SECTION A

Answer **all** *the questions in the spaces provided.*

1. An isotope of magnesium, ^{27}Mg, is used to detect leaks in water pipes.

(a) It decays by β–emission with a half life of 9·5 minutes.

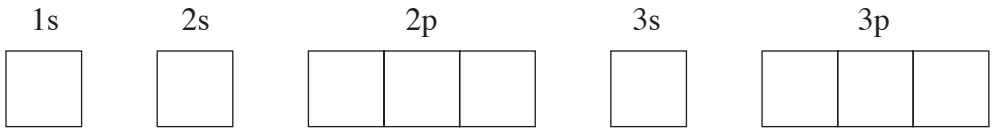
(i) Give the symbol and mass number of the atom formed by the loss of one β particle from an atom of ^{27}Mg. [1]

.....

(ii) Calculate how long it will take for the activity of the isotope to decay to $\frac{1}{16}^{th}$ of its original activity. [1]

..... minutes

(b) Complete the boxes below, by inserting arrows to represent electrons, to show the electronic configuration of an atom of magnesium. [1]



2. Calcium oxide is made by heating calcium carbonate in air.

$$\underset{1 \text{ mole}}{CaCO_3} \longrightarrow \underset{1 \text{ mole}}{CaO} + CO_2$$

Calculate the maximum mass of calcium oxide formed when 0·500 mole of pure calcium carbonate is heated. [2]

.....

.....

.....

4. The values for some standard molar ionisation energies are given in the table.

Element	*Standard molar ionisation energies* / kJ mol^{-1}	
	First	*Second*
Argon	1521	2666
Potassium	419	3051

(i) Give **two** reasons why the **first** standard molar ionisation energy for potassium is much less than that of argon. [2]

1. .....

.....

2. .....

.....

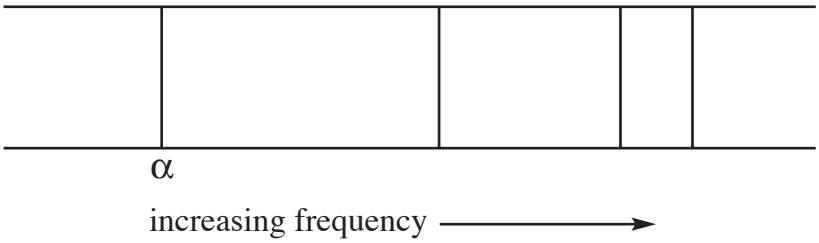
(ii) Give a reason why the value for the **second** standard molar ionisation energy of potassium is larger than that of argon. [1]

.....

.....

Section A Total [10]

8. *(a)* The diagram below shows the first four lines of the visible atomic emission spectrum for hydrogen (part of the Balmer series).



(i) Explain why the spectrum is seen as a series of sharp lines and not as a continuous spectrum. [2]

QWC [1]

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.....

(ii) The line labelled α, the first line of the Balmer series, has a wavelength of 657 nm.
The visible emission spectrum of neon shows a prominent line at 585 nm.
State the relationship between energy, frequency and wavelength and use this to complete the table below, using the words *higher* or *lower*. [4]

.....

.....

Wavelength / nm	*Frequency* / Hz	*Energy* / J
585		
657		

SECTION A

Answer **all** *the questions in the spaces provided.*

1. The symbols $^{35}_{17}Cl$, $^{37}_{17}Cl$ and $^{39}_{19}K$, represent chlorine atoms and potassium atoms respectively.

(a) Use these symbols to explain the meaning of the terms

(i) atomic number, [1]

.....

.....

(ii) isotope. [1]

.....

.....

(b) By inserting arrows to represent electrons, complete the boxes below to show the electronic configuration of a potassium atom. [1]

1s	2s	2p			3s	3p			3d					4s
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

SECTION B

Answer **all** *the questions in the spaces provided.*

5. *(a)* The table below shows the molar first ionisation energy values, IE, for the first ten elements of the Periodic Table.

Element	H	He	Li	Be	B	C	N	O	F	Ne
IE / kJ mol^{-1}	1310	2370	520	900	800	1090	1400	1310	1680	2080

(i) Complete the graph shown on the next page, to show how first ionisation energy varies for the first ten elements.

Four of the points have been plotted for you. [3]

(ii) Explain why

I. helium has a higher first ionisation energy than neon, [2]

.....

.....

.....

II. neon has a higher first ionisation energy than nitrogen, [1]

.....

.....

III. nitrogen has a higher first ionisation energy than oxygen. [2]

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.....

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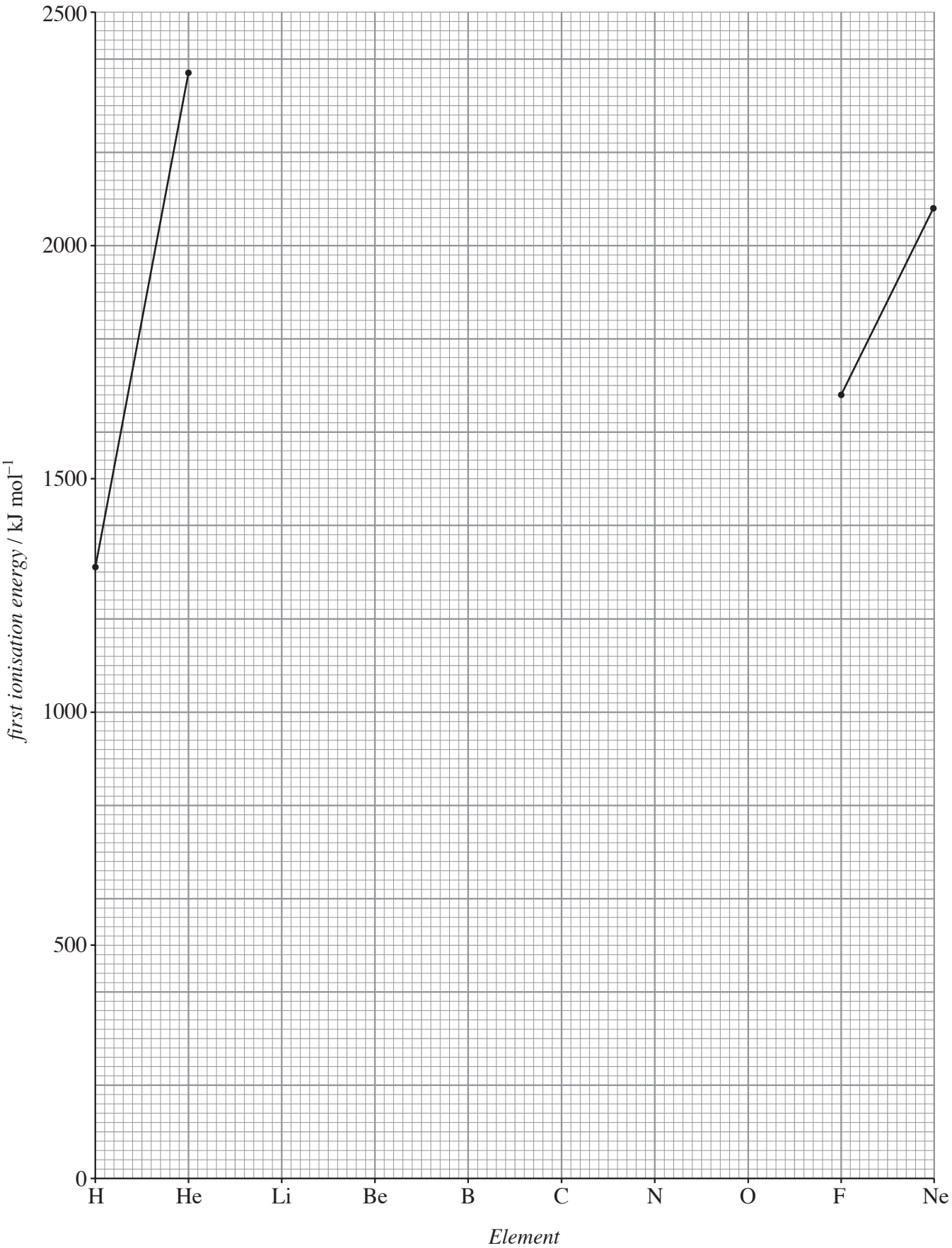
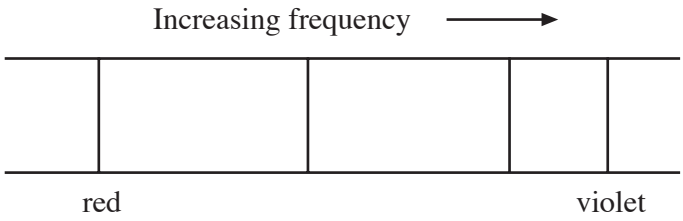

2500
2000
1500
1000
500
0
first ionisation energy / kJ mol−1
H
He
Li
Be
B
C
N
O
F
Ne
Element

7. *(a)* The diagram below shows the emission spectrum of the hydrogen atom in the visible region.



(i) Explain why hydrogen emits only certain definite frequencies of visible light. [2]

.....

