IB · HL · Chemistry

5 hours 37 questions

Structured Questions

The Periodic Table: Classification of Elements

The Periodic Table / Electron Configurations & the Periodic Table / Periodic Trends / Group 1 Metals with Water / Group 17 Elements with Halide Ions / Metallic & Non-Metallic Oxides / Oxidation States / Ionisation Energy Trends Across a Period (HL) / Characteristic Properties of Transition Elements (HL) / Variable Oxidation States in Transition Elements (HL) / Colour in Transition Metal Complexes (HL)

Easy (11 questions)	/68
Medium (15 questions)	/147
Hard (11 questions)	/85
Total Marks	**/300**

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Easy Questions

1 (a) Define the term *first ionisation energy* and state what is meant by the term *periodicity*.

.....

(1 mark)

(b) Distinguish between the terms *group* and *period*.

.....

(1 mark)

(c) State the property that determines the order in which elements are arranged in the periodic table.

.....

(1 mark)

State the relationship between the electron arrangement of an element and its group and period in the periodic table.

.....

.....

(d) **(2 marks)**

2 (a) Explain the following statement.

The first ionisation energy of potassium is smaller than the first ionisation energy of calcium.

.....

.....

(2 marks)

(b) Explain the following statement.

The first ionisation energy of potassium is larger in value than rubidium

.....

.....

(2 marks)

(c) Using section 9 of the data booklet, explain the trend of decreasing electronegativity values of the Group 17 elements from F to I.

.....

.....

.....

(3 marks)

(d) Define the term *electronegativity*.

.....

(1 mark)

3 (a) Define what is meant by the term *electron affinity.*

.....

(1 mark)

(b) State whether first electron affinity is an exothermic or endothermic process.

.....

(1 mark)

(c) Write an equation, including state symbols, for the first electron affinity of bromine.

.....

.....

(2 marks)

(d) State whether the first electron affinity of I is more or less exothermic than Br.

.....

(1 mark)

4 (a) An element has the following electron configuration.

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^4$

i) State which block of the periodic table the element is in.

[1]

ii) State how many electrons it has in its outer shell.

[1]

.....

.....

(2 marks)

(b) Magnesium can be ionised to form a cation, Mg^+.

i) Write the electron configuration of an Mg^+.

[1]

ii) Define the term *'first ionisation energy'* in relation to magnesium.

[2]

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(3 marks)

(c) The periodic table can be divided into blocks.

State why are silicon, carbon, oxygen and chlorine all classified as p-block elements.

.....

(1 mark)

(d) This question is about the periodicity of period 3 elements.

i) State the trend in atomic radius across period 3.

[1]

ii) State the general trend in first ionisation energies across period 3.

[1]

.....

.....

(2 marks)

5 (a) Antimony, Sb, has atomic number 51.

Using Section 7 of the data booklet, complete the table to show where antimony is found in the periodic table.

Period	Block

.....

(1 mark)

(b) Identify the element that is in the d-block of the periodic table which forms a 3+ ion with the following electron configuration.

$[Ar]\ 3d^3$

.....

(1 mark)

(c) Ionisation energies can provide evidence for electron structure.

Write an equation, including state symbols, for the first ionisation energy of chlorine.

.....

(1 mark)

(d) An element Y has the following six first ionisation energies in kJ mol^{-1}. These are shown in the table below.

	1st	2nd	3rd	4th	5th	6th
Ionisation energy (kJ mol^{-1})	577	1820	2740	11 600	14 800	18 400

State what group of the periodic table this element belongs to.

.....

(1 mark)

6 (a) State the changes in the acid-base nature of the oxides across period 3 (from Na_2O to Cl_2O_7).

.....

(1 mark)

(b) Write an equation for the reaction of sodium oxide with water.

.....

(1 mark)

(c) Predict how the pH of water will change when phosphorus(V) oxide is added.

.....

(1 mark)

(d) What is the product when SO_3 reacts with water.

.....

(1 mark)

7 (a) State the equation for the reaction of sodium metal with water.

.....

(1 mark)

(b) Describe **two** changes that could be observed during the reaction of sodium metal with water.

.....

.....

(2 marks)

(c) Predict the relative reaction rates of lithium, sodium and potassium with water.

.....

(1 mark)

(d) State **two** differences between the reactions of sodium and potassium with water.

