Particles AS Revision Pack

Name: ______________________

Class: ______________________

Date: ______________________

Time: **243 minutes**

Marks: **223 marks**

Comments:

1 The element uranium has an isotope $^{237}_{92}U$.

(a) Explain what is meant by an isotope.

____

____

____

____

(2)

(b) Determine the charge in coulomb of the $^{237}_{92}U$ nucleus.

charge = ______________________ C

(2)

(c) A positive ion of $^{237}_{92}U$ has a charge of $+4.80 \times 10^{-19}$ C.

Determine the number of electrons in the ion.

number of electrons = ______________________

(2)

(d) $^{237}_{92}U$ decays by β^- emission to form an isotope of neptunium (Np).

Complete the equation for this decay.

$$^{237}_{92}U \rightarrow \,^{\dots\dots}_{\dots\dots}Np + \,^{\dots\dots}_{\dots\dots}\beta^- + \dots\dots\dots\dots$$

(3)

(Total 9 marks)

2 Helium is the second most abundant element in the universe. The most common isotope of helium is ${}^{4}_{2}He$ and a nucleus of this isotope has a rest energy of 3728 MeV.

In 2011, at the Relativistic Heavy Ion Collider, anti-helium nuclei were produced. Nuclei of anti-helium are made up of antiprotons and antineutrons.
It is suggested that an antineutron can decay to form an antiproton in a process similar to β^- decay.

In one particular collision between an anti-helium nucleus and a helium nucleus, the nuclei are annihilated and two photons are formed.

(a) State what is meant by isotopes.

___

___

___

___

(2)

(b) Explain why two photons are formed instead of a single photon when a helium nucleus annihilates with the anti-helium nucleus.

___

___

___

___

___

___

___

___

(2)

(c) Calculate, using data from the passage, the maximum frequency of the photons produced in this annihilation of a $^{4}_{2}\text{He}$ nucleus.

frequency = ____________________ Hz

(4)

(d) Complete this equation for the possible decay of an antineutron.

$$^{1}_{0}\bar{\text{n}} \rightarrow \,_{-1}^{1}\bar{\text{p}} + \,^{\_\_}_{\_\_}\_\_\_\_ + \_\_\_\_$$

(2)

(e) What interaction would be responsible for the decay in **part (d)**?
Tick (✓) the correct answer in the right-hand column.

	✓ if correct
electromagnetic	
gravitational	
strong nuclear	
weak nuclear	

(1)

(Total 11 marks)

3 (a) Name the only stable baryon.

____

(1)

(b) (i) When aluminium-25($^{25}_{13}$Al) decays to magnesium-25 (Mg-25) an electron neutrino (ν_e) and another particle are also emitted.

Complete the equation to show the changes that occur.

$$^{25}_{13}\text{Al} \rightarrow \,^{25}_{\cdots\cdots}\text{Mg} + \,^{\cdots\cdots}_{\cdots\cdots}\cdots\cdots\cdots + \nu_e$$

(2)

(ii) Name the exchange particle responsible for the decay.

____

(1)
(Total 4 marks)

4 (a) Complete the table comparing some of the properties of the positive pion, π^+, and the proton.

Name	π^+	**Proton**
Relative charge	+1	
Baryon number		
Quark composition		

(5)

(b) When a positive pion interacts with a proton, a kaon can be produced, along with another strange particle, as shown in this equation

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

Circle the type of interaction shown in this equation.

Electromagnetic   Gravitational   Strong Nuclear   Weak Nuclear

(1)

(c) Deduce the relative charge, baryon number and strangeness of particle X.

(3)

(d) Particle X can decay to produce a neutron and positive pion as shown in this equation

$$X \rightarrow n + \pi^{+}$$

Circle the type of interaction shown in this equation.

Electromagnetic Gravitational Strong Nuclear Weak Nuclear

(1)

(e) Explain your answer.

___

___

___

___

(2)

(f) The neutron and positive pion will then decay. The positive pion can decay into a positron and an electron neutrino.

Write down the equation for the decay of the neutron.

(2)

(g) Explain why no further decays occur.

___

___

___

___

(2)

(Total 16 marks)

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

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

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.

____

____

____

____

____

(2)

(Total 10 marks)

6 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.

____

____

(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)

7 (a) Baryons, mesons and leptons are affected by particle interactions.

Write an account of these interactions. Your account should:

- include the names of the interactions
- identify the groups of particles that are affected by the interaction
- identify the exchange particles involved in the interaction
- give examples of **two** of the interactions you mention.