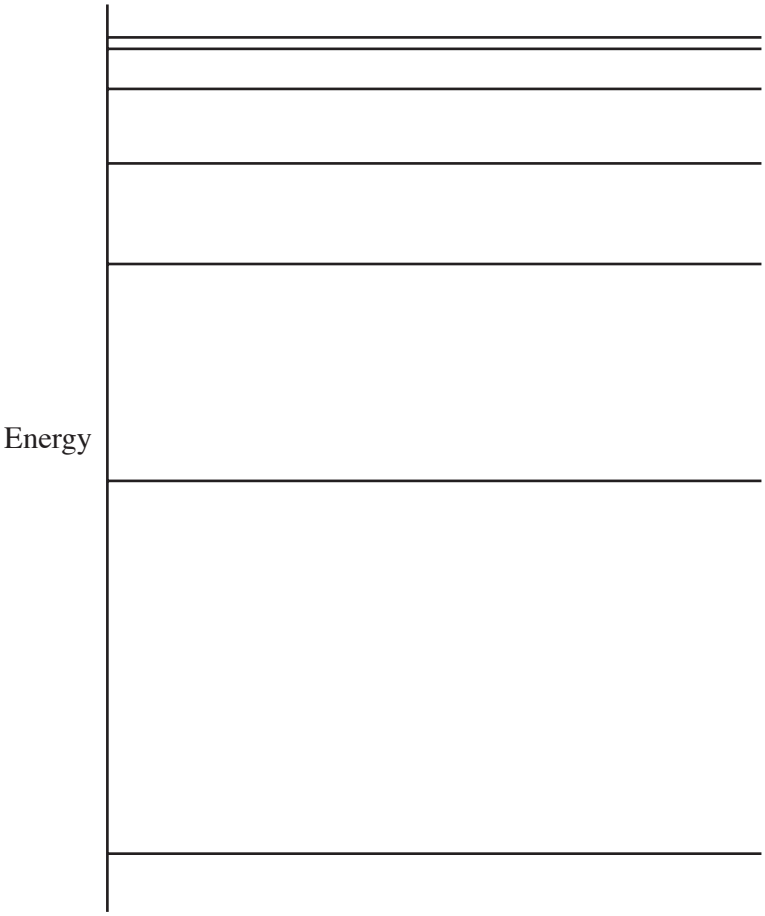
.....

.....

.....

(ii) The horizontal lines below show the electron energy levels of a hydrogen atom.

Label these horizontal lines and draw the transitions corresponding to the four spectral lines in *(a)* above, clearly indicating which transition represents the red spectral line. [3]



(iii) On the diagram, draw and label the transition corresponding to the ionisation of the atom. [1]

(b) Hydrogen exists as two naturally occurring isotopes, ^{1}H and ^{2}H.

(i) A mass spectrum of a sample of hydrogen showed that it contained ^{1}H 99.20% and ^{2}H 0.8000%.

Calculate the relative atomic mass of the hydrogen sample, giving your answer to **four significant figures**. [2]

.....

.....

.....

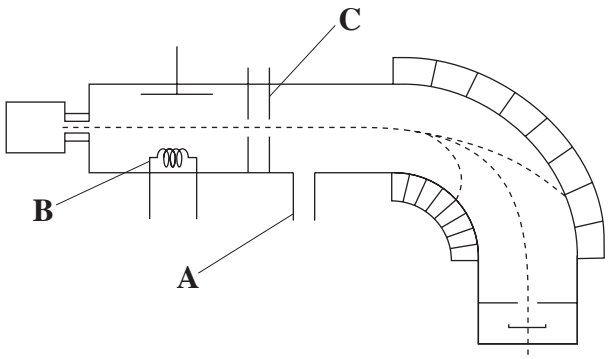
.....

(ii) In the mass spectrum, explain why peaks due to hydrogen atoms are present, although hydrogen gas contains only H_2 molecules. [1]

.....

.....

(c) Below is a diagram of a mass spectrometer.



(i) Name part **B**. [1]

.....

(ii) Name part **C**. [1]

.....

(iii) State the function of part **A**. [1]

.....

.....

Examiner only

(d) Hydrogen also has an artificial isotope which is radioactive by β decay.

Complete the table below which shows the nature and effect of radioactive emission. [4]

Type	*Nature*	*Effect on atomic number*
α particle		
β particle		
γ radiation	Electromagnetic radiation of high energy	No effect

Total [16]

Examiner only

SECTION A

Answer **all** *the questions in the spaces provided.*

1. Complete the boxes below, by inserting arrows to represent electrons, to show the electron configuration of an atom of aluminium, Al. [1]

2. State which **one** of the following letters represents the first five ionisation energies of aluminium, Al. Give a reason for your choice. [2]

Ionisation energy / kJ mol^{-1}

	1st	2nd	3rd	4th	5th
A	496	4563	6913	9544	13352
B	578	1817	2745	11578	14831
C	1402	2856	4578	7475	9445
D	789	1577	3232	4356	16091

Letter .....

Reason .....

.....

.....

Examiner only

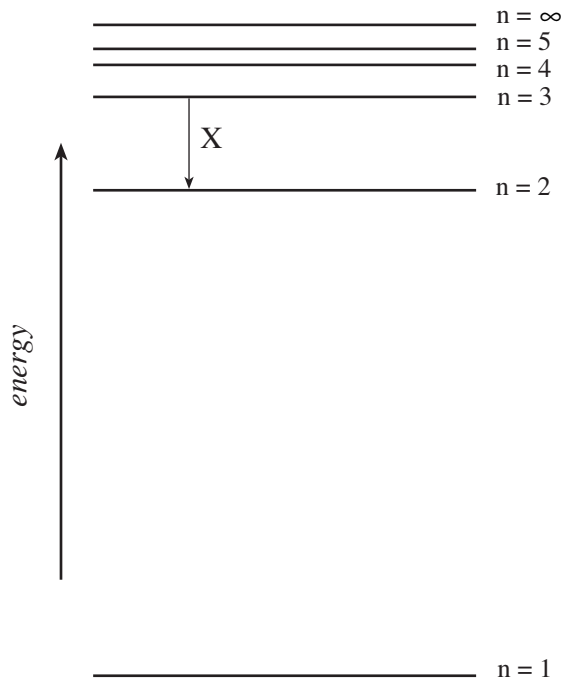
3. *(a)* Complete the following definition of the ***mole***: [1]

A mole is the amount of material containing the same number of particles as there are atoms in ..... .

(b) State the number of moles of sulfur atoms, S, in 0.3 mol iron(III) sulfate, $Fe_2(SO_4)_3$. [1]

.....

4. The diagram below shows the electron energy levels for a hydrogen atom.



(a) State which one of the following correctly describes the transition represented by arrow X: [1]

A The first line in the Lyman series
B The second line in the Lyman series
C The first line in the Balmer series
D The second line in the Balmer series

.....

(b) Draw on the energy level diagram an arrow to represent the transition which occurs when a hydrogen atom is ionised. [1]

Examiner only

5. Sketch a diagram to show the shape of a p-orbital. [1]

6. *(a)* Explain the term *dynamic equilibrium* for a chemical system. [1]

.....

.....

(b) Explain how you would tell, from the properties of the system, that equilibrium has been reached. [1]

.....

.....

Section A Total [10]

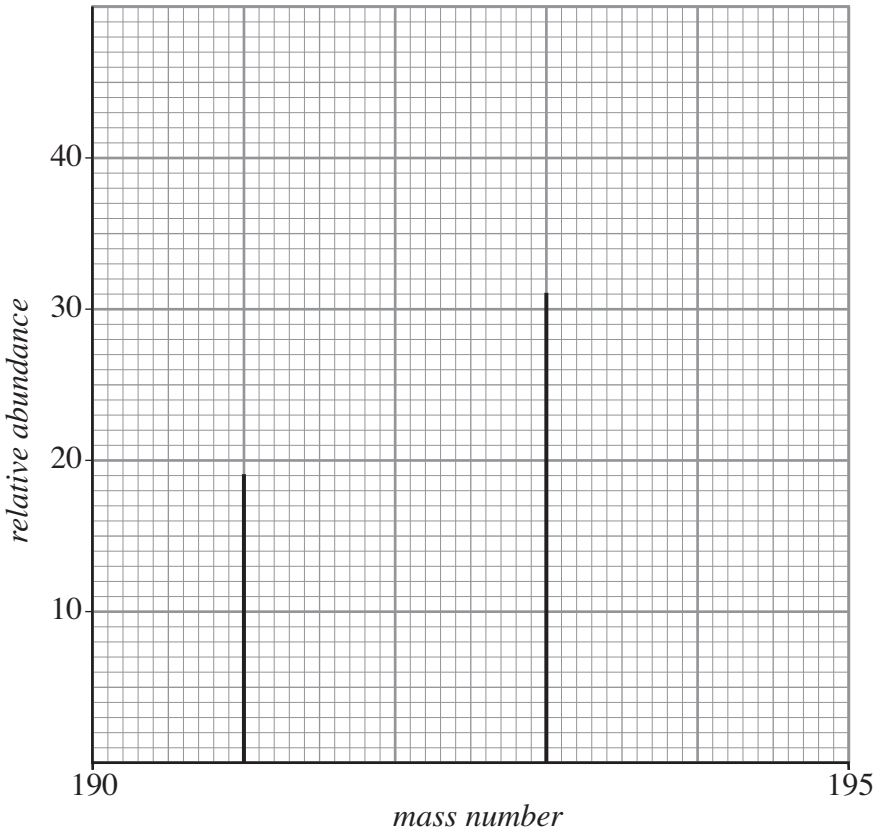
Examiner only

SECTION B

Answer **all** *the questions in the spaces provided.*

7. Iridium, Ir, is the element with atomic number 77.

(a) Its mass spectrum shows that iridium has two naturally-occurring isotopes.