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(2 marks)

8 (a) State the balanced chemical equation for the reaction of potassium bromide, KBr (aq), with chlorine, Cl_2 (g).

.....

(1 mark)

(b) Describe the colour change likely to be observed in the previous reaction.

.....

(1 mark)

State the equation for the reaction between potassium and chlorine.

(c) .....

(1 mark)

(d) Explain the trend in reactivity of the halogens.

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(3 marks)

9 (a) Transition metals can form complex ions where ligands are coordinately bonded to the central metal ion.

i) Define the term *ligand.*

[1]

ii) State what is meant by the term *bidentate ligand*

[1]

.....

.....

(2 marks)

(b) Transition metals are located in the d-block of the periodic table.

i) State the electron configuration of V^{2+}.

[1]

ii) Explain why scandium is not considered a transition metal.

[1]

.....

.....

(2 marks)

(c) State the oxidation state of Fe in $[Fe(CN)_6]^{4-}$.

.....

(1 mark)

(d) Iron and zinc are in the d-block of the Periodic Table. Iron(II) ions, $[Fe(H_2O)_6]^{2+}$, form a pale green solution but zinc ions, $[Zn(H_2O)_6]^{2+}$, form a colourless solution.

i) Write the electron configuration of Zn^{2+}.

[1]

ii) Explain why zinc ions are colourless.

[2]

.....

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(3 marks)

10 (a) State the formula of a bidentate ligand.

.....

(1 mark)

State three factors that affect the value of the splitting energy, Δ*E,* in the d-orbitals.

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.....

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(b) **(3 marks)**

(c) Outline why transition metals form coloured compounds.

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(5 marks)

(d) Explain why adding ammonia to aqueous copper(II) ions results in a darker blue complex.

.....

.....

(2 marks)

11 (a) Deduce the oxidation state of vanadium in the compound NH_4VO_3.

.....

(1 mark)

(b) Transition elements can be used to catalyse certain reactions.

Define the term *heterogeneous* in relation to catalysts.

.....

(1 mark)

(c) Describe the splitting of the d orbitals in an octahedral crystal field.

.....

(1 mark)

Medium Questions

1 (a) The periodic table displays the chemical elements, arranged in order of increasing atomic number. It is made up of groups and periods of elements.

State and explain the general trend in first ionisation energy across a period of the periodic table.

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.....

(4 marks)

(b) The general trend in first ionisation energies stated in part (a) is seen across period 2 of the periodic table. However, boron and one other period 2 element deviate from this trend.

Identify this element and explain why it deviates from the general trend.

.....

.....

.....

(3 marks)

(c) State why nitrogen is classed as a p block element and give its full electron configuration.

.....

.....

(2 marks)

(d) Identify the period 3 element that has the lowest melting point.

Explain your answer with reference to bonding and structure.

.....

.....

.....

(3 marks)

2 (a) The first ionisation energy for all the elements is found in Section 9 of the IB data booklet.

i) Define the term *first ionisation energy* of an element.

[2]

ii) Write the equation for the first ionisation energy of aluminium.

[1]

.....

.....

.....

(3 marks)

(b) The table below shows successive ionisation energies of an element **A**, found in period 3 of the periodic table.

Table 1

Number of electrons	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Ionisation Energy (kJ mol^{-1})	1012	1907	2914	4964	6274	21268	25431	29872

Identify element **A**.

Explain your answer using data from **Table 1**.