The quality of your written communication will be assessed in your answer.

____

____

____

____

____

____

____

____

____

____

(6)

(b) Draw a labelled diagram that represents a particle interaction.

(3)

(Total 9 marks)

8 The equation shows an interaction between a proton and a negative kaon that results in the formation of particle, X.

$$K^{-} + p \rightarrow K^{+} + K^{0} + X$$

(a) (i) State and explain whether X is a charged particle.

____

____

(2)

(ii) State and explain whether X is a lepton, baryon or meson.

____

____

(2)

(iii) State the quark structure of the K^-, K^+ and the K^0.

K^- ______________________________

K^+ ______________________________

K^0 ______________________________

(3)

(iv) Strangeness is conserved in the interaction.

Determine, explaining your answer, the quark structure of X.

____

____

____

____

(3)

(Total 10 marks)

9 (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.

____

____

____

____

____

____

(2)

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

$$^{14}_{6}\text{R} \rightarrow \, ^{\dots\dots}_{\dots\dots}\text{X} + \, ^{\dots\dots}_{\dots\dots} \dots\dots\dots\dots + \dots\dots\dots\dots$$

(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)

10 (a) The positive kaon, K^+, has a strangeness of +1.

(i) What is the quark structure of the K^+?

____

(1)

(ii) What is the baryon number of the K^+?

____

(1)

(iii) What is the antiparticle of the K^+?

____

(1)

(b) The K^+ may decay into a neutrino and an antimuon in the following way.

$$K^+ \rightarrow \nu_\mu + \mu^+$$

(i) Complete the table using ticks and crosses as indicated in the first row.

Classification	K^+	ν_μ	μ^+
lepton	×	✓	✓
charged particle			
hadron			
meson			

(3)

(ii) In this decay, charge, energy and momentum are conserved.
Give another quantity that is conserved in this decay and one that is not conserved.

Conserved ____

Not conserved ____

(2)

(c) Another possible decay of the K^+ is shown in the following equation,

$$K^+ \rightarrow \pi^+ + X$$

(i) Identify X by ticking **one** box from the following list.

electron	
muon	
negative pion	
neutral pion	
neutrino	
neutron	
positron	

(1)

(ii) Give **one** reason for your choice in part (i).

____

____

____

____

(1)

(Total 10 marks)

11 An atom of calcium, $^{48}_{20}Ca$, 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)

12 (a) Complete the table to show the four fundamental forces and their corresponding exchange particles.

fundamental force	**corresponding exchange particle**
strong nuclear	gluon
electromagnetic	
	$W^{+}W^{-}$ Z^{0}
gravitational	graviton

(2)

(b) Name the physical quantity that a particle must have for the electromagnetic force to act on it.

____

(1)

(c) Name the particle believed to be responsible for mass.

____

(1)

(Total 4 marks)

13 (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

$$^{99}_{43}\mathrm{Tc} \rightarrow {}^{A}_{Z}\mathrm{Ru} + {}^{0}_{-1}\beta + \mathrm{X}$$

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 $\left({}^{99}_{43}\mathrm{Tc} \right)$ nucleus. State an appropriate unit for your answer.

specific charge = ___ unit ___

(4)

(Total 10 marks)

14 Under certain circumstances it is possible for a photon to be converted into an electron and a positron.

(a) State what this process is called.

___

(1)

(b) A photon must have a minimum energy in order to create an electron and a positron.

Calculate the minimum energy of the photon in joules. Give your answer to an appropriate number of significant figures.

minimum energy = ____________________ J

(3)

(c) A photon of slightly higher energy than that calculated in part (b) is converted into an electron and a positron.

State what happens to the excess energy.

___

___

(1)

(d) Describe what is likely to happen to the positron shortly after its creation.

___

___

___

___

(2)

(Total 7 marks)

15 (a) The nucleus of a particular atom has a *nucleon number* of 14 and a *proton number* of 6.

(i) State what is meant by nucleon number and proton number.

nucleon number ___

___

___

proton number ___

___

___

(1)

(ii) Calculate the number of neutrons in the nucleus of this atom.

answer = ____________________

(1)

(iii) Calculate the specific charge of the nucleus.

answer = ____________________ Ckg^{-1}

(3)

(b) The specific charge of the nucleus of another isotope of the element is 4.8×10^7 Ckg^{-1}.

(i) State what is meant by an isotope.

____

____

____

(2)

(ii) Calculate the number of neutrons in this isotope.

answer = ____________________

(3)

(Total 10 marks)

16 (a) The table gives information about some fundamental particles.