(i) Explain the term *isotopes*. [1]

.....

.....

(ii) State the numbers of electrons, neutrons and protons present in **each** of the two isotopes. [2]

.....

.....

.....

(iii) Measure the height of each peak and hence calculate the percentage abundance of each isotope in naturally-occurring iridium. [2]

.....

.....

Examiner only

(b) A further man-made, radioactive isotope of iridium, ^{192}Ir, is manufactured by bombarding naturally-occurring iridium with neutrons in a nuclear reactor. ^{192}Ir is used in the radiotherapy of certain cancers.

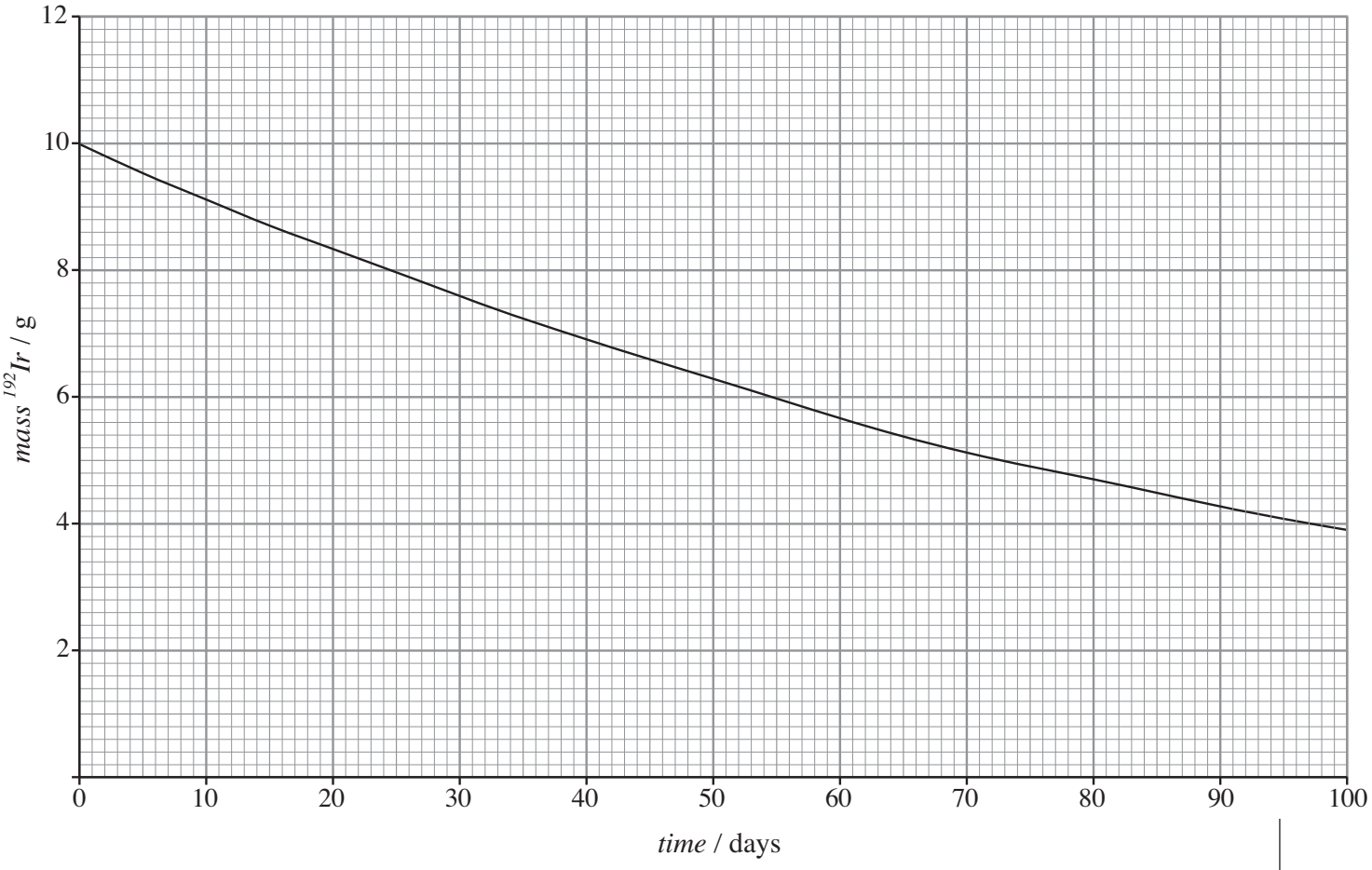
(i) ^{192}Ir decays by β–emission. Explain what is meant by β–emission. [1]

.....

(ii) Give the mass number and symbol of the product atom in *(b)*(i). [2]

Mass number ..... *Symbol* .....

(c) The decay of a 10g sample of ^{192}Ir with time is shown in the graph.



(i) Explain the term *half-life*. [1]

.....

.....

(ii) Determine the half-life of ^{192}Ir from the graph. [1]

.....

Examiner only

(iii) Determine the total time required for the 10 g mass of ^{192}Ir to decay to 1.25 g. [2]

.....

.....

(iv) Calculate, from the graph, the rate of decay of ^{192}Ir (g day^{-1}) during the first 20 days. [2]

.....

.....

.....

(d) Compound **P**, one of the most important compounds of iridium, is a black solid containing 10.2 % sodium, Na, 42.6 % iridium, Ir, and 47.2 % chlorine, Cl, by mass.

(i) Calculate the empirical formula (which is also the molecular formula) of compound **P**.

A_r(Na) = 23.0; A_r(Cl) = 35.5; A_r(Ir) = 192. [2]

.....

.....

.....

(ii) Compound **P** is made by reacting a mixture of sodium chloride, NaCl, and an iridium chloride, $IrCl_x$. There is only one product of the reaction. By constructing a balanced equation, or otherwise, determine the value of **x** in the iridium chloride formula, $IrCl_x$. [1]

.....

.....

Total [17]

Examiner only

SECTION A

Answer **all** *questions in the spaces provided.*

1. A gaseous isotope of hydrogen, tritium, $^{3}_{1}H$, is produced in the upper atmosphere.

(i) State which of the following correctly describes an atom of tritium. [1]

	Number of protons	Number of neutrons	Number of electrons
A	1	1	1
B	1	1	2
C	1	2	1
D	1	2	0

.....

(ii) Tritium is a radioactive gas with a half-life of 12.5 years. A sample of tritium has a mass of 0.960 g.
Calculate the mass of tritium remaining after 37.5 years. [1]

.....

.....

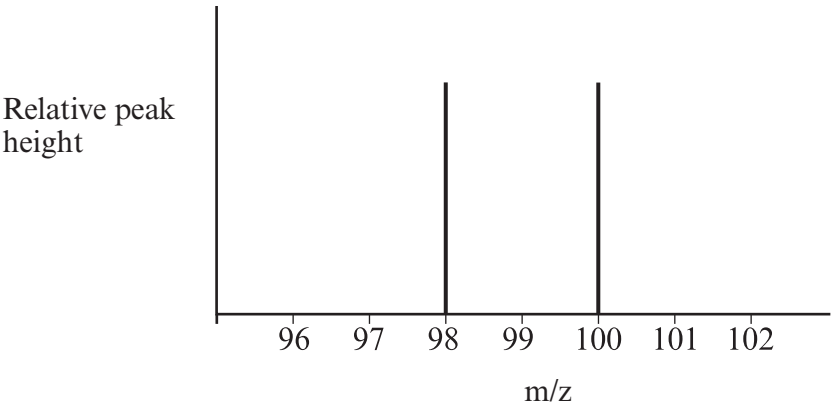
2. Cyanogen is a compound containing only carbon and nitrogen.
It has a relative molecular mass of 52.

(i) State the molecular formula of cyanogen. ..... [1]

(ii) State the empirical formula of cyanogen. ..... [1]

Examiner only

3. The mass spectrum of the colourless gas bromine fluoride, $Br^{19}F$, shows two molecular ions.



(i) State the mass numbers of the two bromine isotopes present in bromine fluoride. [1]

..... and .....

(ii) Bromine fluoride is unstable and readily gives $Br^{19}F_3$.
State the mass/charge (m/z) value for the molecular ion $Br^{19}F_3^+$, when all the bromine is present as the isotope ^{85}Br. [1]

.....

4. The first two standard molar ionisation energies for magnesium are shown in the table.

Electron removed	Standard molar ionisation energy / kJ mol^{-1}
first	736
second	1450

State which of the following is the value for the third molar standard ionisation energy, in kJ mol^{-1}, of magnesium. [1]

A 457

B 923

C 2170

D 7740 .....

