1. (a) (i) Define the terms:

atomic number .....

.....

mass number .....

....

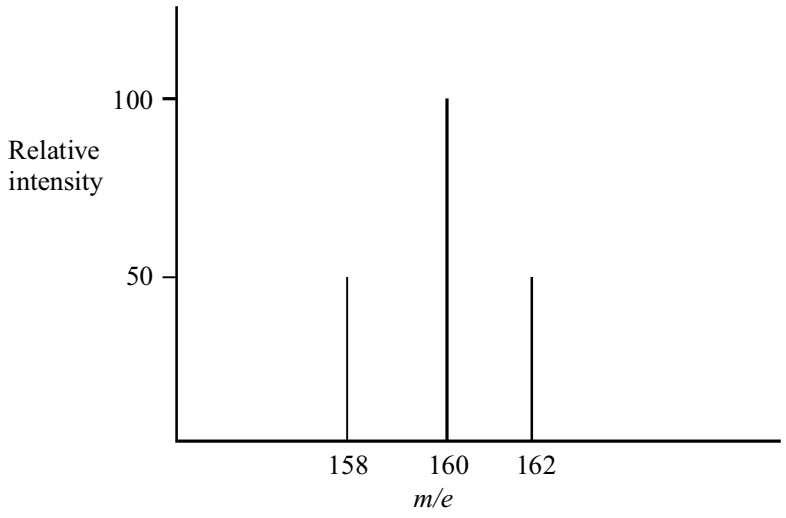
(2)

(ii) Identify the particle which contains 11 protons, 12 neutrons and 10 electrons.

....

(1)

(b) Bromine consists of two isotopes, mass numbers 79 and 81. A sample of bromine gas, Br_2, was examined in a mass spectrometer. The mass spectrum showing the molecular ions is given below.



(i) Identify the species responsible for the peak at $m/e = 160$.

.....

(1)

(ii) Deduce the relative abundances of the two isotopes,

(2)

(c) Define the term **first electron affinity** for bromine atoms, illustrating your answer with an equation.

.....

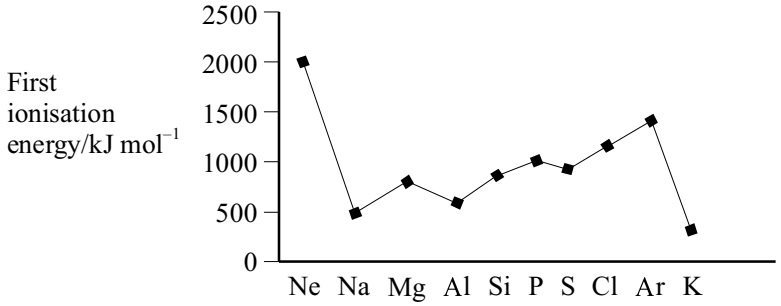
.....

.....

.....

(3)

(d) The graph showing the variation of the first ionisation energies of the elements **neon** to **potassium** is given below.



(i) Define the term **first ionisation energy** with reference to **neon**.

.....

.....

.....

(2)

(ii) Explain the general trend in the first ionisation energies of the elements **sodium** to **argon**.

.....

.....

....

(2)

(iii) Explain why the first ionisation energy of **neon** is greater than the first ionisation energy of **argon**.

....

.....

.....

(2)
(Total 15 marks)

2. Hydrogen forms compounds with most non-metallic elements and with some metals.

(a) Calculate the empirical formula of the compound used in the manufacture of artificial rubber which has the following composition by mass.

Hydrogen 11.1% Carbon 88.9%

(3)

(b) The boiling temperatures of hydrogen chloride and hydrogen iodide are:

Hydrogen chloride –85ºC

Hydrogen iodide –35ºC

Explain why hydrogen iodide has a higher boiling temperature than hydrogen chloride.

.....

.....

.....

(2)

(c) Draw and explain the shapes of:

(i) the PH_3 molecule;

.....

.....

(2)

(ii) the AlH_4^- ion.

.....

.....

(2)

(d) Calculate the number of **molecules** in 8.0 cm^3 of gaseous phosphine, PH_3, at room temperature and pressure.

(The molar volume of a gas at room temperature and pressure should be taken as 2.4×10^4 cm^3 mol^{-1}. The Avogadro constant is 6.0×10^{23} mol^{-1}.)

(2)
(Total 11 marks)

3. (a) Define:

(i) the standard enthalpy of formation of benzene, $C_6H_6(l)$;

.....

.....

.....

(2)

(ii) the standard enthalpy of combustion of benzene, $C_6H_6(l)$.

.....

.....

.....

(2)

(b) Calculate the standard enthalpy of formation of benzene, $C_6H_6(l)$, using the following enthalpy of combustion data:

Substance	$\Delta H_c^{\ominus}$/kJ mol^{-1}
$C_6H_6(l)$	–3273
$H_2(g)$	–286
C(s)	–394

(3)

(c) If the standard enthalpy of formation is calculated from average bond enthalpy data assuming that benzene has three C==C and three C—C bonds, its value is found to be +215 kJ mol^{-1}.
Explain, with reference to the structure and stability of benzene, why this value differs from that calculated in (b). Use an enthalpy level diagram to illustrate your answer.

.....

.....

.....

(4)

(d) Benzene reacts with bromine when gently warmed in the presence of a catalyst of anhydrous iron(III) bromide.

(i) The reaction is first order with respect to benzene and first order with respect to

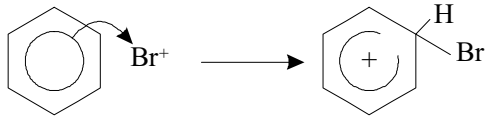
bromine. Write the rate equation for the reaction.

.....

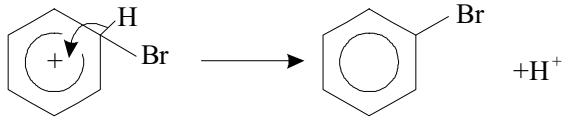
(1)

(ii) The mechanism of this reaction involves an attack by Br^+ followed by loss of H^+.

Step 1.



Step 2.



Deuterium, symbol D, is an isotope of hydrogen, and the C—D bond is slightly **stronger** than the C—H bond. If step 2 were the rate-determining (slower) step, suggest how the rate of this reaction would alter if deuterated benzene, C_6D_6, were used instead of ordinary benzene, C_6H_6, and explain your answer.

.....

....

.....

(2)
(Total 14 marks)

4. (a) Iron has several isotopes. One of them has the electronic configuration $[Ar]3d^6 4s^2$, an atomic number of 26 and a mass number of 56.

(i) Which of these pieces of information would be the most use in helping a chemist decide on the likely chemical reactions of iron?

.....

.....

(1)

(ii) State how many of each of the following particles is found in an atom of ^{56}Fe.

Protons ..... electrons ..... neutrons .....

(2)

(iii) What are isotopes?

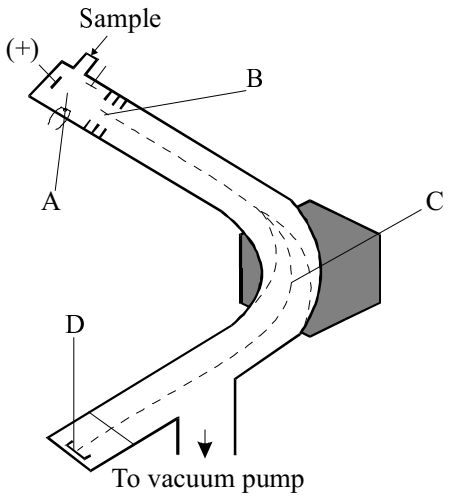
....

.....

(2)

(b) The relative atomic mass of a sample of iron may be found by using a mass spectrometer to determine the isotopic composition.

(i) The diagram below represents a low-resolution mass spectrometer in which four areas have been identified. State what happens in each of these areas.



Area **A** .....

Area **B** .....

Area **C** .....

Area **D** .....

(4)

(ii) In such a determination the following isotopic composition was found.

Isotope	Percentage composition
^{54}Fe	5.8
^{56}Fe	91.6
^{57}Fe	2.2
^{58}Fe	0.33

Calculate the relative atomic mass of this sample of iron, giving your answer to two decimal places.

(2)
(Total 11 marks)

5. In the Periodic Table, where elements are arranged by atomic number, chlorine is a p-block element whereas manganese, a transition element, is in the d-block.

(a) (i) Define the term *atomic number*.

.....

.....

(1)

(ii) Define the term *d-block element*

.....

.....

(1)

(iii) Define the term *transition element.*

.....

....

.....

(1)

(b) The electron configuration of chlorine is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$. Write the electron configuration for manganese in a similar manner.

....

(1)

(c) (i) Define the terrm *first ionisation energy of chlorine.*

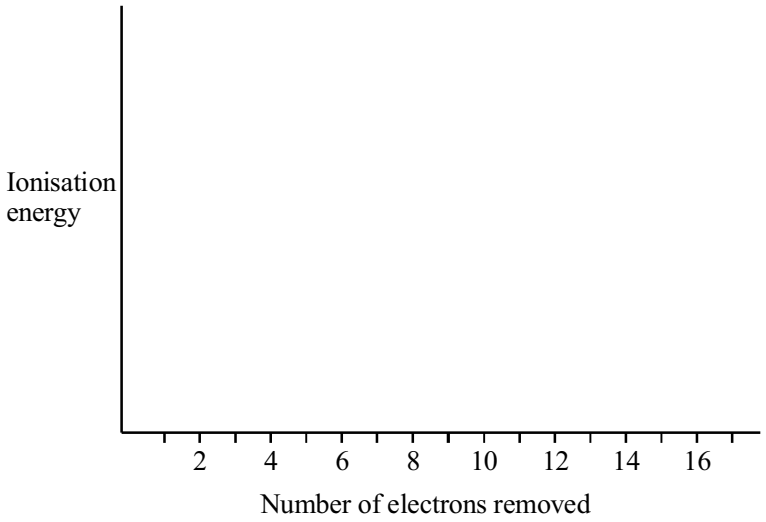
.....

.....

....

(2)

(ii) Sketch the **pattern** you would expect to see in a plot of successive ionisation energies of chlorine against the number of electrons removed.