Complete the table by filling in the missing information.

particle	**quark structure**	**charge**	**strangene**	**baryon number**
	uud		0	
Sigma $^+$	uus	+ 1		
	$u\bar{d}$		0	0

(7)

(b) Each of the particles in the table has an antiparticle.

(i) Give **one** example of a baryon particle **and** its corresponding antiparticle.

particle ______________________________

antiparticle ______________________________

(1)

(ii) State the quark structure of an antibaryon.

____

(1)

(iii) Give **one** property of an antiparticle that is the same for its corresponding particle and **one** property that is different.

Same ______________________________

____

Different ______________________________

____

(2)

(Total 11 marks)

17 (a) State what is meant by the specific charge of a nucleus and give an appropriate unit for this quantity.

____

____

____

____

unit: ______________

(2)

(b) Nucleus X has the same nucleon number as nucleus Y. The specific charge of X is 1.25 times greater than that of Y.

(i) Explain, in terms of protons and neutrons, why the specific charge of X is greater than that of Y.

____

____

____

____

(2)

(ii) Nucleus X is $^{10}_{5}\mathrm{B}$. Deduce the number of protons and the number of neutrons in nucleus Y.

number of protons ______________________

number of neutrons ______________________

(4)

(Total 8 marks)

18 (a) (i) Name two baryons.

____

(2)

(ii) State the quark structure of the pion π^{+}.

____

(1)

(b) (i) The K^{+} kaon is a strange particle. Give **one** characteristic of a strange particle that makes it different from a particle that is not strange.

____

____

(1)

(ii) One of the following equations represent a possible decay of the K^+ kaon.

$$K^+ \rightarrow \pi^+ + \pi^0$$

$$K^+ \rightarrow \mu^+ + \overline{\nu_\mu}$$

State, with a reason, which one of these decays is not possible.

____

____

(2)

(c) Another strange particle, X, decays in the following way:

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

(i) State what interaction is involved in this decay.

____

(1)

(ii) Show that X must be a neutral particle.

____

____

(1)

(iii) Deduce whether X is a meson, baryon or lepton, explaining how you arrive at your answer.

____

____

____

____

(2)

(iv) Which particle in this interaction is the most stable?

____

(1)

(Total 11 marks)

19 Alpha decay is a process by which an unstable *isotope* of an element may decay.

(i) State what is meant by isotopes.

____

____

____

____

(2)

(ii) Complete this equation for alpha decay.

$$^{A}_{Z}\mathrm{X} \rightarrow \,^{\ldots\ldots}_{\ldots\ldots}\mathrm{Y} + \,^{4}_{2}\alpha$$

(2)

(iii) Calculate the specific charge of an alpha particle, stating an appropriate unit.

answer = ____________________

(4)

(iv) Explain why the alpha particle, once outside the nucleus, is unaffected by the strong nuclear force.

____

____

____

____

____

(2)

(Total 10 marks)

20 (a) Describe how the strong nuclear force between two nucleons varies with the separation of the nucleons quoting suitable values for separation.

____

____

____

____

____

____

(3)

(b) An unstable nucleus can decay by the emission of an *alpha particle*.

(i) State the nature of an alpha particle.

____

____

(1)

(ii) Complete the equation below to represent the emission of an α particle by a $^{238}_{92}U$ nucleus.

$$^{238}_{92}U \rightarrow \,^{\cdots\cdots}_{\cdots\cdots}Th + \,^{\cdots\cdots}_{\cdots\cdots}\alpha$$

(2)

(c) $^{238}_{92}U$ decays in stages by emitting α particles and β^- particles, eventually forming

$^{206}_{82}Pb$, a stable *isotope* of lead.

(i) State what is meant by isotopes.

____

____

(2)

(ii) If there are eight alpha decays involved in the sequence of decays from

$^{238}_{92}U$ to $^{206}_{82}Pb$ deduce how many β^- decays are involved.

answer = ______________________

(3)

(Total 11 marks)

21 (a) An unstable nucleus, $^{A}_{Z}X$, can decay by emitting a β^- particle.

(i) What part of the atom is the same as a β^- particle?

____

(1)

(ii) State the changes, if any, in *A* and *Z* when X decays.

change in *A* ____

change in *Z* ____

(2)

(b) In the process of β^- decay an *anti-neutrino* is also released.

(i) Give an equation for this decay.

____

(1)

(ii) State and explain which conservation law may be used to show that it is an *anti-neutrino* rather than a *neutrino* that is released.

