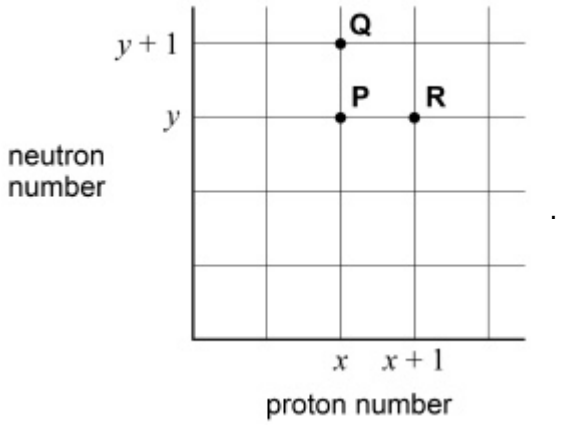
1 The graph of neutron number against proton number shows three nuclei **P**, **Q** and **R**.



Which row identifies an isotope of **P** and the nucleon number of this isotope of **P**?

	Isotope of P	Nucleon number of isotope of P	
A	**Q**	$y + 1$	⬭
B	**Q**	$x + y + 1$	⬭
C	**R**	$x + y + 1$	⬭
D	**R**	$x + 1$	⬭

(Total 1 mark)

2 A nucleus of a particular element decays, emitting a series of α and β^- particles.

Which of the following series of emissions would result in an isotope of the original element?

A 1 α and 1 β^- ⬭

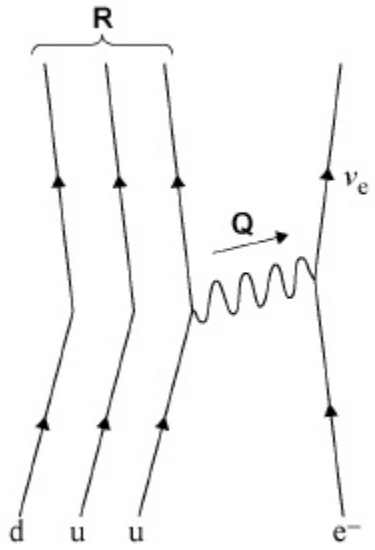
B 1 α and 2 β^- ⬭

C 2 α and 1 β^- ⬭

D 2 α and 2 β^- ⬭

(Total 1 mark)

3 The partially completed diagram represents electron capture.



Which row identifies the exchange particle **Q** and the quark structure of particle **R**?

	Particle Q	Quark structure of particle R	
A	W^-	uuu	⬭
B	W^+	dud	⬭
C	W^+	uuu	⬭
D	W^-	dud	⬭

(Total 1 mark)

4 In a nuclear reaction $^{14}_{7}N$ is bombarded by neutrons. This results in the capture of one neutron and the emission of one proton by one nucleus of $^{14}_{7}N$. The resulting nucleus is

A $^{13}_{7}N$

B $^{14}_{6}C$

C $^{12}_{6}C$

D $^{14}_{8}O$

(Total 1 mark)

5 Fluoride ions are produced by the addition of a single electron to an atom of fluorine $^{19}_{9}F$.

What is the magnitude of specific charge of the fluoride ion?

A 3.2×10^{-26} C kg^{-1} ⬭

B 8.4×10^{-21} C kg^{-1} ⬭

C 5.0×10^{6} C kg^{-1} ⬭

D 4.5×10^{7} C kg^{-1} ⬭

(Total 1 mark)

6 Electron capture can be represented by the following equation.

$$p + e^- \rightarrow X + Y$$

Which row correctly identifies **X** and **Y**?

	X	**Y**	
A	p	K^-	⬭
B	e^-	e^+	⬭
C	n	V_e	⬭
D	n	π^0	⬭

(Total 1 mark)

7 Which equation shows the process of annihilation?

A $\pi^- + \pi \longrightarrow \gamma$ ⬭

B $p + \bar{p} \rightarrow \gamma + \gamma$ ⬭

C $\beta^- + p \longrightarrow \gamma$ ⬭

D $\gamma + \gamma \longrightarrow \beta^+ + \beta^-$ ⬭

(Total 1 mark)

8 The decay of a neutral kaon K^0 is given by the equation

$$K^0 \rightarrow X + Y + \bar{\nu}_e$$

What are X and Y?

	X and Y	
A	e^+ and e^-	⬭
B	μ^+ and e^-	⬭
C	π^+ and e^-	⬭
D	π^- and e^+	⬭

(Total 1 mark)

9 Which of the following is **not** made of quarks?

A kaon ⬭

B muon ⬭

C neutron ⬭

D pion ⬭

(Total 1 mark)

10 What is the quark structure for antiprotons?

A $\bar{u}\bar{d}$ ⬭

B $\bar{d}\bar{d}\bar{s}$ ⬭

C $\bar{d}\bar{d}\bar{u}$ ⬭

D $\bar{u}\bar{u}\bar{d}$ ⬭

(Total 1 mark)

11 An atom of argon $^{37}_{18}Ar$ is ionised by the removal of two orbiting electrons.

(a) How many protons and neutrons are there in this ion?

_____ protons

_____ neutrons

(2)

(b) What is the charge, in C, of this ion?