(3)

(d) Manganese(IV) oxide, MnO_2, reacts with concentrated hydrochloric acid to produce chlorine, water and a salt. The salt has a composition of 43.7% manganese and 56.3% chlorine by mass.

Determine the empirical formula of the salt.

(3)
(Total 12 marks)

6. (a) When a sample of copper is analysed using a mass spectrometer, its atoms are ionised and then accelerated.

(i) Explain how the atoms of the sample are ionised.

.....

.....

.....

(2)

(ii) State how the resulting ions are then accelerated.

.....

.....

(1)

(b) For a particular sample of copper two peaks were obtained in the mass spectrum.

Peak at *m/e*	Relative abundance
63	69.1
65	30.9

(i) Give the formula of the species responsible for the peak at *m/e = 65*.

.....

(1)

(ii) State why **two** peaks, at *m/e* values of 63 and 65, were obtained in the mass spectrum.

.....

(1)

(iii) Calculate the relative atomic mass of this sample of copper, using the table of results above.

(2)
(Total *7 marks*)

7. (a) (i) What is meant by the **mass number** of an atom?

.....

(1)

(ii) Define the term **relative atomic mass**.

.....

(2)

(iii) What are isotopes?

....

(2)

(b) Magnesium has three isotopes. The mass spectrum of magnesium shows peaks at *m/e* 24 (78.60%), 25 (10.11%), and 26 (11.29%). Calculate the relative atomic mass of magnesium to 4 significant figures.

(2)
(Total 7 marks)

8. (a) Define the term **first ionisation energy** for magnesium.

.....

.....

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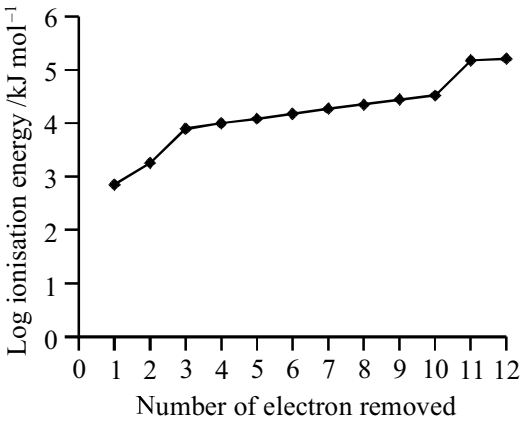
.....

(3)

(b) The logarithm of successive ionisation energies for magnesium is plotted in the graph below.



Explain what this graph tells you about the electron arrangement in the magnesium atom.

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.....

(3)

(c) (i) Give the full electronic configuration of magnesium using the s,p,d notation.

.....

(1)

(ii) Explain why all isotopes of magnesium have the **same** chemical properties.

.....

.....

.....

(2)

(Total 9 marks)

9. (a) Boron forms the chloride BCl_3. Draw a dot-and-cross diagram for BCl_3.

(1)

(b) (i) Draw the shape of the BCl_3 molecule.

(1)

(ii) Explain why BCl_3 has this shape.

.....

.....

.....

(2)

(c) (i) The B—Cl bond is polar due to the different electronegativity of the atoms.
Explain what is meant by the term **electronegativity**.

.....

.....

(2)

(ii) The B—Cl bond is polar. Explain why BCl_3 is **not** a polar molecule.

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....

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(2)
(Total 8 marks)

10. (a) Complete the following table:

Particle	Relative charge	Relative mass
Proton		1
Electron	–1	
Neutron		1

(3)

(b) State the number of each of the above particles present in one molecule of CH_4, showing clearly how you arrive at your answer.

.....

.....

.....

.....

(3)

(c) Complete the electronic configuration of a chlorine atom.

$1s^2$ .....

(1)

(d) Give the **formula** of the chlorine species composed of 17 protons, 20 neutrons and 16 electrons.

.....

(2)

(e) Write one equation in each case to represent the change occurring when the following quantities are measured.

(i) The first electron affinity of sulphur.

.....

(2)

(ii) The first ionisation energy of sulphur.

.....

(1)

(f) Explain why the first ionisation energy of chlorine is higher than that of sulphur.

.....

....

....

....

(2)

(Total 14 marks)

11. (a) (i) Complete the electronic configuration of calcium.

$1s^2$ .....

(1)

(ii) State the number of electrons in the outer shell of an atom of chlorine.

……..

(1)

(b) (i) Write the equation for the reaction of calcium with chlorine to produce calcium chloride.

……..

(1)

(ii) Name the type of bonding in calcium chloride.

……..

(1)

(iii) Draw a dot and cross diagram for calcium chloride showing all the outer electrons.

(3)
(Total 7 marks)

12. (a) State the number of protons, neutrons and electrons in a $^{7}_{3}Li^{+}$ ion.

protons: …… neutrons: …… electrons: ……

(3)

(b) The mass spectrum of lithium shows two peaks. Their mass/charge ratios and percentage abundance are shown below.

Mass/charge	% Abundance
6.02	7.39
7.02	92.61

Calculate the relative atomic mass of lithium, giving your answer to three significant figures.

(2)

(c) Describe a test that you would do to distinguish between solid lithium chloride and solid sodium chloride. Clearly state what you would do and what you would see with both substances.

……

……

……

……

(3)
(Total 8.marks)

13. Both magnesium metal and molten magnesium chloride conduct electricity, but solid magnesium chloride does not.

(a) Describe the structure of magnesium metal and explain why the solid conducts electricity.

……

……

……

……

(3)

(b) Describe, in terms of the position and motion of the particles, what happens when some solid magnesium chloride, M_gCl_2, is heated from room temperature to just above its melting temperature.

……

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……

……

(4)

(c) Explain why magnesium chloride can conduct electricity when molten, but not when solid.

……

……

……

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(2)

(Total 9 marks)

14. (a) The first ionisation energy of potassium is +419 kJ mol^{-1} and that of sodium is +496 kJ mol^{-1}.

(i) Define the term **first ionisation energy**.

……

……

……

(3)

(ii) Explain why the first ionisation energy of potassium is only a little less than the first ionisation energy of sodium.

……

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……

(3)

(b) Potassium forms a superoxide, KO_2. This reacts with carbon dioxide according to the equation:

$$4KO_2(s) + 2CO_2(g) \rightarrow 2K_2CO_3(s) + 3O_2(g)$$

Carbon dioxide gas was reacted with 4.56 g of potassium superoxide.

(i) Calculate the amount, in moles, of KO_2 in 4.56 g of potassium superoxide.

(2)

(ii) Calculate the amount, in moles, of carbon dioxide that would react with 4.56 g of potassium superoxide.

(1)

(iii) Calculate the volume of carbon dioxide, in dm^3, that would react with 4.56 g of potassium superoxide. Assume that 1.00 mol of a gas occupies 24 dm^3 under the conditions of the experiment.

(1)

(iv) What volume of oxygen gas, in dm^3, measured under the same conditions of pressure and temperature, would be released?

(1)
(Total 11 marks)

15. A sample of titanium (atomic number 22) is made up of five isotopes. The sample has the following percentage composition:

Mass number	% composition
46	8.0
47	7.3
48	74.0
49	5.5
50	5.2

(a) (i) What is the average relative atomic mass of titanium? Give your answer to **three** significant figures.

(2)

(ii) What instrument would have been used to find this percentage composition?

....

(1)

(b) (i) Give the electronic configuration of a titanium atom, using s p d notation.

....

(2)

(ii) Name the part of the Periodic Table where titanium appears.

.....

(1)

(c) Titanium occurs naturally as rutile, TiO_2. One possible method of obtaining pure titanium is to heat rutile with carbon.

$$TiO_2(s) + 2C(s) \rightarrow Ti(s) + 2CO(g)$$

(i) What type of reaction is this?

....

(1)

(ii) Calculate ΔH for this reaction given that

$$\Delta H_f^{\ominus} [TiO_2(s)] = -940 \text{ kJ mol}^{-1}$$

$$\Delta H_f^{\ominus} [CO(g)] = -110 \text{ kJ mol}^{-1}$$

Include a sign and units in your answer.

(3)

(iii) Name the law you have used in your calculation.

.....

(1)

(iv) When titanium is manufactured by this method, explain what pollution problem arises.

....

.....

....

(2)

(Total 13 marks)

16. This question is about nitrogen trifluoride, NF_3, and nitrogen trichloride, NCl_3, which are covalent compounds. Van der Waals attractions and permanent dipole–dipole attractions exist between molecules of both compounds in the liquid state.

(a) (i) Describe how van der Waals attractions are caused.

.....

.....

.....

.....

(1)

(ii) In which of the two compounds would you expect there to be greater van der Waals attractions? Justify your answer.

.....

.....

(1)

(iii) In which of the two compounds would you expect there to be the greater permanent dipole–dipole attractions? Justify your answer.

.....

.....

(1)

(iv) The boiling point of nitrogen trichloride is much higher than that of nitrogen trifluoride. How might this be explained in terms of the two types of intermolecular attractions?

.....

.....

(1)

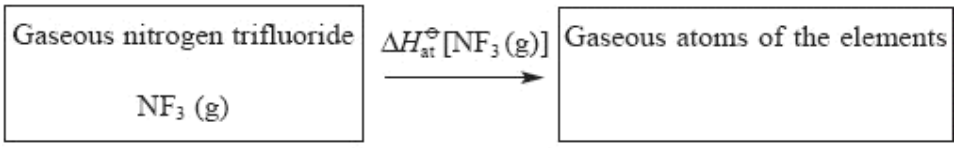
(b) The standard enthalpy change for the formation of gaseous nitrogen trifluoride is -125 kJ mol^{-1}.

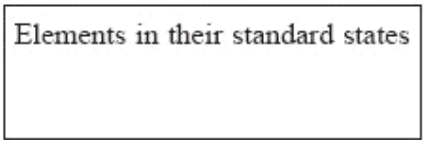
$$\tfrac{1}{2}\,N_2\,(g) + 1\tfrac{1}{2}\,F_2\,(g) \rightarrow NF_3\,(g) \quad \Delta H^{\ominus}_f = -125 \text{ kJ mol}^{-1}$$

The standard molar enthalpy changes of atomisation of nitrogen, N_2, and of fluorine, F_2, are given below.