____

____

____

____

(2)

(iii) What must be done to validate the predictions of an unconfirmed scientific theory?

(2)

(Total 8 marks)

22 (a) Complete the table by naming **one** example of each type of particle.

type of particle	**example**
lepton	
baryon	
meson	

(3)

(b) The following reaction cannot occur.

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

(i) State and explain which conservation law would be broken by this reaction.

(2)

(ii) State and explain **one** conservation law that would **not** be broken in this reaction.

(1)

(c) Describe what happens when a proton and an antiproton collide.

____

____

____

____

(2)

(Total 8 marks)

23 (a) State the role of *exchange particles* in the creation of forces between particles.

____

____

(1)

(b) Complete the table below to show an exchange particle that is responsible for each of the forces mentioned.

force	**exchange particle responsible**
weak nuclear force	
strong force	
electromagnetic force	

(3)

(Total 4 marks)

24 (a) The Σ^+ particle is a baryon with strangeness –1.

(i) How many quarks does the Σ^+ particle contain?

____

____

answer ______________________

(1)

(ii) How many of the quarks are strange?

____

____

answer ______________________

(1)

(b) The Σ^+ decays in the following reaction

$$\Sigma^+ \rightarrow \pi^+ + n$$

(i) State **two** quantities that are conserved in this reaction.

____

____

(2)

(ii) State a quantity that is not conserved in this reaction.

____

(1)

(iii) What interaction is responsible for this reaction?

____

(1)

(iv) Into what particle will the neutron formed in this reaction eventually decay?

____

(1)

(Total 7 marks)

25 (a) Complete the following equations

$$p + e^- \longrightarrow \_\_\_\_ + \_\_\_\_$$

$$n + \nu_m \longrightarrow p + \_\_\_\_$$

$$p + p \longrightarrow p + p + K^- + \_\_\_\_$$

(4)

(b) Give an equation that represents β^- decay, using quarks in the equation rather than nucleons.

____

____

(2)

(c) (i) Which fundamental force is responsible for electron capture?

___

(ii) What type of particle is an electron?

___

(iii) State the other fundamental forces that electrons may experience.

___

(3)
(Total 9 marks)

Mark schemes

1 (a) (isotopes have)

same number of protons ✓

allow atomic mass / proton number

different numbers of neutrons ✓

allow mass number / nucleon number

TO where mix up atomic number and mass number

2

(b) $92 \times 1.60 \times 10^{-19}$ ✓

correct power

penalise minus sign on answer line

(+)1.47×10^{-17} (C) ✓

Allow 2 sf answer 1.5×10^{-17} (C)

Pay attention to powers on answer line

2

(c) ($4.8 \times 10\text{-}19 \div 1.60 \times 10^{-19}$ =) 3 ✓

or

$1.47 \times 10^{-17} - 4.8 \times 10^{-19}$ (= Q) (ecf)

(92 − 3 =) 89 ✓

95 on answer line 1 mark

$$\left(n = \frac{Q}{e} = \frac{1.47 \times 10 - 17 - 4.8 \times 10 - 19}{1.6 \times 10^{-19}}\right) = 89 \text{ (ecf)}$$

Integer value for n

2

(d) ${}^{237}_{92}U \rightarrow {}^{237}_{93}Np + {}^{0}_{-1}\beta + \overline{\nu_{(e)}}$ ✓ ✓ ✓

one mark for:

- *both numbers correct on Np*
- *both numbers correct on β^-*
- *correct symbol for (electron) antineutrino*

3

[9]

2 (a) atoms/nuclei with same number of protons/atomic number ✓

atom/nuclei seen at least once

1

but different numbers of neutrons/mass number ✓

1

(b) momentum must be conserved ✓

1

so need two photons travelling in different directions ✓

1

(c) rest energy = 2 × 3728 = 7456 ✓ (MeV)

must show doubling OR explain that is halved because two photons OR implied because 1.193 × 10^{-9}

1

rest energy = 1.193 × 10^{-9} ✓ (J)

1

use of energy of each photon = *hf* ✓

no working but correct answer scores last three marks

1

f = (1.193 × 10^{-9}/2) /6.63 × 10^{-34} = 8.997 × 10^{23} ✓ (Hz)

RANGE: 8.90 × 10^{23} − 9.00 × 10^{23}

1

(d) $${}^{1}_{0}\overline{\mathrm{n}} \rightarrow {}^{1}_{-1}\overline{\mathrm{p}} + {}^{0}_{1}\overline{e} + \nu_{(e)}$$ ✓✓