Examiner only

8. *(a)* Sodium street lights, with their familiar orange-yellow light, have been used for many years. When these lights are first switched on, a red glow is seen as neon is used as the starter gas. The wavelength of the colour produced by each of these elements is shown in the table.

Element	Colour	Wavelength / nm
sodium	orange-yellow	590
neon	red	640

(i) State which one of these two colours has the higher frequency, explaining your answer. [1]

.....

.....

(ii) State the equation linking energy and frequency. [1]

.....

(b) The atomic emission spectrum of hydrogen consists of several series of lines.

(i) Explain how these lines are formed. [3]

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.....

(ii) State the significance of the frequency of the convergence limit in the Lyman series. [1]

.....

.....

(iii) Explain why there is more than one series of lines. [1]

.....

.....

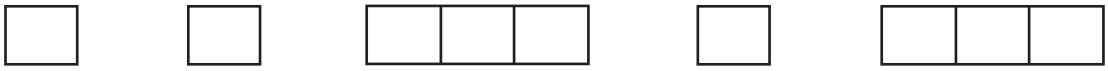
(c) (i) An atom of ^{23}Na absorbs a neutron to give ^{24}Na.
Complete the table to show any **changes** (if any) in the atomic number and mass number. [1]

	Change
Atomic number	
Mass number	

(ii) The isotope ^{24}Na decays by β-emission.
State the mass number and symbol of the species formed by the emission of one β-particle from an atom of ^{24}Na. [1]

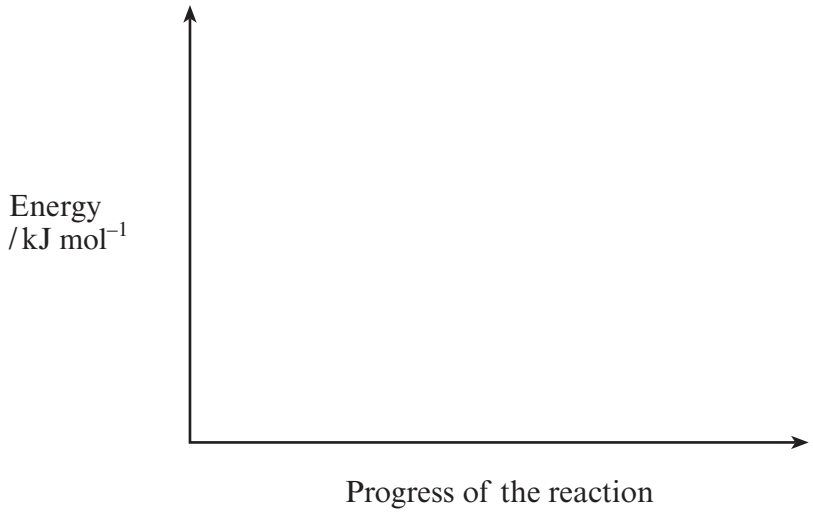
.....

(d) Using the 'arrows in boxes' notation give the electronic configuration of a magnesium atom. [1]



(e) Magnesium burns in air with a brilliant white light, forming magnesium oxide.

(i) Sketch a reaction profile for this reaction, using the axes provided. [1]



(ii) Indicate, on your profile in (i), the activation energy for the reaction. [1]

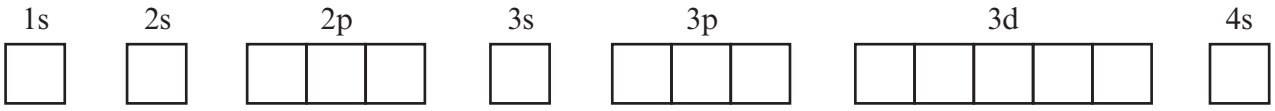
Total [12]

Examiner only

SECTION A

Answer **all** *questions in the spaces provided.*

1. By inserting arrows to represent electrons, complete the boxes below to show the electronic configuration of a calcium atom. [1]



2. *(a)* Calculate the molar mass, in $g\,mol^{-1}$, of calcium sulfate dihydrate, $CaSO_4.2H_2O$. [1]

.....

.....

(b) Calculate the percentage of water, by mass, in calcium sulfate dihydrate. [1]

.....

.....

3. Ions of two isotopes of the metal lithium are shown below.

$^{6}_{3}Li^{+}$ $^{7}_{3}Li^{+}$

State which **one** of the following statements is **correct**. [1]

A The electron arrangement of both these Li^+ ions is $1s^2 2s^1$.

B The $^{7}Li^{+}$ ion will have more protons in its nucleus than the $^{6}Li^{+}$ ion.

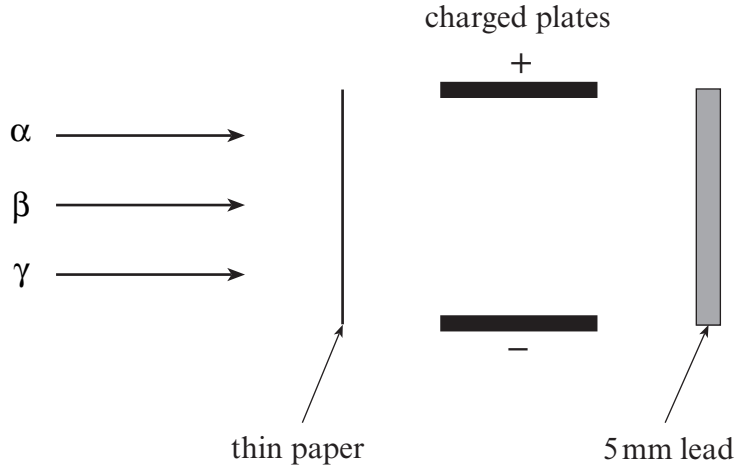
C The $^{7}Li^{+}$ ion will be deflected more than the $^{6}Li^{+}$ ion in a mass spectrometer.

D Both of these Li^+ ions have the same number of electrons.

.....

Examiner only

4. Complete the diagram below to show how radiation is affected by an electric field and by materials of different thickness. [3]



5. A compound of carbon, hydrogen and oxygen has a relative molecular mass of 180. The percentage composition by mass is C 40.0%; H 6.70%; O 53.3%.

1091 010003

(a) Calculate the empirical formula of this compound. [2]

.....

.....

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.....

.....

.....

(b) Determine the molecular formula of this compound. [1]

.....

.....

.....

.....

Section A Total [10]

Examiner only

(c) Potassium-40, $^{40}_{19}K$, is a radioactive isotope that decays by β-emission and has a half-life of 1.25×10^9 years.

(i) Write an equation for the process by which a potassium-40 isotope emits a β-particle. [2]

.....

(ii) Calculate how long it will take for the activity of the isotope to decay to $\frac{1}{8}$ th of its original activity. [1]

.....

.....

(d) The first and second ionisation energies of potassium and sodium are shown in the table below.

	1st ionisation energy / kJ mol^{-1}	2nd ionisation energy / kJ mol^{-1}
potassium	419	3051
sodium	496	4562

(i) Explain the term *molar first ionisation energy*. [2]

.....

.....

.....

(ii) Explain why

I potassium has a lower first ionisation energy than sodium, [2]

.....

.....

.....

.....

II there is a large difference between the first and second ionisation energies of potassium. [2]

.....

.....

.....

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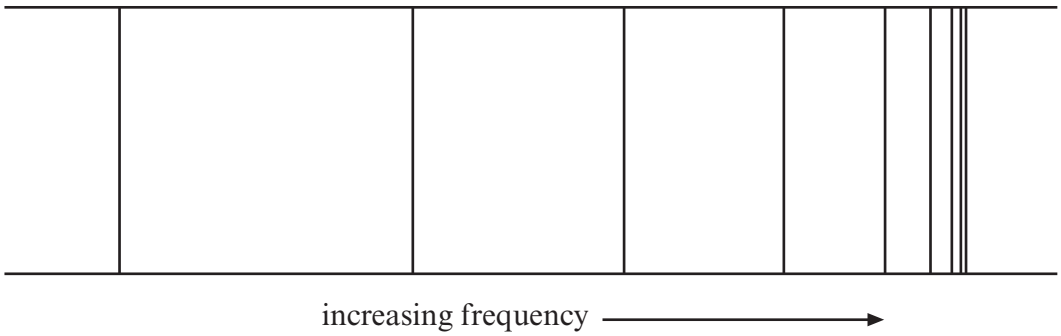
Total [15]

Examiner only

9. *(a)* The diagram below includes the visible atomic emission spectrum of hydrogen (the Balmer series).



(i) Label the line of **lowest** energy on the diagram. [1]

(ii) Explain why the lines become closer together at the high frequency end of the spectrum. [1]

.....

.....

