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

	$^{223}_{88}Ra$	$^{224}_{88}Ra$	$^{225}_{88}Ra$	$^{226}_{88}Ra$
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 $^{225}_{89}Ac$				
Isotope decays by alpha decay to form $^{220}_{86}Rn$				

(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.

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(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) Which ionizing radiation produces the greatest number of ion pairs per mm in air? Tick (✓) the correct answer.

α particles	
β particles	
γ rays	
X−rays	

(1)

(b) (i) Complete the table showing the typical maximum range in air for α and β particles.

Type of radiation	Typical range in air / m
α	
β	

(2)

(ii) γ rays have a range of at least 1 km in air.

However, a γ ray detector placed 0.5 m from a γ ray source detects a noticeably smaller count-rate as it is moved a few centimetres further away from the source.

Explain this observation.

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(1)

(c) Following an accident, a room is contaminated with dust containing americium which is an α−emitter.

Explain the most hazardous aspect of the presence of this dust to an unprotected human entering the room.

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(2)

(Total 6 marks)

Q3.(a) Complete the following equation for beta minus (β^-) decay of strontium-90 ($^{90}_{38}\mathrm{Sr}$) into an isotope of yttrium (Y).

$$^{90}_{38}\mathrm{Sr} \longrightarrow \ ^{\cdots\cdots}_{\cdots\cdots}\mathrm{Y} \ + \ ^{\cdots\cdots}_{\cdots\cdots}\beta^- \ + \ ^{0}_{0}\cdots\cdots$$

(3)

(b) During β^- decay of a nucleus both the nucleon composition and the quark composition change.
State the change in quark composition.

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(1)

(c) A positive kaon consists of an up quark and an antistrange quark $(u\,\bar{s})$. This kaon decays by strong and weak interactions into three pions. Two of the pions have quark compositions of $(u\,\bar{d})$. The third pion has a different quark composition.

(i) Name the unique family of particles to which the kaon and pions belong.

.....

(1)

(ii) Tick the box corresponding to the charge of the third pion.

positive ☐ negative ☐ neutral ☐

(1)

(iii) Positive kaons have unusually long lifetimes.
Give a reason why you would expect this to be the case.

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.....

(1)

(iv) Name the exchange particles which are involved in the strong and weak interactions of the kaon.

strong interaction .....

weak interaction .....

(1)
(Total 8 marks)

Q4.A common type of smoke detector contains a very small amount of americium-241, $^{241}_{95}\mathrm{Am}$

(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, $^{241}_{94}\mathrm{Pu}$

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

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(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.

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(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)

Q5. A radioactive nucleus emits a β^- particle then an α particle and finally another β^- particle. The final nuclide is

A an isotope of the original element ⬭

B the same element with a different proton number ⬭

C a new element of higher proton number ⬭

D a new element of lower nucleon number ⬭

(Total 1 mark)

Q6.(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 .....

(1)

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

nuclei ..... and .....

(1)

(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.

$$^{14}_{6}\mathrm{R} \rightarrow {}^{\cdots\cdots}_{\cdots\cdots}\mathrm{X} + {}^{\cdots\cdots}_{\cdots\cdots} \ldots\ldots\ldots + \ldots\ldots\ldots$$

(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.

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(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)