Can use e^+ OR β in place of e

1

Allow slight loop in bottom of neutrino but must not look like gamma

1

(e)

electromagnetic	
gravitational	
strong nuclear	
weak nuclear	✓

1

[11]

3

(a) proton

1

(b) (i) β^+ identified even if numbers incorrect or correct numbers for β^+ **and** proton number on Mg correct

β or β^+ identified and all numbers correct

i.e Second mark not awarded if numbers are correct but there is a minus on the β particle

Allow 1 for consistent equation for β^- decay

2

(ii) W^+ (condone W but not W^-)

1

[4]

4 (a)

1✓

0✓ 1✓

...

ud✓ uud✓

1 mark each

5

(b) Strong nuclear circled✓

1

(c) Charge $1 + 1 = 1 + X$ $X = 1$✓

1

Baryon number $0 + 1 = 0 + X$ $X = 1$✓

1

Strangeness $0 + 0 = 1 + X$ $X = -1$✓

1

Any order

(d) Weak nuclear circled✓

1

(e) Strangeness of X is -1,

First mark is for showing that strangeness changes

The strangeness of the pion and neutron are both zero

1

The strangeness changes from -1 to 0✓

This can only occur in weak interactions. ✓

Second is for stating that this can only happen if the interaction is weak.

1

(f) .

First mark is for the proton

1

$n \rightarrow p$ ✓ $+ \beta^{-} + \nu_e$ ✓

Second is for the beta minus and antineutrino.

1

(g) The only particles remaining are electrons / positrons and neutrinos / antineutrinos which are stable ✓

1

1

And a proton which is the only stable baryon ✓

1

1

[16]

5 (a) 95 protons ✓

1

241 – 95 = 146 neutrons ✓

1

(b) Beta minus decay. ✓

Marks can be given for a correct equation

1

There is no change in the number of nucleons.

The number of protons increases by 1. ✓

Ignore omitted antineutrino.

1

(c) $^{241}_{95}\text{Am} \rightarrow {}^{A}_{Z}\text{X} + {}^{4}_{2}\alpha$ ✓

1

Nucleon number = A = 241 – 4 = 237 ✓

1

Proton number = Z = 95 – 2 = 93 ✓

1

(d) Ionisation is the removal (or addition) of electrons from (to) an atom or molecule ✓

1

(e) Only a small quantity of material is needed ✓

1

The particles it emits do not travel more than a few centimetres ✓

Alternative for 2nd mark: Would be stopped before reaching the outside of the detector

1

[10]

6 (a)

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

one mark for each correct row (ignore first row as already ticked)
allow cross instead of tick and ignore any crossed out ticks
if more than one tick in a row then no mark

4

(b) (i) the atom has lost <u>two electrons</u>✓

1

(ii) (*use of specific charge = charge ÷ mass*)
mass = $3.2 \times 10^{-19} \div 8.57 \times 10^{5} = 3.734 \times 10^{-25}$ (kg)
mass number = $3.734 \times 10^{-25} \div 1.66 \times 10^{-27}$ ✓(= 225)

hence $^{225}_{(88)}\text{Ra}$ OR 225✓✓
OR
calculate specific charge for each isotope✓

hence $^{225}_{(88)}\text{Ra}$ OR 225✓✓
ignore any reference to electrons
first mark for deduction
bald correct answer scores 2 marks
don't need radium symbol or 88
wrong answer scores zero

3

[8]

7 (a) **The student's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.**

The student's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

High Level (Good to excellent): 5 or 6 marks
The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

Student names strong, weak and electromagnetic interactions. Identifies that only hadrons experience the strong interaction but hadrons and leptons experience weak interaction. Charged particles experience electromagnetic interaction. Is able to identify all exchange particles such as gluons, W+ and W- and virtual photons. Gives examples of two of the interactions i.e. electrons repelling, electron capture, beta decay.

Intermediate Level (Modest to adequate): 3 or 4 marks
The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

Student names strong, weak and electromagnetic interactions. Identifies that only hadrons experience the strong interaction but hadrons and leptons experience weak interaction. Charged particles experience electromagnetic interaction. Is able to identify some exchange particles such as gluons, W^+ and W^- and virtual photons.

Low Level (Poor to limited): 1 or 2 marks
The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.

Student names strong, weak and electromagnetic interactions. Identifies that only hadrons experience the strong interaction. Identifies one exchange particle.

The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.