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Examiner only

SECTION A

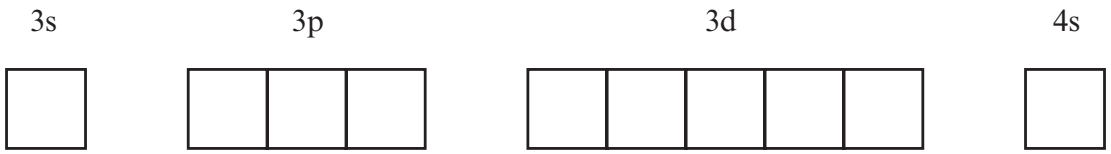
Answer **all** *questions in the spaces provided.*

1. Enter the number of protons, neutrons and electrons present in the atoms/ions listed in the table below.

Atom/ion	Number of protons	Number of neutrons	Number of electrons
^{24}Mg			
^{26}Mg			
$^{24}Mg^{2+}$			

[3]

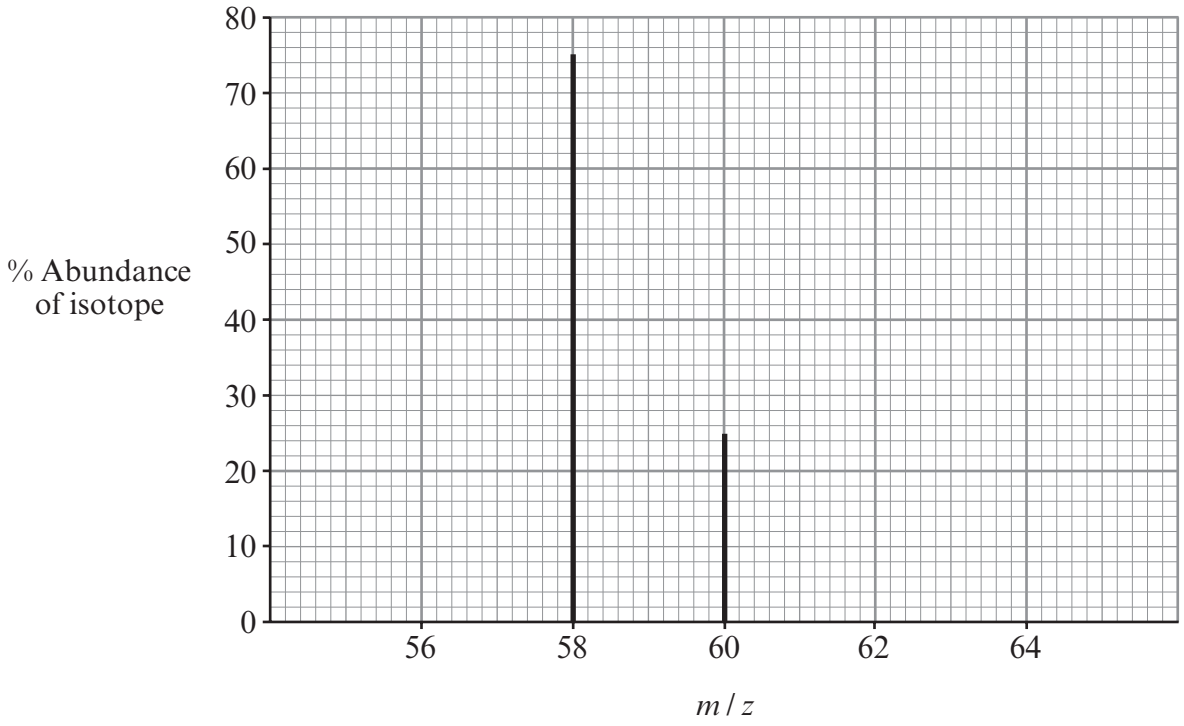
2. By inserting arrows to represent electrons, complete the boxes below to show the electronic configuration of an iron atom, Fe. The 1s, 2s and 2p orbitals are assumed to be already filled.



[1]

Examiner only

3. The mass spectrum of a sample of nickel is shown below.



Use the data to calculate the relative atomic mass of this sample to **three** significant figures. **You must show your working.** [1]

.....

.....

4. State which of the following letters corresponds to the number of moles of each element in 53 g of sodium carbonate, Na_2CO_3, which has an M_r of 106.

	Na	C	O
A	0.5	0.5	0.5
B	1	0.5	3
C	1	0.5	1.5
D	2	1	3

[1]

Letter .....

Examiner only

SECTION B

Answer **all** *questions in the spaces provided.*

7. An understanding of atoms is a vital part of chemistry and this is gained by studies of spectra, ionisation energies and radioactivity.

(a) Explain briefly the origin of atomic absorption spectra in terms of electron transitions. [2]

.....

.....

.....

(b) Describe the visible emission spectrum of a hydrogen atom and explain, in terms of the atom's electronic structure, why it does not consist of a continuous, rainbow-like spectrum. [3]

QWC [1]

.....

.....

.....

.....

Examiner only

(c) Describe and explain the **general** change in ionisation energies

(i) across a period e.g. from Na to Ar, [2]

.....

.....

.....

(ii) down a group e.g. from Li to Cs. [2]

.....

.....

.....

(d) Complete the table below to show the effects that the emission of alpha, beta and gamma radiation have on the atomic number and mass number of a radioactive atom (by inserting e.g. +1, –2, etc). [3]

Radiation	Effect on atomic number	Effect on mass number
alpha particle		
beta particle		
gamma radiation		

1091 010007

(e) (i) The half-life of carbon-14 is 5500 years and that of uranium-238 is 4.5 billion years. State what is meant by the *half-life* of an isotope and explain in principle how knowledge of such half-lives is useful in studies of rocks **or** ancient organic objects. [2]

.....

.....

.....

(ii) Give **two other** uses of radioactive materials in analysis, industry or medicine. [2]

.....

.....

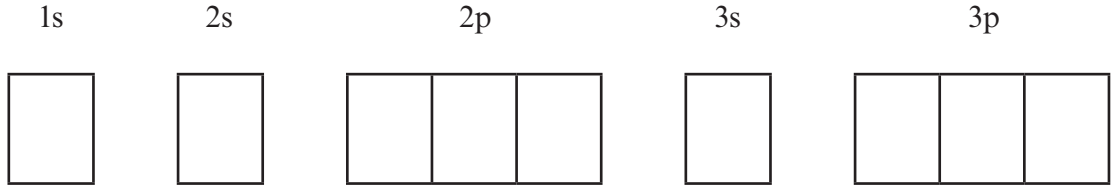
Total [17]

Examiner only

SECTION A

Answer **all** *questions in the spaces provided.*

1. By inserting arrows to represent electrons, complete the boxes below to show the electronic configuration of a sulfur atom. [1]



2. State the number of protons present in an aluminium ion, Al^{3+}. [1]

A 10
B 13
C 14
D 16

.....

3. Weak *acids* establish a *dynamic equilibrium* when dissolved in water.
Give brief explanations of what is meant by the following terms. [2]

Acid .....

.....

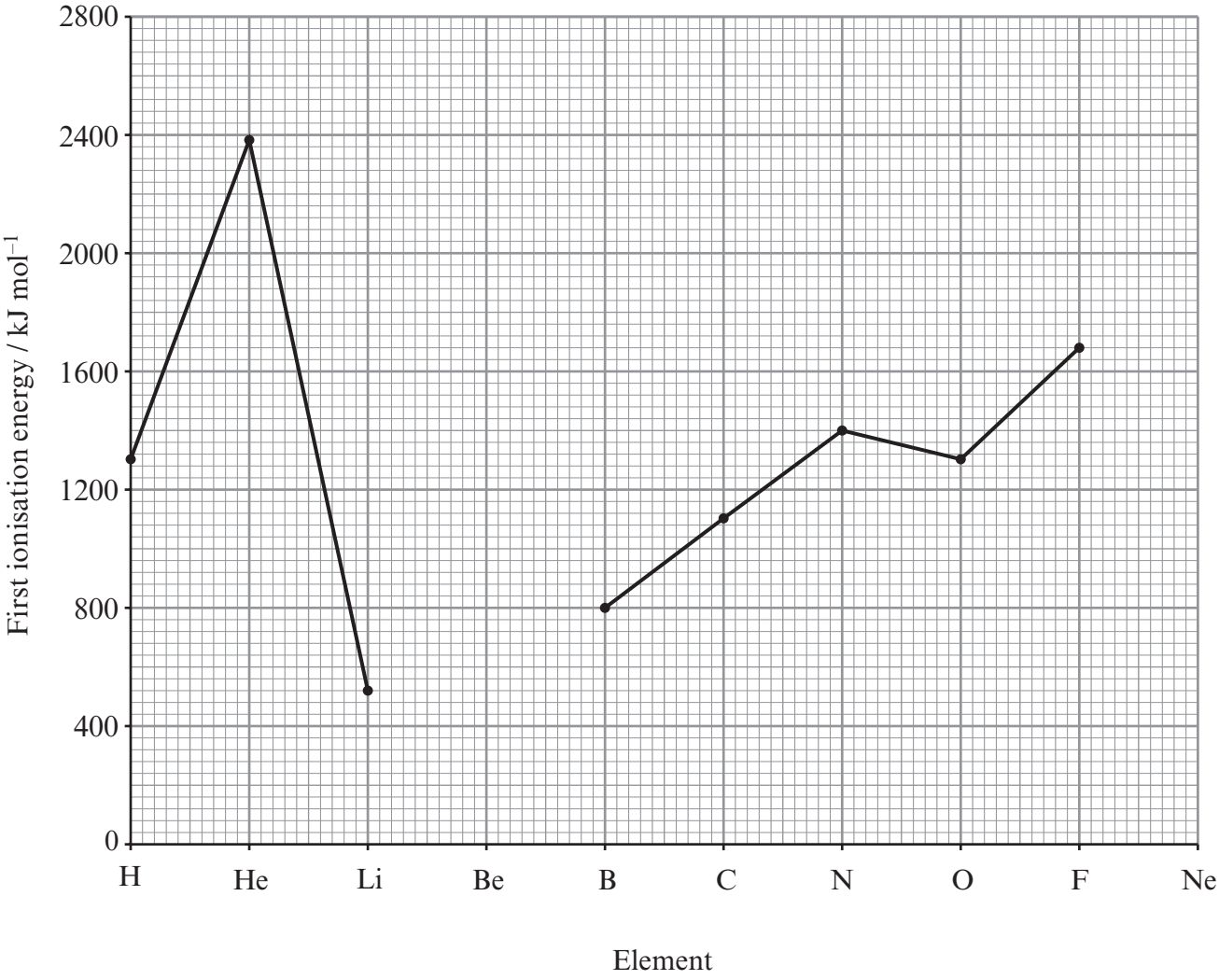
Dynamic equilibrium .....