	ΔH_{at}/kJ mol^{-1}
$\tfrac{1}{2}\,N_2\,(g) \rightarrow N\,(g)$	+ 473
$\tfrac{1}{2}\,F_2\,(g) \rightarrow F\,(g)$	+ 79

This information can be represented on a Hess cycle in the following way, and then used to calculate bond energies.





(i) Insert formulae, showing the correct quantities of each element, into the appropriate boxes.

(1)

(ii) Insert arrows between the boxes and write the correct numerical data alongside the appropriate arrows.

(2)

(iii) Use the cycle to calculate the N — F bond energy in nitrogen trifluoride.

(2)
(Total 9 marks)

17. (a) State the meaning of the terms

(i) relative atomic mass

.....

....

.....

(2)

(ii) mass number

....

.....

(1)

(iii) isotopes

.....

.....

.....

(2)

(b) The isotopic composition of a sample of sulphur is found using a mass spectrometer.

(i) Explain how atoms of the sample of sulphur are ionised.

.....

.....

.....

(2)

(ii) State the type of charge on the sulphur ions formed in the mass spectrometer.

....

(1)

(iii) State how the resulting sulphur ions are then accelerated.

.....

(1)

(c) For a particular sample of sulphur atoms the following isotopic composition was recorded.

Isotope	Percentage composition
^{32}S	95.00
^{33}S	0.76
^{34}S	4.24

Calculate the relative atomic mass of this sample of sulphur. Give your answer to two decimal places.

(2)

(d) Predict the electronic configuration of a ^{34}S atom, using *s*, *p* and *d* notation.

$1s^2$ .....

(1)

(Total 12 marks)

18. (a) State and explain the trend in the boiling temperatures of the noble gases.

....

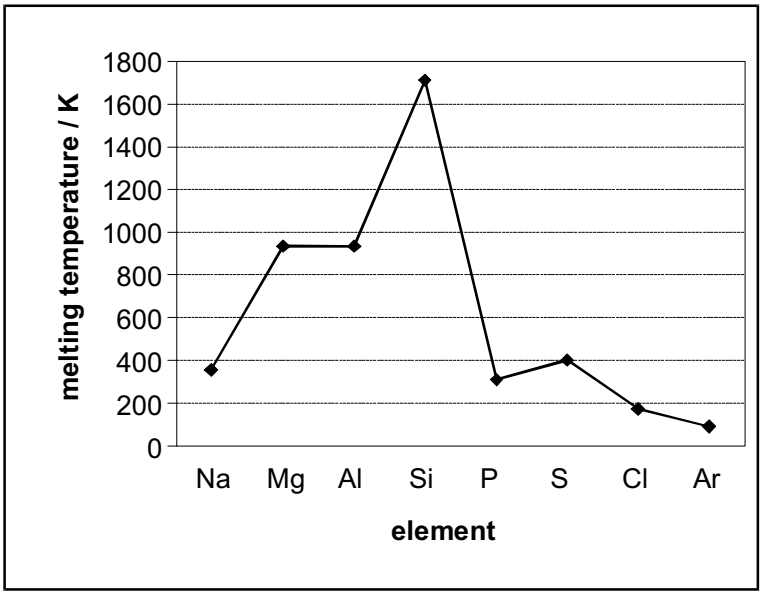
....

....

....

(3)

(b) The graph below shows the melting temperatures of the elements of Period 3 of the Periodic Table, sodium to argon, plotted against atomic number.



(i) Identify one of the elements above that is composed of simple molecules at room temperature.

.....

(1)

(ii) Silicon has a giant atomic structure. Explain how this structure results in the high melting temperature shown on the graph.

.....

.....

.....

.....

(2)

(iii) Explain why the melting temperature of magnesium is higher than that of sodium.

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....

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(3)
(Total 9 marks)

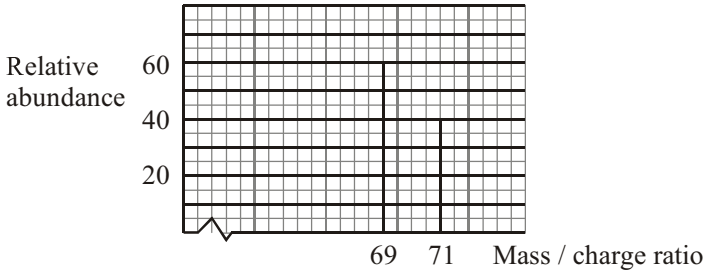
19. (a) An atom of gallium has mass number 69.

Complete the table to show the number of sub-atomic particles in this gallium atom.

Electrons	Neutrons	Protons

(2)

(b) The mass spectrum of a sample of gallium is shown below.



What is the average relative atomic mass of gallium in this sample? Give your answer to **three** significant figures.

(2)

(c) What type of bonding would you expect to find in gallium?

....

(1)

(Total 5 marks)

20. (a) Complete the electronic configurations of the following noble gases.

(i) Neon: $1s^2$ .....

(1)

(ii) Krypton: $1s^2$ ....

(1)

(b) Explain whether krypton or neon has the higher boiling temperature.

....

....

....

....

(2)

(c) A mass spectrometer can be used to analyse a sample of a certain element.

Explain how each of the following is achieved in a mass spectrometer.

(i) Ionisation: ....

....

....

(2)

(ii) Acceleration: .....

....

(1)

(iii) Deflection: ..... .

....

(1)

(Total 8 marks)

21. (a) Define the term **relative atomic mass**.

....

....

....

....

(2)

(b) Give the symbol, including the atomic number and mass number, of the isotope whose nucleus contains two more protons and three more neutrons than the isotope $^{14}_{7}N$.

....

(2)

(c) The table below shows the first five successive ionisation energy values for an element.

Ionisation energy	Value/kJ mol^{-1}
1^{st}	577
2^{nd}	1820
3^{rd}	2740
4^{th}	11600

5^{th}	14800

Use this data, and the Periodic Table, to suggest an element which could have produced these results. Explain your answer.

.....

.....

.....

.....

(2)

(Total 6 marks)

22. Explain each of the following.

Silicon and phosphorus are both covalent substances, but silicon has a much higher melting temperature than phosphorus.

.....

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.....

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.....

(Total 5 marks)

23. (a) Draw a 'dot-and-cross' diagram for a magnesium **ion**.

Show ALL the electrons present and give the charge on this ion.

(2)

(b) Why do salts containing magnesium ions give no colour in a flame test?

.....

.....

(1)

(Total 3 marks)

24. The element gallium has two isotopes.

$^{69}_{31}Ga$ $^{71}_{31}Ga$

(a) (i) State ONE similarity and ONE difference between these two isotopes in terms of the numbers of their fundamental particles.

Similarity .....

Difference ....

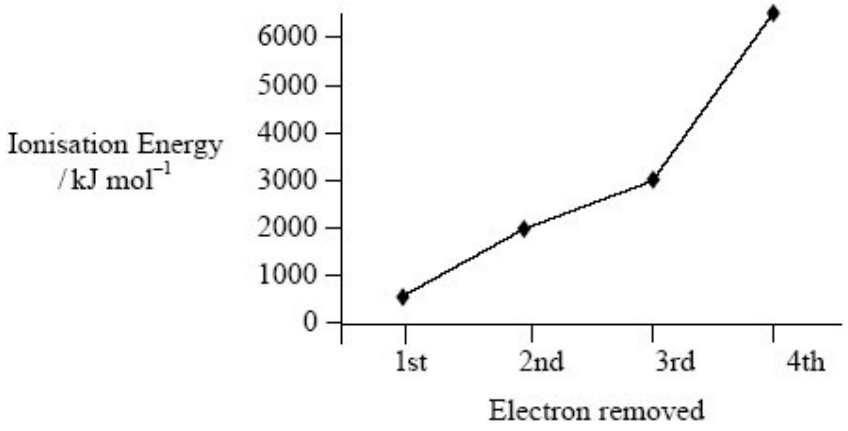
(2)

(ii) The molar mass of a sample of gallium is 69.8 g mol^{-1}.

Calculate the percentage abundance of the isotope $^{69}_{31}Ga$ in the sample.

(2)

(b) The first four ionisation energies of gallium are plotted below.



(i) Write the chemical equation, with state symbols, which corresponds to the first ionisation energy of gallium.

(2)

(ii) Why is there a general rise in the ionisation energy as successive electrons are removed?

.....

.....

(1)

(iii) Explain why there is a comparatively large increase in value between the third and fourth ionisation energies.

.....

....

.....

....

(2)

(c) (i) Suggest the formula of gallium chloride.
(You may find it helpful to refer to the Periodic Table.)

.....

(1)

(ii) Gallium chloride dissolves in water to form a solution containing ions.

Suggest an experiment to show that the solution contains ions. State the result you would expect.

Experiment .....

....

.....

Result ....

(2)

(Total 12 marks)

25. (a) A sample of an element can be analysed using a mass spectrometer. State how the following are achieved in this instrument:

(i) ionisation..... ..

....

(2)

(ii) deflection..... ..

....

(b) The following data were obtained from the mass spectrum of a sample of gallium.

Peak at m/e	%
69.0	60.4
71.0	39.6

Calculate the relative atomic mass of this sample of gallium, to 3 significant figures.

(2)

(c) An atom contains five protons and five neutrons.

(i) Give the symbol for this atom, including the mass number.

....

(2)

(ii) Complete the electronic configuration of this atom.

$1s^2$ ....

(1)

(iii) Give the formula of the compound formed between this element and chlorine.

....

(1)

(Total 9 marks)

26. Phosphorus(III) chloride, PCl_3, can be formed by the reaction of phosphorus and chlorine.

$$2P(s) + 3Cl_2(g) \rightarrow 2PCl_3(s)$$

(a) (i) Calculate the maximum mass of phosphorus(III) chloride, PCl_3, which could be obtained from 93.0 g of phosphorus.

(3)

(ii) Calculate the minimum volume of chlorine required to react completely with 93.0 g of phosphorus.
[One mole of gas occupies a volume of 24.0 dm^3 under the conditions of the experiment].

(2)

(iii) Identify the oxidising agent in the above reaction and explain your answer.

.....

.....

(2)

(b) (i) Draw a dot and cross diagram for a molecule of PCl_3.

(2)

(ii) Draw the predicted shape of a PCl_3 molecule and mark on the diagram a value for the bond angle.