Names of interactions – strong, weak and electromagnetic
hadrons experience strong
hadrons and leptons experience weak
charged particles experience electromagnetic
identify exchange particles
give examples of various interactions e.g. electron capture
(either weak interaction or electromagnetic or strong interaction)
first mark conservation at left hand junction of charge, baryon and lepton number ✓
second mark conservation at right hand junction of charge, baryon and lepton number ✓
third mark for correct exchange particle ✓

ignore any reference to gravity
ignore any Feynman diagrams electrostatic not allowed as alternative for electromagnetic

Properties of interactions

- *correct exchange particle ($W^{(+/-)}$boson / Z_0 boson, (virtual) photon, gluon / pion) NB sign on W not required*
- *correct group of particles affected (strong: baryons andmesons, weak: baryons, mesons and leptons, electromagnetic: charged particles)*
- *example of the interaction*

Lower band

1 mark – two interactions OR one interaction and one property for that interaction

2 marks – two interactions and one property for one interaction

Middle band

3 marks – two interactions plus two properties

4 marks – two interactions plus minimum of four properties (e.g. 3 props plus 1 OR 2 props plus 2), if three interactions quoted then properties can be spread between the 3 e.g. one property for each (3) plus one additional

Top band

5 marks – 3 interactions plus two properties for each

6 marks – must give first two properties for all three interactions AND correctly state two examples of interactions e.g. electron capture example of weak, strong nuclear responsible for binding protons / neutrons / baryons together

A table may help:

	strong	weak	EM
property 1			
property 2			
property 3			

(b)

if exchange particle not identified but baryon and lepton numbers conserved on both sides − 1 mark
ignore orientation of line showing exchange particle or any arrows on exchange particle line when awarding first two marks

if arrows on incoming and outgoing interacting particles in wrong direction then lose mark

if lines do not meet at a junction lose 1 mark
***with third mark** orientation of exchange*
particle line must be consistent with exchange particle shown and no arrow required

if exchange particle line is horizontal (for weak) then must be a correct arrow
arrow overrides slope

3

[9]

8 (a) (i) X must have a <u>negative charge</u>✓
to conserve charge✓

second mark dependent on first i.e. conserve charge alone scores nothing

can gain second mark by showing balanced equation

2

(ii) X must be a baryon✓
to conserve baryon number✓

here two marks are independent i.e. conserve baryon number alone scores 1 mark

can gain second mark by showing balanced equation

2

(iii) K^-: s $\bar{u}$ OR strange anti-up ✓
K^+: u $\bar{s}$ OR up anti-strange✓
K^0: d $\bar{s}$ OR s$\bar{d}$ OR down anti-strange OR strange anti–down✓

in each case the symbols or words can be in either order

must be a bar over anti – quark
can be upper case letters e.g. U

3

(iv) (strangeness on LHS is -1)
strangeness on RHS without X is +2 / strangeness of X is -3 ✓
thus sss
OR
strangeness on RHS without X is +2 / strangeness of X is -1✓
thus sdd✓✓

correct strangeness without X on RHS is minimum working needed for first mark
next two marks awarded for correct quark structure

3

[10]

9 (a) (i) Q / boron / B ✓

1

(ii) P and R / R and P ✓

1

(iii) R ✓

6 / 14 is smallest fraction / 0.43 smallest ratio / 4.13 × 10^7 C / kg ✓

Cannot get second mark if not awarded first mark

2

(iv) ${}^{14}_{6}R \rightarrow {}^{14}_{7}X + {}^{0}_{-1}e + \overline{\nu_{(e)}}$ ✓✓✓

One mark for each correct symbol on rhs
Ignore −ve sign on e.
Can have neutrino with 0,0 on answer lines
Ignore any subscript on neutrino

3

(b) (i) <u>repulsive</u> below / at 0.5 fm (accept any value less or equal to 1 fm) ✓
<u>attractive</u> up to / at 3 fm (accept any value between 0.5 and 10 fm) ✓
short range OR becomes zero OR no effect ✓

Can get marks from labelled graph

Don't accept negligible for 3rd mark

3

(ii) interaction: electromagnetic / em ✓

(virtual) photon/ γ ✓

2

[12]

10 (a) (i) $u\bar{s}$ / up and anti-strange ✓

In any order
Bar must be over s only

1

(ii) 0 / zero / nothing ✓

1

(iii) K^- / negative kaon / $\overline{us}$ ✓

1

(b) (i)

classification	K^+	ν_μ	μ^+
lepton	×	✓	✓
charged particle	✓	×	✓
hadron	✓	×	×
meson	✓	×	×