.....

.....

Examiner only

8. The graph below shows the first molar ionisation energies for a selection of the first 10 elements.



(a) Complete the graph above by adding points that represent the first ionisation energies for the elements beryllium and neon. [2]

(b) Write an equation to represent the first ionisation of a beryllium atom. [1]

.....

Examiner only

(c) Explain why

(i) helium has a higher first ionisation energy than hydrogen, [2]

.....

.....

.....

(ii) nitrogen has a higher first ionisation energy than oxygen. [2]

.....

.....

.....

(d) The atomic emission spectrum can be used to calculate the ionisation energy of hydrogen.

(i) Explain how the lines in the atomic emission spectrum are formed. [3]
QWC [1]

.....

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(ii) Explain how the ionisation energy of a hydrogen atom can be calculated from a feature in the atomic emission spectrum. [3]

.....

.....

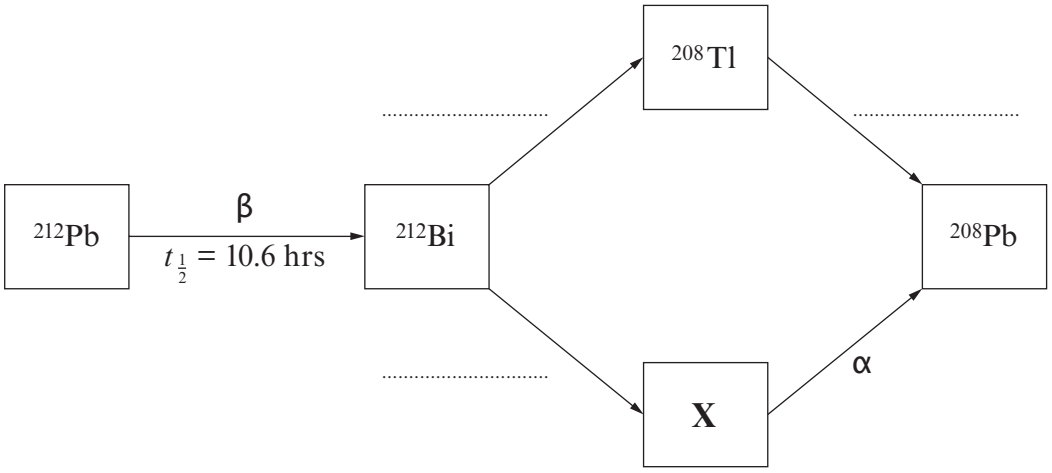
.....

.....

Total [14]

Examiner only

(c) Lead has a wide range of isotopes, some of which are stable and others that are radioactive. Radioactive lead-212 decays to eventually form the stable isotope ^{208}Pb. This process involves the decay of ^{212}Pb into ^{212}Bi followed by two alternative routes that both lead to ^{208}Pb, as shown in the scheme below.



(i) Give the correct symbol and mass number of the isotope indicated by **X** on the scheme above. [2]

Symbol ..... *Mass Number* .....

(ii) Two arrows have been labelled with α and β.
Label the remaining **three** arrows to indicate the nature of the radioactive decay occurring in each step. [2]

Examiner only

(iii) It is not possible to identify whether γ-radiation is also produced during any of the radioactive decay processes from the information given in the scheme.

State what is meant by γ-radiation and why it cannot be identified from the information given in the scheme. [2]

.....

.....

.....

(iv) A sample of 24 mg of ^{212}Pb was allowed to stand for 31.8 hours. Calculate the mass of ^{212}Pb that would remain after this time. [2]

.....

.....

..... mg

(d) Naturally-occurring lead consists of a mixture of stable isotopes which include ^{206}Pb, ^{207}Pb and ^{208}Pb. The relative amounts of these isotopes can vary between different sources. The abundance of each isotope in a sample is given below.

Isotope	Relative isotopic mass	Percentage abundance
^{206}Pb	206.0	25.48%
^{207}Pb	207.0	22.12%
^{208}Pb	208.0	52.40%

Calculate the relative atomic mass (A_r) for this sample of lead. Give your answer to **four significant figures**. [3]

.....

.....

.....

.....

Total [19]

Examiner only

SECTION A

Answer **all** *questions in the spaces provided.*

1. Sketch a diagram to show the shape of a *p* orbital. [1]

2. Complete the following definition of *relative atomic mass*: [1]

The relative atomic mass of an element is the average mass of one atom of the element relative to

.....

.....

3. State which **one** of the following contains the greatest number of molecules. [1]

A 3 g of hydrogen

B 32 g of oxygen

C 36 g of water

D 66 g of carbon dioxide .....

4. Phosgene is a compound of carbon, oxygen and chlorine. It is used to make polyurethanes and polycarbonates. Its percentage composition, by mass, is as follows.

C 12.1% O 16.2% Cl 71.7%

(a) Calculate the **empirical** formula of this compound. [2]

.....

.....

.....

.....

(b) What other information would you need to know to be able to deduce the **molecular** formula of this compound? [1]

.....

Examiner only

5. *(a)* The electronic structures of five atoms, **A** to **E**, are listed below. Arrange these atoms in order of increasing molar first ionisation energy. [2]

Atom	**A**	**B**	**C**	**D**	**E**
Electronic structure	$1s^2$	$1s^2\,2s^2$	$1s^2\,2s^2\,2p^1$	$1s^2\,2s^2\,2p^3$	$1s^2\,2s^2\,2p^6$

lowest ..... *highest*

(b) State, giving a reason for your choice, which **one** of the following gives the first four ionisation energies for silicon, Si. [2]

	Ionisation energy / kJ mol^{-1}			
	1st	2nd	3rd	4th
W	496	4563	6913	9544
X	578	1817	2745	11578
Y	738	1451	7733	10541
Z	789	1577	3232	4356

Letter .....

Reason .....

.....

.....

Section A Total [10]

1091 010003

Examiner only

SECTION B

Answer **all** *questions in the spaces provided.*

6. Magnesium is best known for burning with a characteristic brilliant white light, however in industry it is the third most commonly used structural metal. The metal itself was first produced by Sir Humphry Davy in 1808 by the electrolysis of a mixture of magnesia and mercury oxide.

(a) Magnesium has three stable isotopes ^{24}Mg, ^{25}Mg and ^{26}Mg.

(i) State the number of protons present in an atom of ^{24}Mg. [1]

.....

(ii) Deduce the number of neutrons present in an atom of ^{26}Mg. [1]

.....

(iii) In order to calculate the relative atomic mass of magnesium, what would you need to know in addition to the relative mass of each isotope? [1]

.....

(b) Magnesium also has a radioactive isotope ^{28}Mg which has a half-life of 21 hours.

(i) If you started with 2.0 g of ^{28}Mg, calculate the mass of this isotope remaining after 84 hours. [1]

.....

.....

(ii) Name **one** useful radioactive isotope and briefly describe how it is used in medicine, industry or analysis. [2]

.....

.....

Examiner only

(c) In order to obtain a mass spectrum of a gaseous sample of magnesium, the sample must be ionised.

(i) State how the magnesium atoms are ionised in the sample. [1]

.....

.....

(ii) Give a reason why it is necessary to ionise the magnesium atoms in the sample. [1]

.....

.....

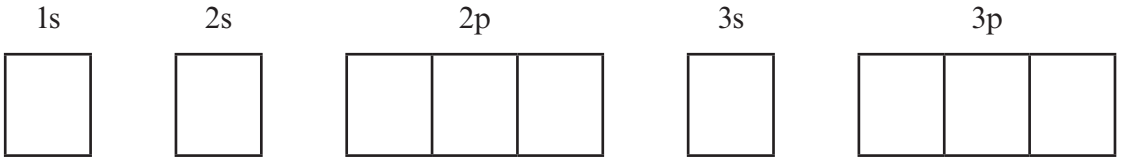
(iii) State how the ions of magnesium are separated. [1]

.....

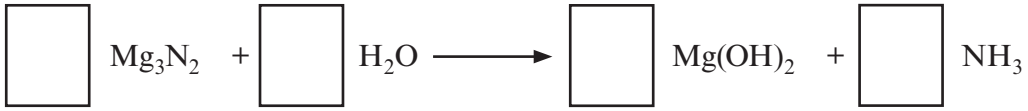
.....