(2)

(c) Suggest the name for the shape of the PCl_4^+ ion.

....

(1)

(Total 12 marks)

27. (a) State the type of bonding in the following substances and draw diagrams to illustrate their 3-dimensional structures.

Diamond

Bonding .....

Diagram

(3)

(b) Explain why sodium chloride conducts electricity when molten but not when solid.

....

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(2)

(Total 5 marks)

28. (a) (i) Define the term **first ionisation energy**.

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(3)

(ii) State and explain the general trend in the first ionisation energy across the period sodium to argon of the Periodic Table.

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(3)

(b) (i) Write an equation to illustrate the process occurring when the second electron affinity of nitrogen is measured.

.....

(2)

(ii) Explain why the second electron affinity of any element is endothermic.

.....

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(2)
(Total 10 marks)

29. An isotope of the element bohrium, $^{267}_{107}Bh$, was recently discovered. How many **neutrons** are there in a nucleus of this isotope?

.....

(Total 1 mark)

30. Write the electron configuration of a magnesium **atom**, using the s, p, d notation.

.....

(Total 1 mark)

31. The industrial processes involved in the production of poly(chloroethene) are summarised in the flow chart:

ethane → ethene → 1,2-dichloroethane → chloroethene → poly(chloroethene)

(a) (i) Ethane is converted to ethene by dehydrogenation.

Write a balanced equation, including state symbols, for this equilibrium reaction.

(1)

(ii) Explain why conditions of high pressure are less favourable for ethene production.

.....

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(2)

(b) Draw a labelled diagram of an ethene molecule, showing the electron density distribution in the σ and π bonds between the carbon atoms.

(2)

(c) Give a chemical test which would distinguish between ethane and ethene.

State the result of your test with ethene.

Test ..... .

Result ....

(2)

(d) 1,2-dichloroethane is formed from ethene by reaction with chlorine.

State the type and mechanism of this reaction.

Type ....

Mechanism ....

(2)

(Total 9 marks)

32. Phosphine, PH_3, is a hydride of the Group 5 element, phosphorus.

(a) (i) Draw a 'dot-and-cross' diagram of a phosphine molecule. You should include only outer shell electrons.

(1)

(ii) Draw the shape you would expect for the phosphine molecule, suggesting a value for the HPH bond angle.

HPH bond angle .....

(2)

(iii) Explain the shape of the phosphine molecule you have given in your answer in (ii).

Justify your value for the HPH bond angle.

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(2)

(b) (i) Write a balanced equation, including state symbols, for the atomisation of phosphine gas.

.....

(1)

(ii) Use your answer to (i) and the data below to calculate the standard enthalpy change of atomisation of phosphine at 298 K. Include a sign and units in your answer.

$\Delta H^{\ominus}_{f}[PH_3(g)]$ = + 5.4 kJ mol^{-1}

$\Delta H^{\ominus}_{at}[\frac{1}{2}H_2(g)]$ = +218.0 kJ mol^{-1}

$\Delta H^{\ominus}_{at}[P(s)]$ = +314.6 kJ mol^{-1}

(3)

(iii) Calculate a value for the bond energy of the bond between phosphorus and hydrogen, using your answer to (ii).

(1)
(Total 10 marks)

33. The element bromine has an atomic number of 35 and has two isotopes of relative isotopic mass 79 and 81.

(a) (i) Define the term **relative isotopic mass**.

.....

.....

.....

.....

(2)

(ii) Complete the table below.

Atom	Number of protons	Number of neutrons
^{79}Br		
^{81}Br		

(3)

(b) Bromine gas has the formula Br_2. When a sample of bromine gas was analysed in a mass spectrometer, three peaks were obtained of *m/e* values of 158, 160 and 162.

Give the formulae of the species responsible for the peaks with *m/e* values 158, 160 and 162.

.....

.....

.....

(3)

(Total 8 marks)

34. (a) Complete the electronic configuration of an

Al atom ls^2.....

Al^{3+} ion ls^2..... ...

(2)

(b) Describe the structure of aluminium metal and explain why it conducts electricity.

....

....

....

....

....

(3)

(c) (i) Define the term **first ionisation energy**.

....

....

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....

(3)

(ii) Explain why the first ionisation energy of aluminium is less than that of magnesium.

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(2)

(Total 10 marks)

35. (a) Hydrogen iodide, HI, has a boiling temperature of –35 °C, and hydrogen chloride, HCl, a boiling temperature of –85 °C.

(i) Draw a dot and cross diagram of a hydrogen iodide molecule (showing outer shell electrons only).

(2)

(ii) Explain why hydrogen iodide has a higher boiling temperature than hydrogen chloride.

.....

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.....

(3)

(b) Hydrogen iodide and hydrogen chloride react with water to form acidic solutions.

(i) Write the equation for the reaction of hydrogen iodide with water.

....

(1)

(ii) State why the solution formed is acidic.

....

(1)

(c) (i) Excess dilute hydrochloric acid reacts with a lump of calcium oxide, CaO, to form an aqueous solution of calcium chloride.

Write the equation for this reaction, including state symbols.

....

(2)

(ii) In a similar reaction with dilute sulphuric acid and a lump of calcium oxide, the reaction stops after a short time even though some calcium oxide remains. State why the reaction stops so quickly.

.....

....

(1)

(Total 10 marks)

36. (a) Draw diagrams to show how the following bonds are formed from atomic orbitals.

σ bond

π bond

(2)

(b) (i) State the shape of a methane, CH_4, molecule, and explain why it has this shape.

Shape: .....

Explanation: .....

....

(3)

(ii) State the shape of a carbon dioxide, CO_2, molecule, and explain why it has this shape.

Shape: ....

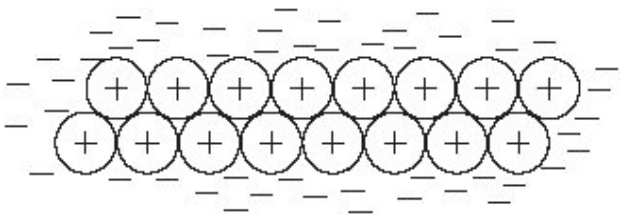
Explanation: .....

....

(2)

(Total 7 marks)

37. Give TWO errors in this representation of the simple model of metallic bonding in sodium.



Error 1 ....

Error 2 ....

(Total 2 marks)

38. Magnesium burns in oxygen to form magnesium oxide, MgO.

(a) Write the equation for the reaction.

....

(1)

(b) Draw a dot and cross diagram of magnesium oxide. Show all the electrons.

(2)

(c) Describe the bonding in magnesium. Explain why it is a good conductor of electricity.

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(3)
(Total 6 marks)

39. (a) Complete the electronic configuration for calcium, Ca.

$1s^2$ .....

(1)

(b) (i) Define the term **first ionisation energy**.

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(3)

(ii) Explain why the first ionisation energy of calcium is lower than that of magnesium.

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(3)

(c) A sample of magnesium contains three isotopes of mass numbers 24, 25 and 26.

(i) In terms of sub-atomic particles, state ONE similarity and ONE difference between these isotopes.

Similarity .....

.....

Difference .....

.....

(2)

(ii) The following data were obtained from the mass spectrum of this sample of magnesium.

Peak at *m/e*	%
24.0	78.6
25.0	10.1
26.0	11.3

Calculate the relative atomic mass of this sample of magnesium. Give your answer to 3 significant figures.

(2)
(Total 11 marks)

40. Silicon reacts with chlorine to produce silicon tetrachloride, as shown in the following equation

$$Si(s) + 2Cl_2(g) \rightarrow SiCl_4(l)$$

(a) (i) Calculate the mass of silicon tetrachloride obtained from 10.0 g of silicon.

(3)

(ii) Calculate the minimum volume of chlorine that would be required to react completely with 10.0 g of silicon.

[1 mol of gas occupies 24.0 dm^3 under the conditions of the experiment]

(2)

(b) Draw a silicon tetrachloride molecule, $SiCl_4$, showing its three-dimensional shape. Name the shape and state the bond angle. Explain why the molecule has this shape.

Diagram

Name of shape .....

Bond angle .....

Explanation of shape

....

....

....

....

(5)

(c) (i) Why are silicon-chlorine bonds polar?

.....

.....

(1)

(ii) Explain why the silicon tetrachloride molecule has no permanent dipole.

....

.....

....

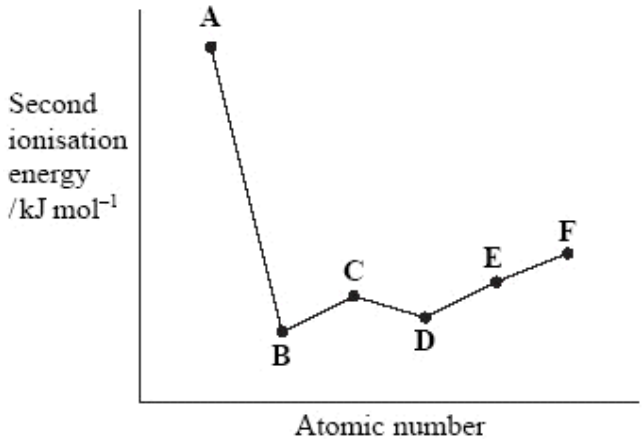
.....

(2)
(Total 13 marks)

41. (a) (i) Write a balanced equation which represents the change that corresponds to the **second** ionisation energy of magnesium. Include state symbols in your answer.

(2)

(ii) The graph below shows how the **second** ionisation energy of six consecutive elements in the Periodic Table, represented by the letters **A** to **F**, varies with increasing atomic number.



Which of the elements, **A** to **F**, could represent magnesium?

.....

(1)

(b) Draw a 'dot and cross' diagram to show the ions in magnesium fluoride.
Include all electrons and the charges on the ions.

(2)
(Total 5 marks)

42. (a) One of the naturally occurring potassium isotopes is ^{39}K.

(i) Write down the numbers of protons, neutrons and electrons present in an atom of ^{39}K. Use the Periodic Table as a source of data.

protons ..... electrons .....

neutrons .....