_____

_____

(2)

(c) Which constituent particle of this ion has

(i) a zero charge per unit mass ratio,

_____

_____

(ii) the largest charge per unit mass ratio?

_____

(2)

(d) Calculate the percentage of the total mass of this ion that is accounted for by the mass of its electrons.

_____

_____

_____

_____

(3)

(Total 9 marks)

12 Under certain conditions a γ photon may be converted into an electron and a positron.

(a) What is this process called?

_____

(1)

(b) (i) Explain why there is a minimum energy of the γ photon for this conversion to take place and what happens when a γ photon has slightly more energy than this value.

_____

_____

_____

_____

_____

(ii) Using values from the data sheet calculate this minimum energy in MeV.

_____

_____

(3)

(c) Under suitable conditions, a γ photon may be converted into two other particles rather than an electron and positron.
Give an example of the two other particles it could create.

_____

(1)

(Total 5 marks)

13 (a) (i) Explain what is meant by an *exchange particle.*

_____

_____

_____

_____

(2)

(ii) Name the exchange particle that mediates the strong force.

_____

(1)

(iii) The weak nuclear force acts over a much shorter distance than the strong force. Explain **two** differences between the relevant exchange particles that account for this.

_____

_____

_____

_____

(2)

(b) The following equation shows the β^- decay of a free neutron.

$$^{1}_{0}\text{n} \rightarrow \mathbf{X} + {}^{0}_{-1}\beta + \mathbf{Y}$$

Identify each of the particles **X** and **Y**.

Show the appropriate nucleon and proton number for each of the particles.

X _____

Y _____

(2)

(c) For a decay to be possible each of baryon number, lepton number and charge must be conserved. Use these rules to show that the following decay is possible.

$$\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu$$

conservation of baryon number:

conservation of lepton number:

conservation of charge:

(3)

(Total 10 marks)

14 (a) Name **two** hadrons.

_____

_____

(b) Name **two** leptons which are also antiparticles.

_____

_____

(c) State a possible quark structure of the pion π^0.
A table of the properties of quarks is given in the Data booklet.

_____

(d) A K^- kaon is a strange particle.
State **one** characteristic of a strange particle.

_____

_____

(Total 4 marks)

15 (a) A stable atom contains 28 nucleons.

Write down a possible number of protons, neutrons and electrons contained in the atom.

_____ protons

_____ neutrons

_____ electrons

(2)

(b) An unstable *isotope* of uranium may split into a caesium nucleus, a rubidium nucleus and four neutrons in the following process.

$$^{236}_{92}\mathrm{U} \Rightarrow {}^{137}_{55}\mathrm{Cs} + {}^{X}_{37}\mathrm{Rb} + 4\,{}^{1}_{0}\mathrm{n}$$

(i) Explain what is meant by isotopes.

_____

_____

_____

(ii) How many neutrons are there in the $^{137}_{55}\mathrm{Cs}$ nucleus?

_____

(iii) Calculate the ratio $\frac{\text{charge}}{\text{mass}}$, in C kg^{-1}, for the $^{236}_{92}U$ nucleus.

_____

_____

_____

(iv) Determine the value of X for the rubidium nucleus.

_____

X = _____

(6)

(Total 8 marks)

16 (a) (i) How do hadrons differ from all other subatomic particles?

_____

_____

(ii) Give the quark composition of the following particles.

neutron _____

neutral pion _____

_____

(iii) Classify the following as either leptons, baryons or mesons.

kaon _____

muon _____

(5)

(b) Which is the most stable baryon?

_____

(1)

(c) This table may be useful in answering the questions which follow.

particle	baryon number	lepton number	strangeness
π^-	0	0	0
p	1	0	0
$\bar{p}$	−1	0	0
e^-	0	1	0
e^+	0	−1	0
$\bar{\nu}_e$	0	−1	0

The particle X, which is a strange particle, decays in the following way:

$$X \rightarrow \pi^- + p$$

(i) State whether X is a meson, a baryon or a lepton.

_____

(ii) Use conservation laws to decide whether each of the following decays of the π^- is possible. Give a reason for your answer.

(A) $\pi^- \rightarrow e^+ + \nu_e$

Is this decay possible? _____

reason _____

(B) $\pi^- \rightarrow \bar{p} + e^- + e^+$

Is this decay possible? _____

reason _____

(5)

(Total 11 marks)

17 (a) State whether or not each of the following properties of a baryon is conserved when it decays by the weak interaction.

charge _____

baryon number _____

strangeness _____

(2)

(b) State, with a reason, whether or not each of the following particle reactions is possible.

(i) $p + \pi^- \rightarrow K^- + \pi^+$

_____

_____

_____

(ii) $p + \bar{\nu} \rightarrow n = e^+$

_____

_____

_____

(4)

(Total 6 marks)

18 (a) Quarks may be combined together in a number of ways to form sub-groups of hadrons. Name **two** of these sub-groups and for each, state its quark composition.

sub-group 1 _____

_____

sub-group 2 _____

_____

(3)

(b) A free neutron is an unstable particle.

(i) Complete the following to give an equation that represents the decay of a neutron.

$n \rightarrow$

(ii) Describe the change that occurs to the quark structure when a neutron decays.

_____

_____

_____

_____

_____

(4)

(Total 7 marks)