Q1. The table below contains five statements that refer to isotopes and some radium isotopes.

	$^{223}_{88}\text{Ra}$	$^{224}_{88}\text{Ra}$	$^{225}_{88}\text{Ra}$	$^{226}_{88}\text{Ra}$
Isotope with the smallest mass number	✓			
Isotope with most neutrons in nucleus				
Isotope with nucleus which has the largest specific charge				
Isotope decays by β^- decay to form $^{225}_{89}\text{Ac}$				
Isotope decays by alpha decay to form $^{220}_{86}\text{Rn}$				

(a)   Complete the table by ticking **one** box in each row to identify the appropriate isotope. The first row has been completed for you.

(4)

(b)   (i)   An atom of one of the radium isotopes in the table is ionised so that it has a charge of $+3.2 \times 10^{-19}$ C.

State what happens in the process of ionising this radium atom.

....

....

(1)

(ii)   The specific charge of the ion formed is 8.57×10^5 C kg^{-1}.

Deduce which isotope in the table has been ionised. Assume that both the mass of a proton and the mass of a neutron in the nucleus is 1.66×10^{-27} kg.

isotope = ...

(3)
(Total 8 marks)

Q2. A positive ion has a charge−to−mass ratio of 2.40×10^7 C kg^{-1}. It is held stationary in a vertical electric field.

Which line, **A** to **D**, in the table shows correctly both the strength and the direction of the electric field?

	Electric field strength / V m^{-1}	Direction
A	4.09×10^{-7}	upwards
B	4.09×10^{-7}	downwards
C	2.45×10^6	upwards
D	2.45×10^6	downwards

(Total 1 mark)

Q3. What are the numbers of hadrons, baryons and mesons in an atom of $^7_3$Li?

	hadrons	baryons	mesons	
A	7	3	3	▢
B	7	4	4	▢
C	7	7	0	▢
D	10	7	0	▢

(Total 1 mark)

Q4. A calcium ion is formed by removing two electrons from an atom of $^{40}_{20}$Ca. What is the specific charge of the calcium ion?

    A 3.2×10^{-19} C kg^{-1}

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B 2.9×10^{-18} C kg^{-1} ☐

C 4.8×10^{6} C kg^{-1} ☐

D 4.8×10^{7} C kg^{-1} ☐

(Total 1 mark)

Q5. A common type of smoke detector contains a very small amount of americium-241, $^{241}_{95}\text{Am}$

(a)   Determine the number of each type of nucleon in one americium-241 nucleus.

type of nucleon .... number ....

type of nucleon .... number ....

(2)

(b)   Americium-241 is produced in nuclear reactors through the decay of plutonium, $^{241}_{94}\text{Pu}$

State the decay process responsible for the production of americium-241. Explain your answer.

....

....

....

(2)

(c)   An americium-241 nucleus decays into nuclide X by emitting an alpha particle.

Write an equation for the decay of the nucleus and determine the proton number and nucleon number of X.

nucleon number ....

proton number ....

(3)

(d)   The alpha radiation produced by americium-241 causes the ionisation of nitrogen and oxygen molecules in the smoke detector.

State what is meant by ionisation.

....

....

....

(1)

(e)   A friend who has not studied physics suggests that a smoke detector containing radioactive material should not be sold.

Use your knowledge of physics to explain why a smoke detector containing americium-241 does not provide any risk to the user.

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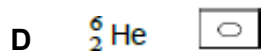
(2)
(Total 10 marks)

Q6. The nucleus of $^{9}_{4}Be$ captures a proton and emits an α particle. What is the product nucleus?

A $^{10}_{6}C$ ☐

B $^{7}_{3}Li$ ☐

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C ^6_3Li ☐

D ^6_2He ☐

<div align="right">

(Total 1 mark)

</div>

Q7.(a) The table below contains data for four different nuclei, P, Q, R and S.

Nuclei	Number of neutrons	Nucleon number
P	5	11
Q	6	11
R	8	14
S	9	17

(i) Which nucleus contains the fewest protons?

nucleus ....

<div align="right">

(1)

</div>

(ii) Which **two** nuclei are isotopes of the same element?

nuclei .... and ....

<div align="right">

(1)

</div>

(iii) State and explain which nucleus has the smallest specific charge.

....

....

....

....

....

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....

(2)

(iv) Complete the following equation to represent β⁻ decay of nucleus R to form nucleus X.

$$^{14}_{6}R \rightarrow \, ^{\cdots}_{\cdots} X + \, ^{\cdots}_{\cdots} \, \cdots\cdots\cdots + \cdots\cdots\cdots$$
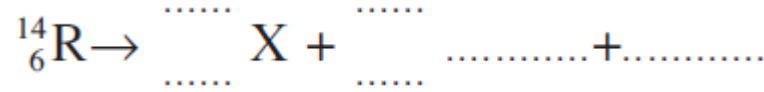
(3)

(b) (i) The strong nuclear force is responsible for keeping the protons and neutrons bound in a nucleus.
Describe how the strong nuclear force between two nucleons varies with the separation of the nucleons, quoting suitable values for separation.

....

....

....

....

....

....

(3)

(ii) Another significant interaction acts between the protons in the nucleus of an atom.
Name the interaction and name the exchange particle responsible for the interaction.

Interaction ....

Exchange particle ....

(2)
(Total 12 marks)

Q8. An atom of calcium, $_{20}^{48}\text{Ca}$, is ionised by removing two electrons.

    (i)   State the number of protons, neutrons and electrons in the ion formed.

        protons...

        neutrons..

        electrons...

(3)

    (ii)   Calculate the charge of the ion.

        charge C

(1)

    (iii)   Calculate the specific charge of the ion.

        specific charge .... C kg^{-1}

(2)
(Total 6 marks)

Q9. (a)   Name the constituent of an atom which

    (i)   has zero charge,

    ....

(1)

    (ii)   has the largest specific charge,

    ....

(1)

(iii)   when removed leaves a different isotope of the element.

(1)

....

(b)   The equation

$$^{99}_{43}\text{Tc} \rightarrow {}^{A}_{Z}\text{Ru} + {}^{0}_{-1}\beta + X$$
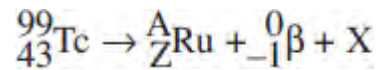
represents the decay of technetium−99 by the emission of a β⁻ particle.

(i)   Identify the particle X.

....

(1)

(ii)   Determine the values of A and Z.

A =...

Z = ...

(2)

(iii)   Calculate the specific charge of the technetium−99 $\left(^{99}_{43}\text{Tc} \right)$ nucleus. State an appropriate unit for your answer.

specific charge = ... unit ....

(4)
(Total 10 marks)