The nuclear equation for the reaction is



Some data for this reaction are given in Fig. 9.1.

	mass/u
deuterium (${}^2_1\text{H}$)	2.01356
tritium (${}^3_1\text{H}$)	3.01551
helium-4 (${}^4_2\text{He}$)	4.00151
neutron (${}^1_0\text{n}$)	1.00867

Fig. 9.1

(i) Calculate the energy, in MeV, equivalent to 1.00u. Explain your working.

energy = MeV [3]

(ii) Use data from Fig. 9.1 and your answer in (i) to determine the energy released in this D-T reaction:

energy = MeV [2]



- (iii) Suggest why, for the D-T reaction to take place, the temperature of the deuterium and the tritium must be high.

.....
.....
..... [2]

Q31.

- 9 During the de-commissioning of a nuclear reactor, a mass of 2.5×10^6 kg of steel is found to be contaminated with radioactive nickel-63 ($^{63}_{28}\text{Ni}$).
The total activity of the steel due to the nickel-63 contamination is 1.7×10^{14} Bq.

- (a) Calculate the activity per unit mass of the steel.

activity per unit mass = Bqkg⁻¹ [1]



(b) Special storage precautions need to be taken when the activity per unit mass due to contamination exceeds 400Bqkg^{-1} .
Nickel-63 is a β -emitter with a half-life of 92 years.
The maximum energy of an emitted β -particle is 0.067MeV .

(i) Use your answer in (a) to calculate the energy, in J, released per second in a mass of 1.0kg of steel due to the radioactive decay of the nickel.

energy = J [1]

(ii) Use your answer in (i) to suggest, with a reason, whether the steel will be at a high temperature.

.....
.....
..... [1]

(iii) Use your answer in (a) to determine the time interval before special storage precautions for the steel are not required.

time = years [3]





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