1 mark for each correct row

3

(ii) conserved: baryon number OR lepton number ✓
not conserved: strangeness / kinetic energy ✓

Mass in either loses mark

2

(c) (i) neutral pion ✓

Indicated clearly in table in any way e.g. circled or cross. If more than one box used then must be a tick with neutral pion only

1

(ii) must be neutral / no charge / 0 charge to obey charge conservation
OR
cannot be baryon to obey conservation of baryon number
OR
cannot be lepton to obey conservation of lepton number ✓

Can show by using equation and appropriate quantum numbers

1

[10]

11 (a) (i) protons = 20✓
neutrons = 28 ✓
electrons = 18 ✓

3

(ii) $2 \times 1.6 \times 10^{-19} = 3.2 \times 10^{-19}$ ✓(C)

-ve sign loses mark

1

(iii) specific charge = 3.2×10^{-19} / (48 ×; 1.67×10^{-27} +18 × 9.11×10^{-31}) ✓

specific charge = 4.0×10^{6} C kg^{-1} ✓

Allow 1.66

Allow CE from (ii)

First mark is for mass if miss out electron mass and do not justify lose first mark

2

[6]

12 (a) Photon

(right-hand box) TO for listing
Must state name

Weak (nuclear) / weak interaction / weak nuclear interaction / weak force

B1

(left-hand box) TO for listing

2

(b) Charge / (electric) charge

B1

TO for listing any other physical quantity

Must be word; do not accept symbol

1

(c) Higgs (boson) / Higgs (particle) / Higgs (boson particle)

Not graviton

Accept Higg / Higs / Hig

B1

TO for listing

1

[4]

13 (a) (i) neutron✓

accept symbols
symbols e.g. n

1

(ii) electron✓

accept symbols

1

(iii) neutron✓

accept symbols

1

(b) (i) antineutrino✓

$\overline{V}_{(e)}$

1

(ii) A=99✓
Z= 44 ✓

2

(iii) specific charge = $43 \times 1.6 \times 10^{-19}$ ✓ / $99 \times 1.66 \times 10^{-27}$ ✓

specific charge = 4.2×10^{7} ✓C kg^{-1} ✓

Correct answer no working −1

If include mass of electrons lose 2 and 3 mark

4

[10]

14 (a) pair production ✓

1

(b) (energy = 2 × rest mass energy)

energy = 2 × 0.510999 = 1.021998 (MeV) ✓

energy = $1.021998 \times 1.60 \times 10^{-13} = 1.64 \times 10^{-13}$ J ✓

(3 sig figs ✓)

If miss out 2 factor can get CE

Can use $E=2mc^2$

First mark for full substitution and second mark for answer

3

(c) kinetic energy (of electron and positron) ✓

KE of photon gets zero

1

(d) (meet an electron and) annihilate ✓

(converting into two or more) photon<u>s</u> ✓ OR gamma rays

2

[7]

15 (a) (i) nucleon number is the number of protons and neutrons OR mass number

proton number is the number of protons OR atomic number ✓

1

(ii) 14 – 6 = 8 ✓

1

(iii) specific charge = $6 \times 1.6 \times 10^{-19}$✓ /($14 \times 1.66 \times 10^{-27}$ ✓)

specific charge = 4.1 × 107 (C kg^{-1}) ✓

3

(b) (i) isotopes are variations of an element that have same proton/atomic number ✓

but different nucleon number OR different number of neutrons ✓

2

(ii) $4.8 \times 10^7 = 6 \times 1.6 \times 10^{-19}$ ✓ $/(A \times 1.66 \times 10^{-27})$

$A = 6 \times 1.6 \times 10^{-19}/(4.8 \times 10^7 \times 1.66 \times 10^{-27})$

A = 12 ✓

Number of neutrons = 12-6 ✓

3

[10]

16 (a)

particle	quark structure	charge	strangeness	baryon number
proton✓	uud	+ 1✓	0	1✓
sigma$^+$	uus	+1	-1✓	1✓
π^+✓	$u\bar{d}$	+1✓	0	0

7

(b) (i) examples:
proton, antiquarks✓

1

(ii) consists of 3 antiquarks✓

1

(iii) same (rest) mass (energy)✓

difference eg baryon number/charge✓

2

[11]