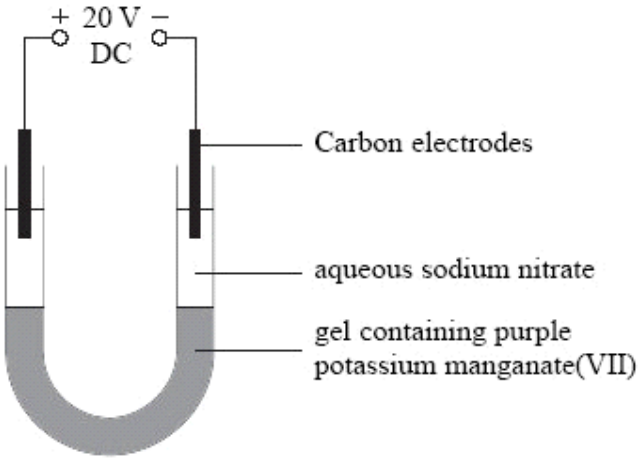
(2)

(ii) Write down the electronic configuration of a potassium atom using s,p,d notation.

....

(1)

(b) To show that potassium manganate(VII), $KMnO_4$, is ionic, the apparatus below can be used.



The power supply is connected for about 30 minutes.

(i) Give the formula of the coloured ion present in potassium manganate(VII), $KMnO_4$.

....

(1)

(ii) What would you expect to **see** after 30 minutes?

....

....

....

....

(1)

(iii) The gel was replaced with one containing copper(II) sulphate and the experiment repeated. Describe and explain what would be seen.

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.....

(2)
(Total 7 marks)

Diagram adapted from Nuffield Advanced Science Chemistry Student's Book, 4th Edition, p. 64, Fig. 3.20.

43. (a) Sodium chloride, NaCl, can be made by the reaction of sodium with chlorine.

$$2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$$

(i) Calculate the maximum mass of sodium chloride which could be obtained from 92 g of sodium.

(2)

(ii) Calculate the concentration of the solution obtained when this mass of sodium chloride is dissolved in water and made up to a volume of 10 dm^3 with distilled water.

(1)

(iii) Calculate the volume of chlorine gas required to react with 92 g of sodium.

[1 mol of gas occupies 24 dm^3 under the conditions of the experiment]

(2)

(b) Describe the structure of solid sodium metal and explain why it conducts electricity.

.....

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.....

.....

(3)

(c) (i) Define the term **first ionisation energy.**

.....

.....

.....

.....

(3)

(ii) Explain why the first ionisation energy of chlorine is higher than that of sodium.

.....

.....

.....

(2)
(Total 13 marks)

44. (a) Calculate the number of atoms in 3.50 g of lithium.

Use the Periodic Table as a source of data.

[The Avogadro constant, $L = 6.02 \times 10^{23}$ mol^{-1}]

(2)

(b) The equation for the reaction of lithium with hydrochloric acid is shown below.

$$2Li(s) + 2HCl(aq) \rightarrow 2LiCl(aq) + H_2(g)$$

(i) Rewrite this equation as an ionic equation, omitting the spectator ions.

(1)

(ii) Draw a 'dot and cross' diagram of lithium chloride showing **all** the electrons. Indicate charges clearly on your diagram.

(2)

(iii) The value of the standard enthalpy change for the reaction, $\Delta H^{\ominus}$, is –557 kJ mol^{-1}. State TWO of the reaction conditions necessary for this enthalpy change to be **standard**.

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(2)
(Total 7 marks)

45. (a) An atom of argon has mass number 40. Complete the table below showing the composition of this argon atom.

Use the Periodic Table as a source of data.

Protons	
Electrons	
Neutrons	

(2)

(b) An atom of potassium has mass number 39. Explain, in terms of atomic structure, why argon comes before potassium in the Periodic Table.

....

....

....

....

(1)

(c) A sample of argon contains a mixture of isotopes as shown below.

Calculate the relative atomic mass of argon in the sample. Give your answer to **three** significant figures.

Isotopic mass	% abundance
36.0	1.34
38.0	0.160
40.0	98.5

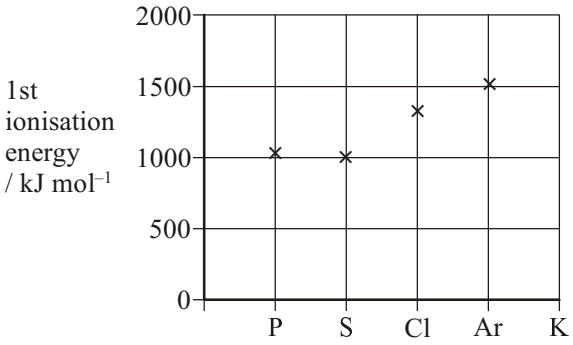
(2)

(d) Write the electron configuration of argon in s, p notation.

....

(1)

(e) The chart shows the first ionisation energy of some elements in the third period of the Periodic Table.



(i) Write the chemical equation, with state symbols, which corresponds to the first ionisation energy of argon.

.....

(1)

(ii) On the chart, add a cross to show the first ionisation energy of potassium. Justify your choice of the position of the cross.

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(2)

(iii) Explain why there is a small decrease in first ionisation energy going from phosphorus to sulphur.

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....

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(2)

(iv) Explain why there is an increase in first ionisation energy going from sulphur to chlorine.

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.....

(2)

(f) Suggest why argon is used to fill some types of light bulbs.

.....

.....

(1)

(Total 14 marks)

46. (a) Complete the electron configuration for carbon.

$1s^2$ .....

(1)

(b) Explain how successive ionisation energy data could be used to confirm that carbon is in Group 4 of the Periodic Table.

.....

.....

.....

(1)

(c) Draw a dot and cross diagram for a molecule of carbon tetrachloride, CCl_4, showing **outer electrons only**.

(2)

(d) Explain how the following are achieved in a mass spectrometer.

(i) Ionisation

.....

.....

(2)

(ii) Deflection

....

(1)

(e) (i) Define the term **relative isotopic mass**.

.....

.....

.....

(3)

(ii) Carbon consists of the isotopes ^{12}C, ^{13}C and ^{14}C. Chlorine consists of the isotopes ^{35}Cl and ^{37}Cl.

Use this data to calculate the maximum relative molecular mass of a molecule of carbon tetrachloride, CCl_4.

(1)

(iii) Explain, in terms of sub-atomic particles, the meaning of the term **isotopes**.

.....

....

.....

(2)

(iv) Why do isotopes of the same element have the same chemical properties?

.....

....

(1)

(Total 14 marks)

47. (a) Methane and poly(ethene) are both hydrocarbons.

(i) State the type of bond between carbon and hydrogen atoms in the molecules of both compounds.

.....

(1)

(ii) State the type of **intermolecular** force present in **both** compounds.

.....

(1)

(iii) Explain why poly(ethene) melts at a higher temperature than methane.

.....

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(3)

(b) Explain, in terms of its bonding, why magnesium has a high melting temperature.

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(2)
(Total 7 marks)

48. (a) Sodium iodide reacts with chlorine to produce sodium chloride and iodine.

(i) State the oxidation numbers of the iodine and chlorine species in the spaces provided.

$$2NaI + Cl_2 \rightarrow 2NaCl + I_2$$

....

(2)

(ii) Use these oxidation numbers to explain why this reaction is a redox reaction.

.....

.....

(2)

(iii) Calculate the maximum mass of iodine that could be produced from 30.0 g of sodium iodide.

(3)

(iv) Calculate the volume of chlorine gas required to produce this amount of iodine.

[1 mol of gas occupies 24 dm^3 under the conditions of the experiment]

(1)

(b) (i) Give the colour of iodine and its physical state at room temperature and pressure.

Colour .....

Physical state .....

(2)

(ii) Write an equation, including state symbols, to represent the process occurring when the first ionisation energy of iodine atoms is measured.

.....

(2)
(Total 12 marks)

49. (a) (i) Explain why a water molecule does **not** have a linear shape.

.....

....

.....

(2)

(ii) State the HOH bond angle in water and explain why it has this value.

.....

.....

.....

(2)

(b) (i) Draw the boron trichloride molecule, BCl_3, making its shape clear. Mark in the bond angle on your diagram.

(2)

(ii) Explain why a B–Cl bond is polar.

.....

....

(1)

(iii) Explain why a BCl_3 molecule is non-polar.

.....

....

.....

....

(1)

(iv) Name the strongest intermolecular force between boron trichloride molecules.

....

.....

(1)

(c) A compound of phosphorus and chlorine has the composition by mass shown below.

Element	% by mass
P	14.9
Cl	85.1

Calculate the empirical formula of this compound.

(2)
(Total 11 marks)

50. (a) The mass of one atom of the isotope $^{79}_{35}Br$ is 1.31×10^{-22} g. The molar mass of $^{79}_{35}Br$ is 79.0 g mol^{-1}.

Use this information to calculate a value for the Avogadro constant. Give your answer to **three** significant figures.

(2)

(b) According to the Periodic Table, the relative atomic mass of naturally occurring bromine is 80.

What information can you deduce from this about naturally occurring bromine?
(No calculation is expected.)

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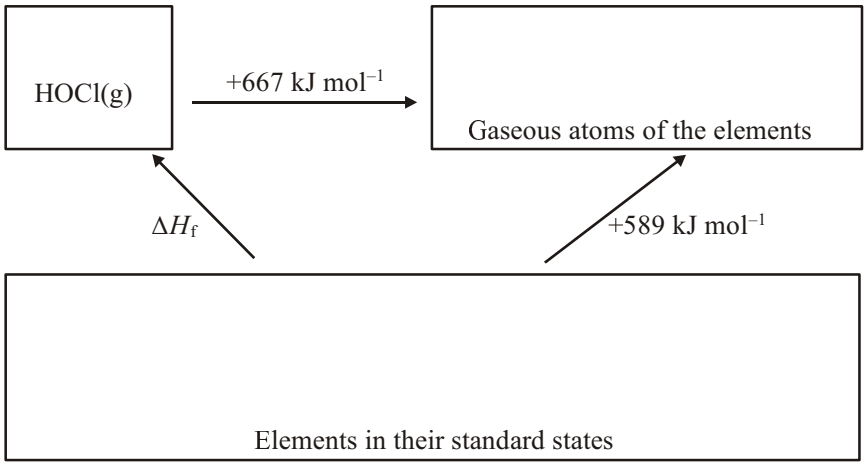
(1)
(Total 3 marks)

51. The Hess cycle below can be used to estimate the enthalpy change of formation, ΔH_f, of the unstable gaseous compound with the formula HOCl(g).