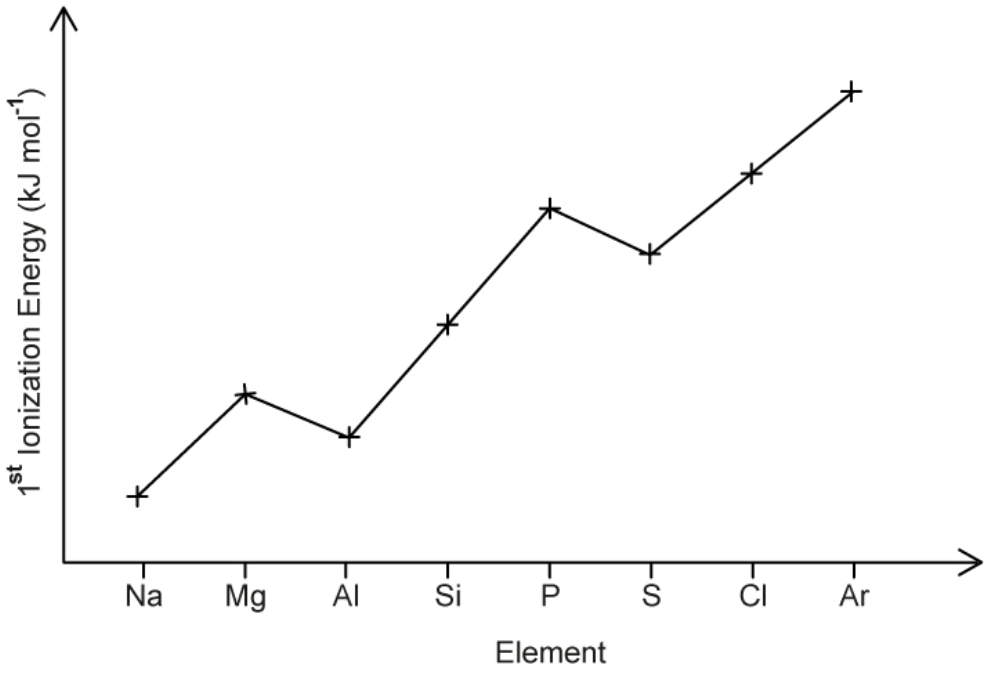
.....

.....

(2 marks)

(c) The graph below in **Figure 1** shows some information on the elements of period 3 of the periodic table.

Figure 1



State and explain the trend that this graph shows, including why there are values that deviate from the trend.

(5 marks)

(d) Explain why the second ionisation energy of aluminium is a larger value than the first ionisation energy.

(1 mark)

3 (a) This question is about the structure of the periodic table.

Throughout the early history of the periodic table, scientists have attempted to order the elements according to different properties.

i) State the property that is used to order the elements in the modern periodic table.

[1]

ii) Outline how the electron configuration of elements is related to their group and period in the periodic table.

[2]

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.....

.....

(3 marks)

(b) This question is about the element phosphorus.

i) State the group number, period number, and block in which you would find the element phosphorus.

[1]

ii) State the full electron configuration of the phosphide ion, P^{3-}.

[1]

.....

.....

(2 marks)

(c) Outline why the atomic radius is seen to decrease across period 2 (from lithium to fluorine).

.....

.....

(2 marks)

(d) Gallium forms an ion smaller than its element, whereas arsenic forms an ion larger than its element.

Explain these differences in ionic radius.

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(3 marks)

4 (a) Bromine and selenium are both found in period 4 of the periodic table.

State and explain which of the two has a higher electronegativity.

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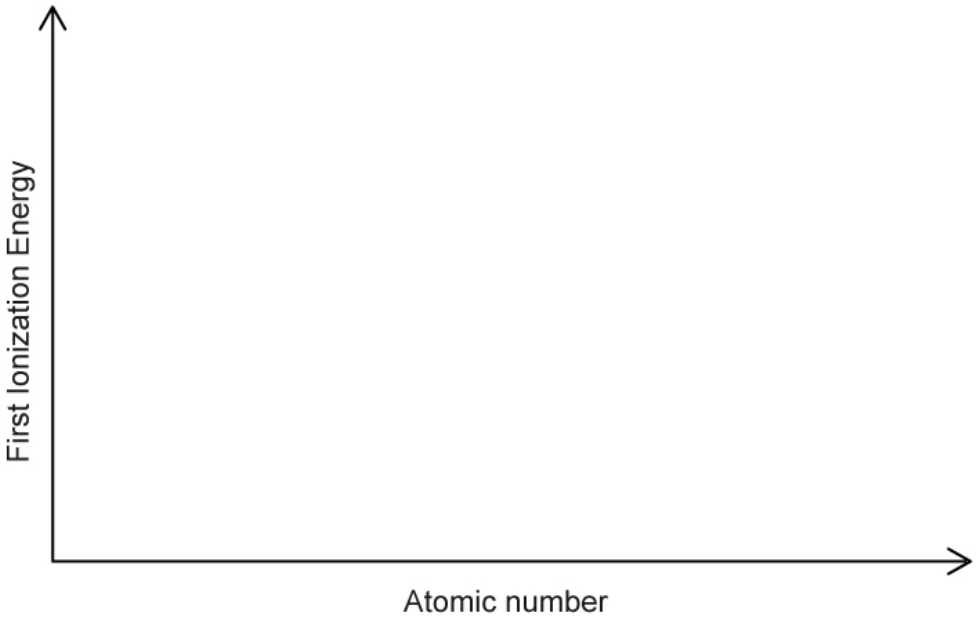
.....