(d) Magnesium reacts with nitrogen forming magnesium nitride, which is an ionic compound.

By inserting arrows to represent electrons, complete the boxes below to show the electronic configuration of a nitride ion, N^{3-}. [1]



(e) Magnesium nitride reacts with water to form magnesium hydroxide and ammonia.



(i) Balance the equation above. [1]

(ii) Calculate the minimum mass of magnesium nitride required to form 1.75 g of magnesium hydroxide, giving your answer to **three** significant figures. [3]

.....

.....

.....

.....

Total [14]

Examiner only

(c) The first line in the visible atomic emission spectrum for hydrogen has a wavelength of 656 nm, while that for helium has a wavelength of 707 nm.
State, giving a reason, which line has

(i) the higher frequency, [1]

.....

.....

(ii) the higher energy. [1]

.....

(d) The first ionisation energy of helium is 2370 kJ mol^{-1} while that of neon is 2080 kJ mol^{-1}.
Explain why neon has a lower first ionisation energy than helium. [2]

.....

.....

.....

(e) Another noble gas is radon. Its more stable isotope ^{222}Rn has a half-life of 3.8 days, decays by α-emission and is responsible for the majority of the public exposure to ionising radiation.

(i) Give the symbol and mass number of the atom formed by the loss of one α-particle from an atom of ^{222}Rn. [1]

.....

(ii) Explain why doctors are concerned that an over-exposure to radon may cause lung cancer. [1]

.....

.....

Total [12]

Examiner only

SECTION A

Answer **all** *questions in the spaces provided.*

1. The mass number of an isotope of gallium is 70.

State the number of neutrons in an atom of this isotope. ..... [1]

2. Write the letter which represents the correct equation for the **second** ionisation energy of gallium in the box below. [1]

A $Ga(g) + 2e^- \longrightarrow Ga^{2-}(g)$

B $Ga(g) \longrightarrow Ga^{2-}(g) + 2e^-$

C $Ga^+(g) \longrightarrow Ga^{2+}(g) + e^-$

D $Ga^{2+}(g) + 2e^- \longrightarrow Ga(g)$

3. An enriched isotopic mixture of lithium contains ^6Li 12.0% and ^7Li 88.0% by mass. Showing your working, calculate the relative atomic mass of this sample of lithium. Give your answer to **three** significant figures. [2]

Relative atomic mass = ...

Examiner only

SECTION B

Answer **all** *questions in the spaces provided.*

7. *(a)* In 2011 a man was detained at Moscow Airport when he tried to smuggle samples containing a radioactive isotope of sodium, ^{22}Na, onto an aircraft.

(i) This isotope is made from an aluminium isotope by loss of an α-particle.

State what is meant by an α-*particle*. [1]

.....

(ii) ^{22}Na decays by the loss of a positron. This may occur by the breakdown of a proton into a neutron and a positron, giving the product, ^{b}X.

Deduce the mass number (b) and the chemical symbol (X) of this product. [2]

b .....

X .....

(iii) The half-life of the isotope ^{22}Na is 2.6 years. The mass of a sample of this isotope is 48 mg.

Calculate the time taken for the mass of ^{22}Na to fall to 3 mg. [1]

Time taken = ... years

(b) The visible emission spectrum of sodium shows a strong yellow-orange line at a wavelength of 589 nm and a weaker green line at 569 nm.

Complete the sentences below by using the words **higher** or **lower** as appropriate. [1]

The frequency of the green line at 569 nm is ..... than the frequency of the yellow-orange line at 589 nm. Another line is seen at 424 nm. This is caused by an electronic transition of ..... energy than the line at 569 nm.

1091 010005

Examiner only

10. *(a)* Potassium hydroxide contains potassium ions, K^+.
Give the electron configuration of a potassium **atom** and use this to explain why most potassium compounds contain the potassium ion. [2]

.....

.....

.....

(b) Michael was asked to make 250 cm^3 of a solution of potassium hydroxide and to record the maximum rise in temperature that occurred as it dissolved.
He measured 250 cm^3 of water in a glass beaker and then added 7.01 g (0.125 mol) of solid potassium hydroxide to this, with stirring.
He noticed that the temperature rose from 20.2 °C to a maximum of 25.0 °C.

(i) Calculate the molar enthalpy change of solution of potassium hydroxide by use of the formula

$$\Delta H = -\frac{mc\Delta T}{n}$$

where m = mass of the solvent in grams (assume 1 cm^3 has a mass of 1 g)
c = 4.2 $J\,g^{-1}\,°C^{-1}$
ΔT = change in temperature of the solution
n = number of moles of the solute
ΔH = molar enthalpy change of solution

You should show the **units** in your answer. [3]

ΔH = ...

(ii) Michael's measurements produced a value for the enthalpy of solution of potassium hydroxide that was different to the literature value.

Use the information given to suggest and explain **two** factors that might produce a different result. [2]

1. .....

.....

2. .....

.....

Examiner only

SECTION A

Answer **all** *questions in the spaces provided.*

1. Carbon-14 is a radioactive isotope of carbon. Give the numbers of protons, neutrons and electrons present in an atom of carbon-14. [2]

Number of protons .....

Number of neutrons .....

Number of electrons .....

2. Circle **all** of the following that carry a negative charge. [2]

electron α-particle γ–ray proton neutron β-particle

3. Many industrial processes use catalysts.

Explain how a catalyst increases the rate of a chemical reaction. [2]

.....

.....

.....

4. Sketch the shape of **one** *p*-orbital. [1]

Examiner only

5. Name an element that has a half-filled set of *p*-orbitals. [1]

.....

6. Vinegar is a dilute solution of a weak acid.

(a) State what is meant by an *acid*. [1]

.....

.....

(b) Suggest a pH value for vinegar. [1]

.....

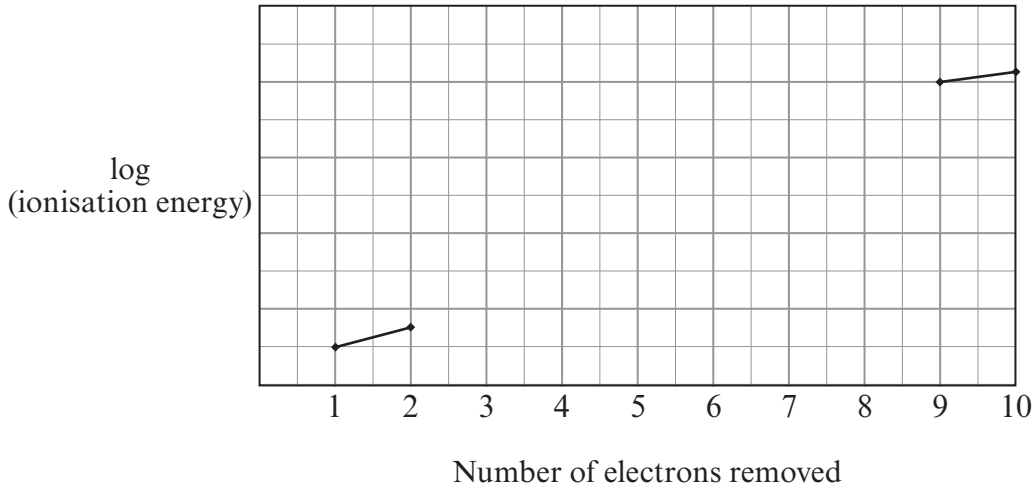
Section A Total [10]

Examiner only

8. The noble gases (Group 0) are a group of very unreactive elements. The first members of the group (helium, neon and argon) do not form any compounds, however it is possible to form a few compounds of krypton and xenon.

(a) Neon has ten electrons in each atom. The sketch below shows the first two and the final two ionisation energies for a neon atom.

(i) Sketch the pattern you would expect to see for the remaining six ionisation energies of neon. [2]



(ii) Explain any significant changes in slope on the graph you have sketched. [2]

.....

.....

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Examiner only

(b) The first compound of a noble gas was formed from Xe atoms and PtF_6. It was the ionic compound $Xe^+ PtF_6^-$.

Explain why it is not possible to form a similar ionic compound of argon, $Ar^+ PtF_6^-$. [2]

.....

.....

.....

(c) Helium was identified in the Sun before it was discovered on Earth. When light from the Sun is split into its different colours by a prism, dark lines are observed against a coloured background which show the atomic absorption spectrum of helium. Explain how an atomic absorption spectrum forms. [2]

.....

.....

.....

.....

(d) Xenon trioxide, XeO_3, is a compound which decomposes explosively at 25 °C according to the following equation.

$$2XeO_3(s) \longrightarrow 2Xe(g) + 3O_2(g)$$

Calculate the volume of gas, in dm^3, released by the decomposition of 1 mol of XeO_3 under these conditions. [2]

[1 mol of any gas at 25 °C occupies a volume of 24.0 dm^3]

Volume = ... dm^3

Total [10]

700010
1601

Examiner only

(b) Some selenium is found amongst the decay products in a nuclear reactor. The mass spectrum found for this sample of selenium had the isotopic composition below.