(a) (i) Insert formulae, with state symbols, into the appropriate boxes, to show the correct quantities of each element.

(1)

(ii) Use the cycle to calculate a value for the enthalpy change of formation, ΔH_f [HOCl(g)].

(1)

(iii) Assuming that the H—O bond energy is +464 kJ mol^{-1}, calculate a value for the O—Cl bond energy.

(1)

(b) (i) Draw a 'dot and cross' diagram for the HOCl molecule showing outer electrons only.

(2)

(ii) Predict the HOCl bond angle. Justify your answer.

Angle .....

Justification .....

....

.....

....

.....

(2)

(c) HOCl(g) can be made from chlorine(I) oxide by the reversible reaction

$$Cl_2O(g) + H_2O(g) \rightleftharpoons 2HOCl(g)$$

What effect, if any, would an increase in pressure have on the proportion of HOCl(g) at equilibrium? Justify your answer.

.....

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.....

.....

(2)

(Total 9 marks)

52. Two reactions of a chloroalkane, **X**, are shown below.

Propanol-2-ol $\xleftarrow{\textbf{Reaction 1}}$ Chloroalkane **X** $\xleftarrow{\textbf{Reaction 2}}$ $CH_2{=}CHCH_3$ propene

(a) The chloroalkane **X** can be used to make propan-2-ol in **Reaction 1**.

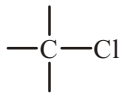
(i) Name and draw the **displayed** formula of the chloroalkane **X**.

Name .....

Displayed formula

(2)

(ii) **Reaction 1** is an example of nucleophilic substitution. The nucleophile is the hydroxide ion. Use the diagram below to show how it is able to attack the chloroalkane **X**.



(2)

(b) (i) What type of reaction is **Reaction 2**?

.....

(1)

(ii) Give the reagent and conditions needed for this reaction.

Reagent ....

Conditions .....

.....

(2)

(c) Propan-2-ol has a higher boiling point than both the chloroalkane **X** and propene.

(i) Name the strongest intermolecular force between propan-2-ol molecules.

.....

(1)

(ii) Draw a diagram to show this force between two propan-2-ol molecules. Clearly mark and label the bond angle between the molecules.

(2)

(d) Propene, $CH_2=CHCH_3$, can be polymerised forming poly(propene).

(i) Draw a section of the poly(propene) polymer chain formed from two monomer units.

(2)

(ii) Explain, in terms of intermolecular forces, why poly(propene) is a solid at room temperature.

.....

.....

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.....

.....

(2)

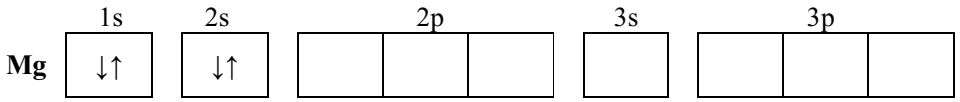
(Total 14 marks)

53. (a) Complete the table below which is about isotopes and an ion of magnesium.

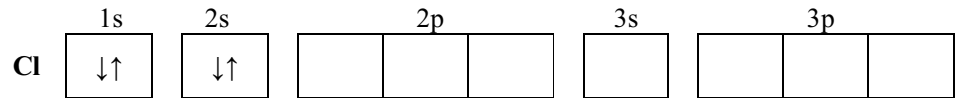
	Numbers of		
	Protons	Neutrons	Electrons
$^{24}_{12}Mg$	12	12	
$^{26}_{12}Mg$	12		12
$^{24}_{12}Mg^{2+}$	12	12	

(3)

(b) Complete the electronic configurations of magnesium and chlorine atoms.



(1)



(1)

(c) Write the equation, including state symbols, for the reaction of magnesium with chlorine.

....

(2)

(d) The mass spectrum of a sample of chlorine molecules shows three molecular peaks. These are formed from the molecules shown below.

Molecule	Percentage abundance
^{35}Cl-^{35}Cl	56.25
^{35}Cl-^{37}Cl	37.50
^{37}Cl-^{37}Cl	6.25

Calculate the relative molecular mass of chlorine in this sample.

(2)

(e) Calculate the volume of 4.73 g of chlorine gas at 100 °C.

[The molar volume of a gas at 100 °C = 30.6 dm^3 mol^{-1}]

(2)

(f) State and explain the type of bond that exists in solid magnesium.

Type .....

Explanation .....

....

.....

(3)

(g) State the type of bond that exists in magnesium chloride. Draw a dot and cross diagram showing the **outer** shell electrons.

Type .....

Dot and cross diagram

(3)
(Total 17 marks)

54. (a) Define the term

(i) **atomic number**

.....

.....

.....

.....

(1)

(ii) **mass number**

.....

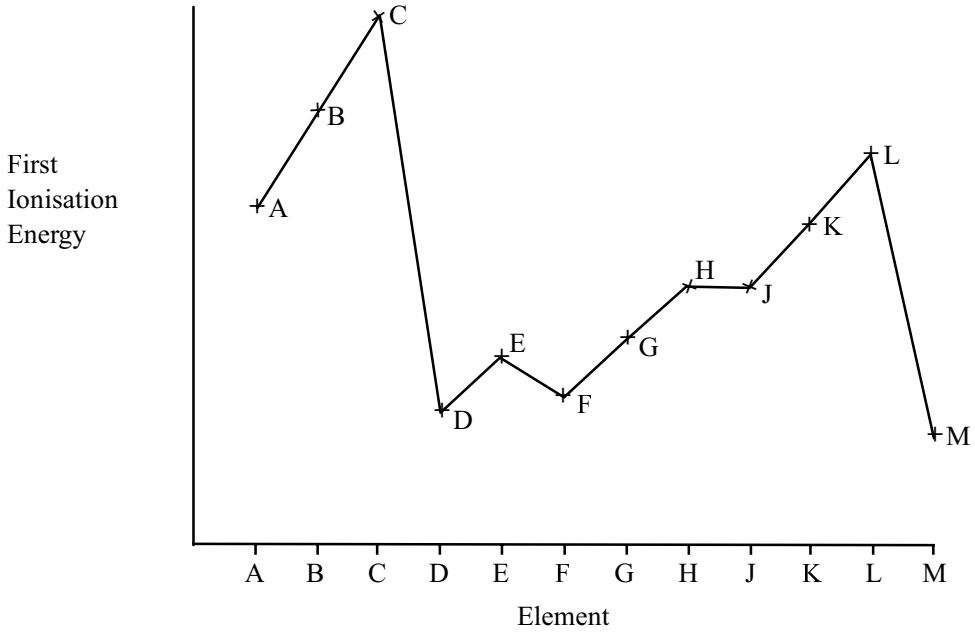
.....

.....

.....

(1)

(b) First ionisation energies of the elements show periodicity. The graph below shows the first ionisation energy of twelve successive elements in the Periodic Table in order of increasing **atomic number**.
The letters are **not** the symbols for the elements.



(i) Give the letters of the **two** elements in **Group 0** (the noble gases).

Explain your answer in terms of ionisation energy.

Letters ..... and .....

Explanation .....

.....

....

.....

(2)

(ii) Give the letter of the **Group 3** element.

Explain your answer in terms of ionisation energy.

Letter .....

Explanation .....

....

.....

....

(2)

(iii) Explain why there is an increase in the first ionisation energy of the elements **from F to H** shown on the graph on the previous page.

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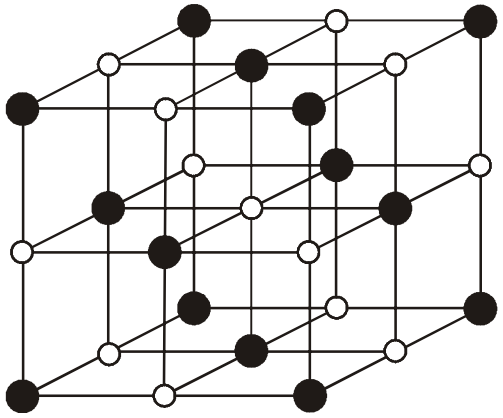
(2)
(Total 8 marks)

55. (a) (i) A diagram of the structure of solid sodium chloride is shown below.

Label the diagram to identify the particles present in solid sodium chloride.



(1)

(ii) Explain why sodium chloride has a high melting temperature.

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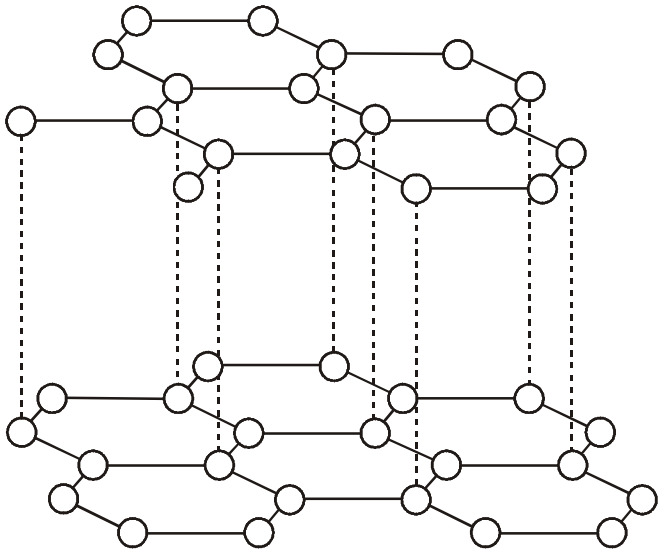
(2)

(b) A diagram of the structure of solid graphite is shown below.

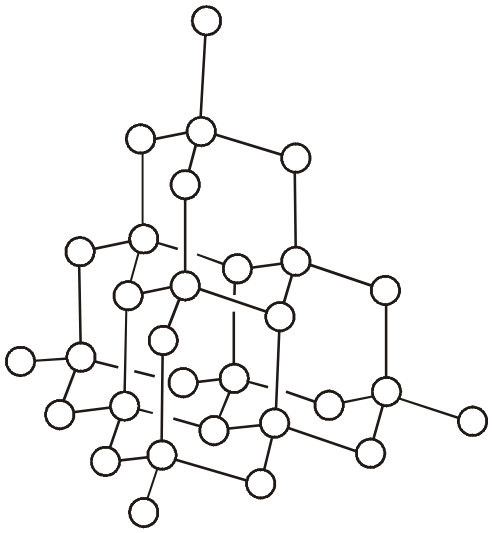
On the diagram name and label the types of bonding that exist in solid graphite.