17 (a) the ratio of charge to mass of nucleus ✓

C kg^{-1} ✓

2

(b) (i) number of protons and neutrons the same **or** number of neutrons less **or** mass the same✓

but more protons therefore greater charge✓

2

(ii) answers add up to 10✓

number of protons = 4 ✓

number of neutrons = 10 − 4 = 6 ✓

evidence of correct calculation ✓

eg 5q = 1.25 × ?q

? = 4

4

[8]

18 (a) (i) any two eg proton, neutron ✓✓

2

(ii) $u\bar{d}$ ✓

1

(b) (i) contains a strange quark

or longer half life than expected

or decays by weak interaction ✓

1

(ii) the second one is not possible ✓

because lepton number is not conserved ✓

2

(c) (i) weak (interaction) ✓

1

(ii) mention of charge conservation

or charge conservation demonstrated by numbers ✓

1

(iii) X must be a baryon ✓

baryon number on right hand side is +1 ✓

2

(iv) proton/p ✓

1

[11]

19 (i) same atomic number/number of protons ✓

different mass/nucleon number/different number of neutrons ✓

2

(ii) $^{A}_{Z}X \rightarrow {}^{A\ \ -4}_{Z\ \ -2}Y + {}^{4}_{2}\alpha$ ✓✓

2

(iii) $\frac{q}{m} = \frac{2 \times 1.6 \times 10^{-19}}{4 \times 1.67 \times 10^{-27}}$ ✓✓

$\frac{q}{m}$ = 4.8 × 10^7 Ckg^{-1}✓✓

4

(iv) strong nuclear force is short range ✓

no effect at distances larger 3 fm
(except any distance less than 10 fm) ✓

2

[10]

20 (a) repulsive then attractive **(1)**

short range (if distance quoted must be of order fm) **(1)**

correct distance for cross over (accept range 0.1 – 1.0 fm) **(1)**

3

(b) (i) a helium nucleus (accept 2p and 2n) **(1)**

1

(ii) (↓92↑238) *U* → (↓90↑234)*Th*(+↓2↑4)α **(1)**

2

(c) (i) same atomic number/proton number **(1)**

different number of neutrons/nucleons **(1)**

2

(ii) evidence of subtraction of mass number or atomic number **(1)**

(thus atomic number decreases to) **76** **(1)**

(atomic number of lead is 82 therefore) **6** (82 – 76) beta decays **(1)**

3

[11]

21 (a) (i) an electron **(1)**

1

(ii) change in *A* = 0 **(1)**

change in *Z* = +1 **(1)**

2

(b) (i) ${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e + \overline{\upsilon_e}$ **(1)**

or $n \rightarrow p + e^{-} + \overline{\upsilon_e}$

or $d \rightarrow u + e^{-} + \overline{\upsilon_e}$

1

(ii) lepton number must be conserved **(1)**

lepton number before decay equals zero

hence after decay lepton number of electrons cancels with lepton

number of anti-neutrino **or** zero on both sides **(1)**

2

(iii) hypothesis needs to be tested by experiment **(1)**

experiment must be repeatable **(1)**

or hypothesis rejected

2

[8]

22 (a) electron/neutrino/tau/muon

B1

proton/neutron

B1

kaon/k particle/k meson/pion/pi meson

B1

3

(b) (i) charge

M1

correct equation: 1 + 0 ≠ 1 + (–1)

1 mark lost for additional conservation law stated as broken

A1

2

(ii) any other correct conservation (lepton: 0 + 0 = 0 + 0; baryon: 0 + 1 = 1 + 0; strangeness: 0 + 0 = 0 + 0)

B1

1

(c) annihilation

B1

release of energy/pair of gamma rays

B1

2

[8]

23 (a) force arises/is medicated/is carried/is created when the exchange particle moves between the other particles

B1

1

(b) W or Z

B1

gluons/pion condone symbols

B1

Photons

B1

3

[4]

24 (a) (i) three **(1)**

one **(1)**

2

(b) (i) charge **(1)**

baryon number **(1)**

lepton number **(1)**

mass **(1)**

energy **(1)**

momentum **(1)**

max 2

(ii) strangeness **(1)**

(iii) weak interaction/(nuclear) force **(1)**

(iv) proton **(1)**

5

[7]

25 (a) n + $v_{(e)}$ **(1)(1)**

μ^- **(1)**

K^+ (1)

4

(b) d $\rightarrow$ u + β^- + $\bar{v}_{(e)}$ **(1)(1)**

2

(c) (i) weak interaction **(1)**

(ii) lepton **(1)**

(iii) electromagnetic and gravitational **(1)**

3

[9]