Isotope	Abundance
^{78}Se	12.2%
^{79}Se	26.4%
^{80}Se	61.4%

Calculate the relative atomic mass of this sample of selenium.
Give your answer to **3 significant figures**. [3]

Relative atomic mass = ...

(c) ^{81}Se is a radioactive isotope of the element selenium, which decays by β-emission with a half life of 18.75 minutes.

(i) The decay of ^{81}Se is shown by the equation below.

$$^{81}Se \longrightarrow {}^{a}X + {}^{0}_{-1}\beta$$

Identify a and X in this equation. [1]

a ..... X .....

(ii) 2.72 g of ^{81}Se is used by a scientist for an experiment. Calculate the mass of ^{81}Se that would remain after 75 minutes. [2]

Mass = ... g

Total [13]

Examiner only

SECTION A

Answer **all** *questions in the spaces provided.*

1. An element, X, has an atomic number of 9 and forms an ion X^-. State which **one** of the following shows the numbers of protons and electrons in this **ion**. [1]

	protons	electrons
A	8	9
B	9	8
C	9	9
D	9	10

2. State which **one** of the following shows the mass of aluminium that contains the same number of atoms as there are molecules in 11.0 g of carbon dioxide, CO_2. [1]

A 6.75 g

B 13.5 g

C 27.0 g

D 54.0 g

3. The isotope ^{32}P is radioactive. It decays by β-emission and has a half-life of 14 days.

(a) State what is meant by *β-emission*. [1]

.....

.....

(b) Give the mass number **and** symbol of the atom formed by the loss of one β-particle from an atom of ^{32}P. [1]

.....

(c) State what is meant by the term *half-life*. [1]

.....

.....

(d) Calculate how long it will take a sample of ^{32}P to decay from 8 g to 1 g. [1]

Time taken = ... days

Examiner only

8. This question is about atomic structure.

(a) Give the full electronic configuration of a nitrogen atom and use this to describe the way in which electrons are arranged in atoms. [4]

QWC [1]

(b) Describe the main features of the atomic emission spectrum of hydrogen in the visible region. Explain how these features arise and how their interpretation provides evidence for energy levels in the atom. [6]

Examiner only

(c) (i) Hydrogen has a first ionisation energy of 1312 kJ mol^{-1}.
Explain why helium has a higher first ionisation energy than hydrogen. [2]

.....

.....

.....

(ii) Beryllium and magnesium are both in Group 2 of the Periodic Table.
Explain why beryllium has a higher first ionisation energy than magnesium. [2]

.....

.....

.....

(iii) The table below gives the first three ionisation energies for boron and potassium.

Element	Ionisation energy / kJ mol^{-1}		
	1st	2nd	3rd
B	800	2420	3660
K	419	3051	4412

I Suggest why compounds containing B^{3+} ions are unlikely to exist. [1]

.....

.....

II Write an equation to represent the **second** ionisation energy of potassium. [1]

.....

III State how the first three ionisation energies of calcium would differ from those of potassium. [2]

.....

.....

.....

Total [19]

Examiner only

SECTION A

Answer **all** *questions in the spaces provided.*

1. Complete the electronic structure for the sulfide ion present in Na_2S. [1]

$1s^2$ .....

2. Which isotope is the standard used in defining relative atomic masses? [1]

.....

3. State **one** example of an industrially or environmentally important heterogeneous catalyst. You should identify the reaction catalysed and name the catalyst. [1]

.....

.....

4. Hydrated sodium carbonate has the formula $Na_2CO_3.10H_2O$.

(a) Calculate the relative molecular mass (M_r) of $Na_2CO_3.10H_2O$. [1]

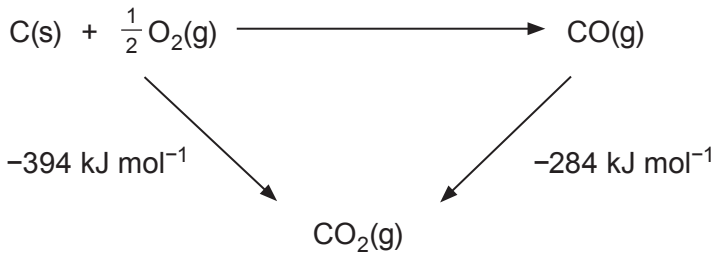
M_r = ...

(b) Calculate the mass of $Na_2CO_3.10H_2O$ needed to make 250 cm^3 of a 0.10 mol dm^{-3} solution. [1]

Mass = ... g

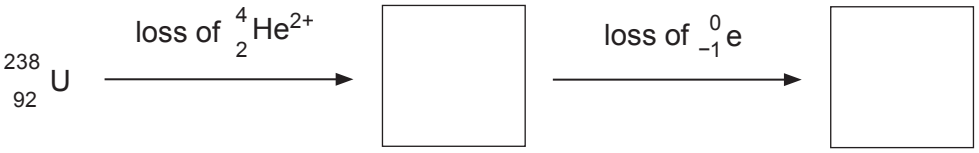
Examiner only

5. Use the energy cycle to calculate the enthalpy change of formation of carbon monoxide. [1]



Enthalpy change of formation = ... kJ mol^{-1}

6. Complete the equation to show the two-stage process by which a radioactive isotope of uranium decays. [2]



1091 010003

Examiner only

SECTION B

Answer **all** *questions in the spaces provided.*

8. *(a)* Hydrogen exists as three isotopes with relative masses of 1, 2 and 3.

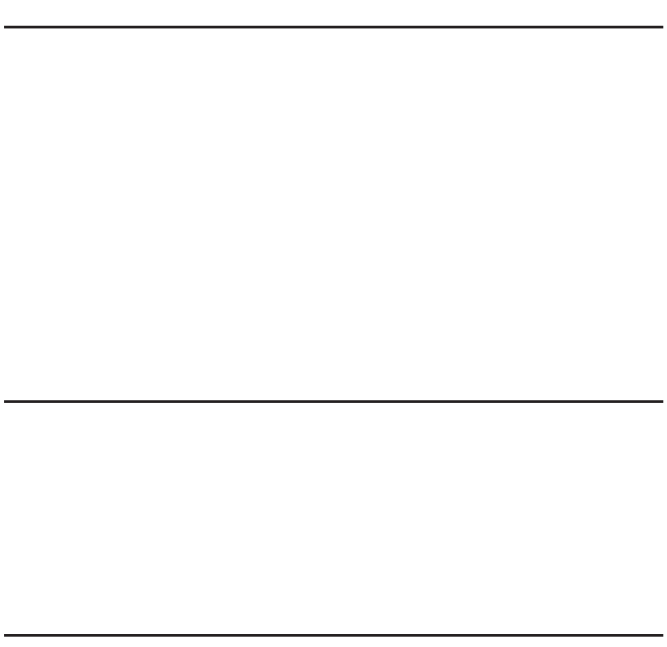
State the similarities and differences in the composition of these specific isotopes. [2]

.....

.....

.....

(b) The first two electronic energy levels in a hydrogen atom are shown on the diagram.



(i) Complete the diagram to show energy levels n = 3, n = 4 and n = 5. [1]

(ii) Mark with an arrow the energy change corresponding to the ionisation energy of hydrogen. [2]

Examiner only

(c) A student said that the ionisation energy of hydrogen could be calculated using the Balmer Series of lines.

(i) In which part of the electromagnetic spectrum does the Balmer Series appear? [1]

.....

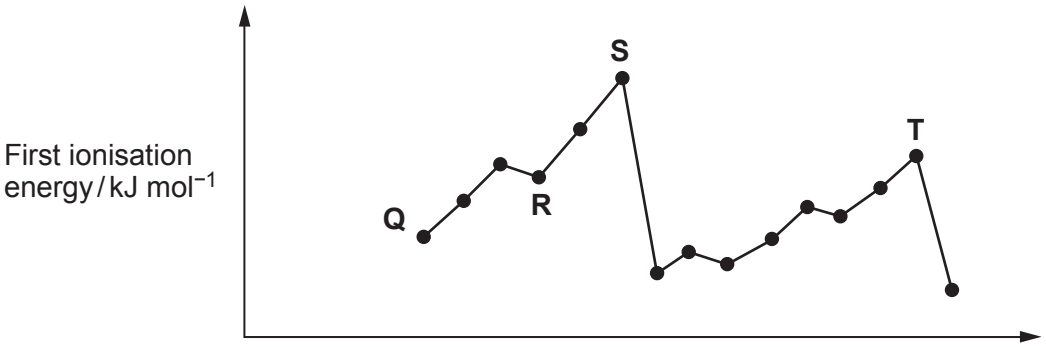
(ii) Explain whether or not this student was correct. [2]

.....

.....

.....

(d) The diagram shows part of a plot of the first ionisation energy of elements against their atomic numbers. Letters **Q**–**T** do **not** represent the symbols of the elements.



(i) Write the equation for the change occurring for the first ionisation energy of element **Q**. [1]

.....

(ii) In which group of the Periodic Table is element **R** found? [1]

.....

(iii) Explain why the first ionisation energy of **S** is greater than that of **T**. [3]
QWC [1]

.....

.....

.....

.....

.....

Total [14]