(2)

(c) A diagram of the structure of solid diamond is shown below.

On the diagram name and label the type of bond that exists in solid diamond.



(1)

(d) The densities of diamond and graphite are

	Density / g cm^{-3}
Diamond	3.53
Graphite	2.25

Suggest, using information from (b) and (c), why diamond is more dense than graphite.

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(2)
(Total 8 marks)

56. (a) What is the formula for strontium fluoride?
Use the Periodic Table as a source of information.

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(1)

(b) Draw a 'dot and cross' diagram for the fluoride ion.
Include all electrons and the charge on the ion.

(1)
(Total 2 marks)

57. A sample of gallium, Ga, (atomic number 31) was found to consist of two different types of atoms with mass numbers 69 and 71. 60.2% of the sample had the lower mass number.

(a) What is the name given to atoms of the same element with different mass numbers?

....

(1)

(b) How many neutrons are there in an atom of gallium with mass number 71?

.....

(1)

(c) (i) What instrument would be used to obtain the percentage composition of the gallium sample?

.....

(1)

(ii) Calculate the average atomic mass of gallium in this sample. Show your working and give your answer to **3 significant figures**.

(2)

(d) (i) Complete the electron configuration of a gallium atom, using the s p d notation.

$1s^2$ .....

(2)

(ii) Write a balanced equation which represents the change that corresponds to the **first** ionisation energy of gallium. Include state symbols in your answer.

(2)

(iii) The first four ionisation energies, in kJ mol^{-1}, of the Group 3 elements gallium and indium and the Group 4 elements germanium and tin are shown below.

A	558	1821	2705	5200
B	579	1979	2963	6200
C	709	1412	2943	3930
D	762	1537	3302	4411

Which set of figures, A, B, C or D, represents **gallium**? .....

(1)

(Total 10 marks)

58. (a) Complete the table below which is about the isotopes and an ion of bromine.

	Number of		
	protons	neutrons	electrons
$^{79}_{35}Br$	35		35
$^{81}_{35}Br$		46	35
$^{81}_{35}Br^-$	35	46	

(3)

(b) Complete the electronic configurations of

Na $1s^2$ .....

Br $1s^2$ .....

(2)

(c) Explain why the isotopes of bromine have identical chemical reactions.

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(1)

(d) What instrument could be used to measure the abundance and mass of the isotopes of bromine?

....

(1)

(e) The isotopic abundance of bromine is shown below.

Relative isotopic mass	Percentage abundance
78.93	50.54
80.91	49.46

Calculate the relative atomic mass of bromine. Give your answer to **four** significant figures.

(2)

(f) State the types of bonding present in bromine **liquid**

between the atoms .....

between the molecules .....

(2)

(Total 11 marks)

59. State the type of bond that exists in sodium bromide.

Draw a dot and cross diagram of sodium bromide, showing only the outer shell electrons.

Type ....

Dot and cross diagram

(Total 3 marks)

60. (a) (i) Define the term **first ionisation energy**.

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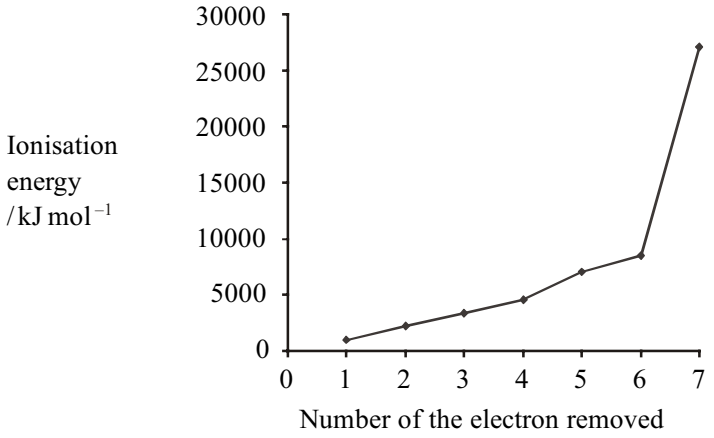
(3)

(ii) Write the equation for the process occurring when the **second** ionisation energy of oxygen is measured.

.....

(1)

(b) The graph below shows the first seven successive ionisation energies of an element, **X**, which is in **Period 3** of the Periodic Table.



(i) Use the information on the graph to state in which **Group** of the Periodic Table **X** is found. Justify your answer.

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(2)

(ii) Identify the element **X**.

....

(1)

(c) The mass spectrum of **X** shows a singly charged molecular ion at *m/e* = 256.

Write the formula of this ion.

....

(2)

(Total 9 marks)

61. Draw a 'dot and cross' diagram to show the ions in calcium oxide. Include ALL the electrons and charges.

(Total 2 marks)

62. (a) Fill in the table below to show the number of protons and electrons present in a hydride ion, H^-, and a lithium ion, Li^+.

Use the Periodic Table as a source of data.

	Protons	Electrons
H^-		
Li^+		

(2)

(b) Which of these ions is larger, H^- or Li^+?

Use the numbers you have entered in the table above to explain your answer.

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(2)
(Total 4 marks)

63. Some of the ionisation energies of four elements, **Q**, **R**, **S** and **T**, with consecutive atomic numbers, are shown in the table below.

	Ionisation Energies / kJ mol^{-1}				
	1st	2nd	3rd	4th	5th
Q	2081	3952	6122	9370	12177
R	496	4563	6913	9544	13352
S	738	1451		10541	13629
T					

(a) To which group of the Periodic Table does **R** belong? Give a reason for your answer.

.....

.....

.....

(2)

(b) Estimate values, in kJ mol^{-1}, for the third ionisation energy of **S**, and the first ionisation energy of **T**, represented by the shaded gaps shown in the table above.

S .....

T .....

(2)

(c) Which element is least likely to form compounds? Give a reason for your answer.

.....

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(1)

(d) Write a balanced equation which represents the change that corresponds to the **third** ionisation energy of **R**.

Use **R** as the symbol for the element and include state symbols in your answer.

(2)

(e) Element **X** is in the same group of the Periodic Table as **R**, but is immediately below it. The first ionisation energy of **X** is 419 kJ mol^{-1}. Explain why this value is lower for **X** than for **R**.

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(1)

(Total 8 marks)

64. (a) Complete the electronic configuration of a copper atom and a bromide ion.

(i) Copper atom, Cu $1s^2 2s^2 2p^6 3s^2 3p^6$ .....

(1)

(ii) Bromide ion, Br^- $1s^2 2s^2 2p^6 3s^2 3p^6$ .....

(1)

(b) Define the term **relative atomic mass**.

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(2)

(c) The following data were obtained for a mass spectrum of a sample of copper.

Relative isotopic mass	Percentage abundance
62.93	69.17
64.93	30.83

Calculate the relative atomic mass of this sample of copper. Give your answer to two decimal places.

(2)

(d) Copper occurs naturally as the mineral malachite. The composition, by mass, of malachite is as follows:

Cu = 57.5% C = 5.4% O = 36.2% H = 0.9%

(i) Calculate its empirical formula.

(2)

(ii) The molar mass of malachite is 221 g mol^{-1}. Calculate its **formula**.

(1)

(e) Copper forms a chloride, $CuCl_2$. Use the data below to calculate the maximum and the minimum values for the molar mass of $CuCl_2$.

Data : Relative isotopic masses of chlorine are 35 and 37.
Relative isotopic masses of copper are 63 and 65.

(2)
(Total 11 marks)

65. First ionisation energy and melting temperature are periodic properties shown by elements.

(a) Define the term first ionisation energy.

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(3)

(b) Explain why the first ionisation energy of potassium is less than that of sodium.

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(3)

(c) The table shows the melting temperatures of the elements of period 3.

	Na	Mg	Al	Si	P (white)	S	Cl	Ar
Melting temperature /K	371	923	933	1683	317	392	172	84
Type of structure								

(i) Complete the table to suggest the type of structure shown by the elements.
Choose your answers from the following list:

giant atomic structure: metallic structure: simple molecular.

(1)

(ii) Explain why silicon has a very high melting temperature.

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(2)

(iii) Explain why aluminium has a higher melting temperature than sodium.

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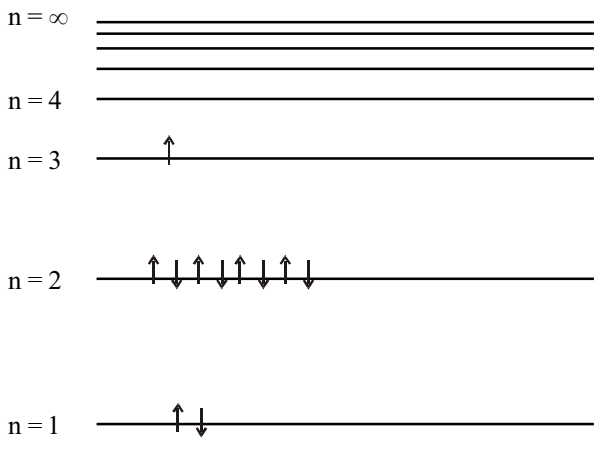
(2)
(Total 11 marks)

66. The diagram below shows the arrangement of electrons in the energy levels of a sodium atom.



(i) Why are the two electrons shown in the n = 1 energy level represented by arrows pointing in opposite directions?

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(1)

(ii) Draw an arrow on the diagram to represent the energy change when a sodium atom ionises by losing an electron.

(2)

(iii) Do all of the electrons in the n = 2 energy level have the same energy? Explain your answer.

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(2)

(iv) How would the arrangement of electrons in a potassium atom differ from this arrangement of electrons in sodium?

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(1)

(Total 6 marks)

67. (a) A sample of an element can be analysed to show its isotopic composition using a mass spectrometer.

(i) Explain how the sample is ionised.

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(2)

(ii) State the TWO properties **of the ion** that determine the path of the ion through the magnetic field.

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(2)

(b) Define **relative isotopic mass**.

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(2)

(c) The following data were obtained from the mass spectrum of a sample of chromium.

Relative isotopic mass	Percentage abundance
49.95	4.345
51.94	83.79
52.94	9.501
53.94	2.364

Calculate the relative atomic mass of this sample of chromium.

Give your answer to **four** significant figures.

(2)

(d) Complete the electron configuration of an iron atom, atomic number 26.

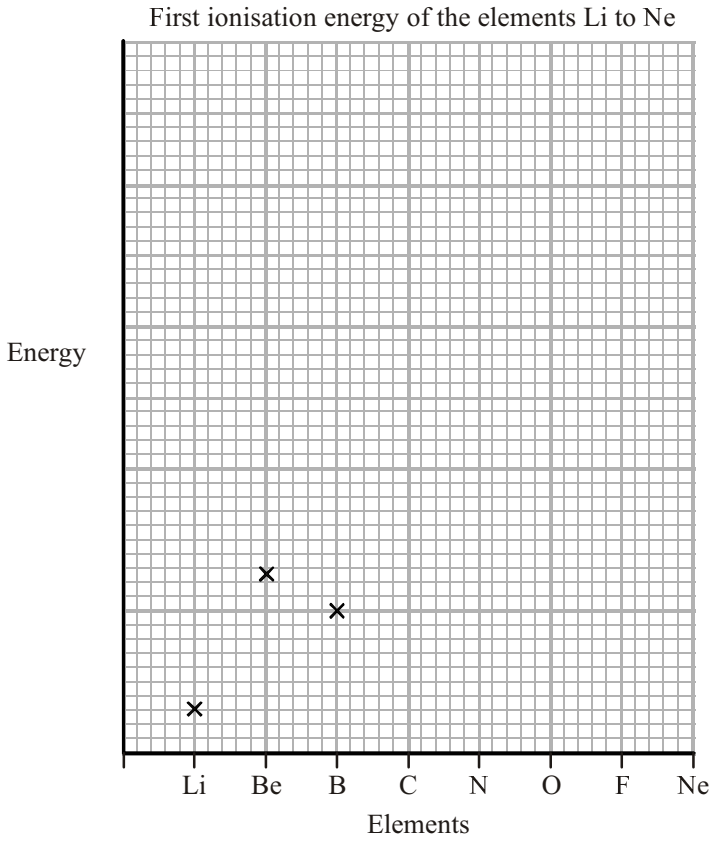
1s	2s	2p			3s	3p			3d					4s
↑↓	↑↓	↑↓	↑↓	↑↓										

(2)

(Total 10 marks)

68. (a) The graph below shows the first ionisation energies of the elements Li, Be, and B.

Complete the graph by adding the **approximate** first ionisation energies of the elements C to Ne.



(2)

(b) Explain why the general trend is for the first ionisation energy to increase across the period.

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(3)

(c) Explain why the first ionisation energy of boron, B, is lower than that of beryllium, Be.

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(2)
(Total 7 marks)

69. A sample of the element osmium, atomic number 76, is made up of four isotopes. The sample has the following percentage composition.

Relative Atomic Mass of Isotope	% Composition
188	15.20
189	17.40
190	26.40
192	41.00

(i) What is the minimum number of neutrons present in any single atom of osmium in the sample?

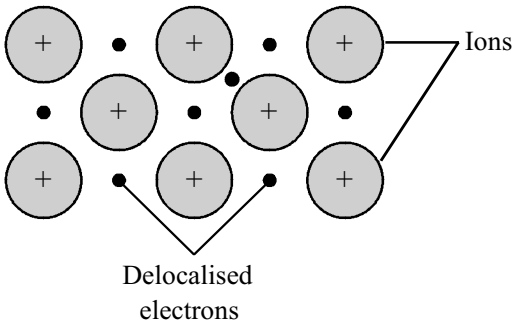
....

(1)

(ii) Calculate the average relative atomic mass of osmium in the sample. Give your answer to **four** significant figures.

(2)
(Total 3 marks)

70. (a) The diagram shows the type of bonding present in the elements lithium and sodium in the solid state.



(i) What name is given to this type of bonding?

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(1)

(ii) Suggest why the melting point of lithium is greater than that of sodium.

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(2)

(b) Lithium can react with chlorine to produce lithium chloride. When a sample of lithium chloride is heated in a Bunsen flame, a red colour is seen.

(i) Draw a 'dot and cross' diagram of lithium chloride showing **all** the electrons. Indicate the charges clearly on your diagram.

(2)

(ii) Describe the changes that occur within the lithium ion to produce the flame colour.

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(2)

(iii) Name ONE other metallic element whose compounds produce a red coloured flame.

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(1)
(Total 8 marks)

71. Going across a period in the Periodic Table from left to right, the general trend is that

A the bonding in the element itself changes from ionic to covalent

B the number of neutrons in the nucleus increases

C the first ionisation energy decreases

D the metallic character increases

(Total 1 mark)

72. The electron configurations of argon, iron, chlorine and one other element are given below, but not in order. Which one represents the unnamed element?

A $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^2$

B $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

C $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$

D $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

(Total 1 mark)

73. Which of the following equations represents the first ionisation of sulfur?

A $S(s) + e^- \rightarrow S^-(g)$

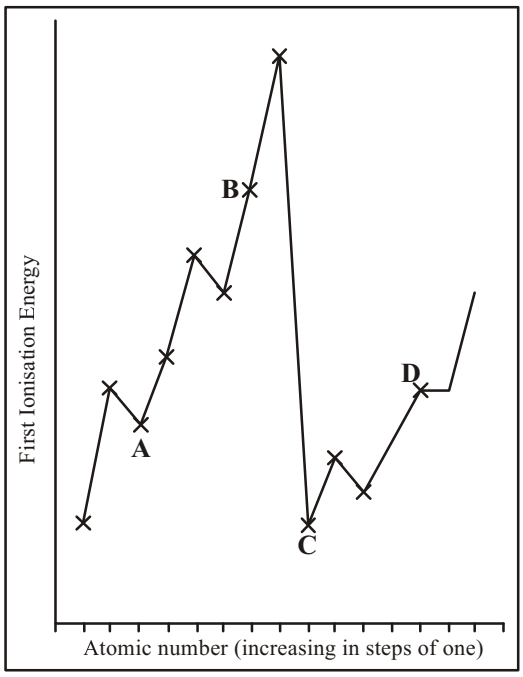
B $S(g) + e^- \rightarrow S^-(g)$

C $S(s) \rightarrow S^+(g) + e^-$

D $S(g) \rightarrow S^+(g) + e^-$

(Total 1 mark)

74. Which element marked on this graph is a halogen?



A

B

C

D

(Total 1 mark)

75. This question is about the following ionisation energy sequences.

The values are all in kJ mol^{-1}.

A	1400	1000	950	830	700
B	420	3100	4400	5900	8000
C	1000	1250	1520	420	590
D	1520	2700	3900	5800	7200

Select from A to D the sequence which is most likely to represent the following:

(a) The first ionisation energies of five consecutive members of the same group in the Periodic Table, in order of increasing atomic number.

A

B

C

D

(1)

(b) The first five ionisation energies of an s-block element.

A

B

C

D

(1)

(c) The first five ionisation energies of a noble gas.

A

B

C

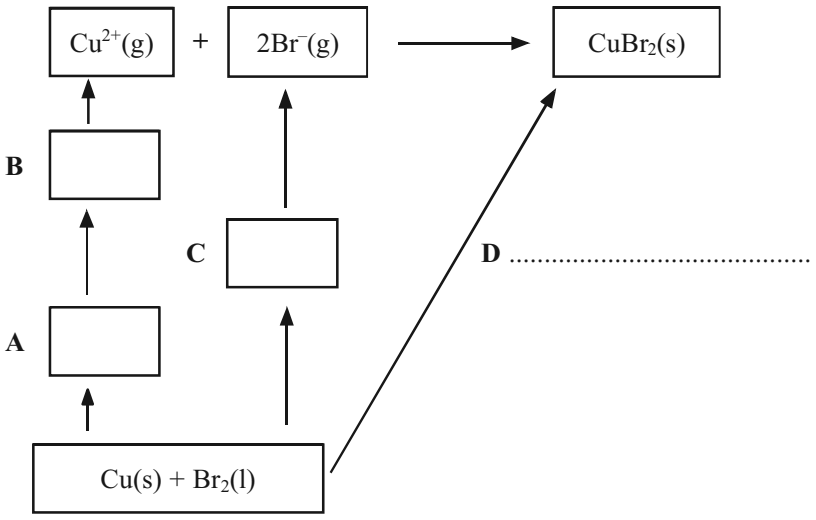
D

(1)
(Total 3 marks)

76. The following data can be used in a Born-Haber cycle for copper(II) bromide, $CuBr_2$.

Enthalpy change of atomisation of bromine $\Delta H^{\ominus}_{at}[\frac{1}{2}Br_2(l)]$	+111.9 kJ mol^{-1}
Enthalpy change of atomisation of copper, $\Delta H^{\ominus}_{at}[Cu(s)]$	+338.3 kJ mol^{-1}
First ionisation energy of copper, $E_{m1}[Cu(g)]$	+746.0 kJ mol^{-1}
Second ionisation energy of copper, E_{m2} [Cu(g)]	+1958.0 kJ mol^{-1}
Electron affinity of bromine, $E_{aff}[Br(g)]$	–342.6 kJ mol^{-1}
Enthalpy change of formation of $CuBr_2(s)$, $\Delta H^{\ominus}_{f}$ [$CuBr_2(s)$]	–141.8 kJ mol^{-1}

(a) On the following outline of a Born-Haber cycle complete the boxes **A**, **B**, and **C** by putting in the formula and state symbol for the appropriate species and writing the name of the enthalpy change **D**.



(3)

(b) Use the data to calculate a value for the lattice energy of copper(II) bromide.

Give a sign and units in your answer.

(3)

(c) When the lattice energy of copper(II) bromide is calculated from ionic radii and charges, the result is a value numerically about 10% less than the one obtained from the Born-Haber cycle.

(i) What does this suggest about the nature of the bonding in copper(II) bromide?

....

.....

(1)

(ii) Draw a diagram to show how the smaller copper ion alters the shape of the larger bromide ion.

(1)
(Total 8 marks)