(3 marks)

(b) Sketch on the axes shown below in **Figure 1**, a graph of the first ionisation energy against atomic number for the elements of Group 1.

Figure 1



Explain the trend in ionisation energy down group 1.

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.....

(2 marks)

(c) Discuss the similarities and differences between the trends in atomic radius and ionic radius down Group 1 and Group 17.

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.....

.....

(3 marks)

(d) State how the first ionisation energy of potassium differs from that of:

i) Calcium.

[1]

ii) Rubidium.

[1]

.....

.....

(2 marks)

5 (a) Group 17 elements are known as highly electronegative non-metal elements.

i) Define the term *electronegativity*.

[1]

ii) State and explain the trend in *electronegativity* in Group 17.

[1]

.....

.....

(2 marks)

(b) Define the term *electron affinity* and write an equation to show the first *electron affinity* of bromine.

.....

.....

(2 marks)

(c) State, with reasons, whether the first electron affinity of iodine is more or less exothermic than bromine.

.....

.....

(2 marks)

(d) Suggest why the second electron affinity of oxygen is endothermic.

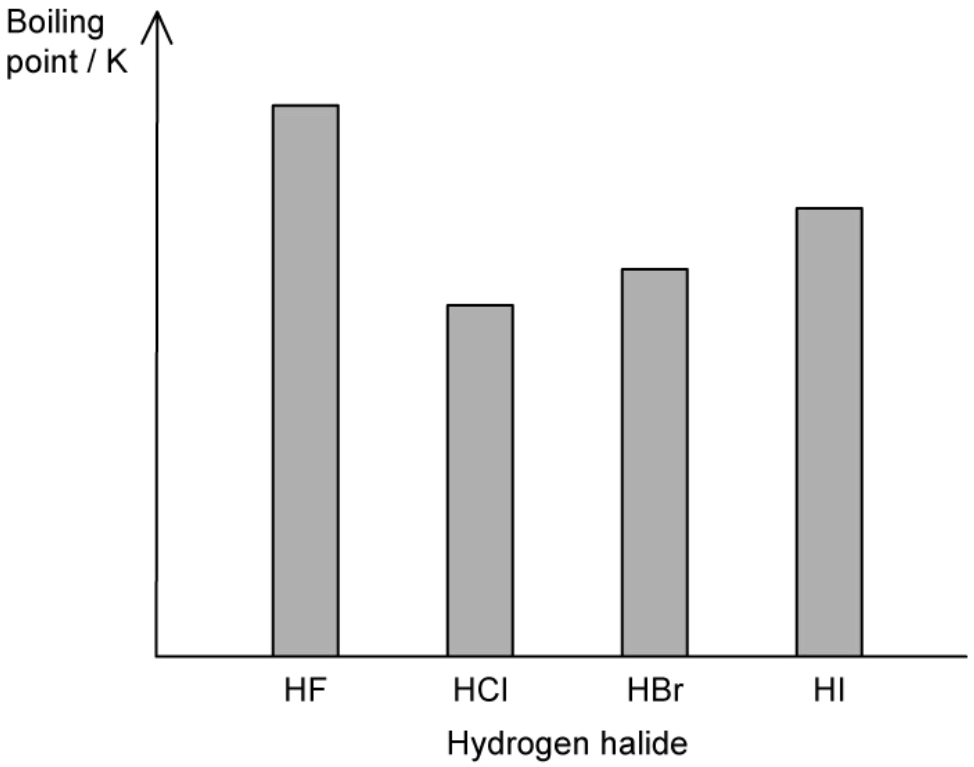
.....

.....

(2 marks)

6 (a) The hydrogen halides do not show perfect periodicity. A bar chart of boiling points, as seen in Figure 1, shows that the boiling point of hydrogen fluoride, HF, is much higher than periodic trends would indicate.

Figure 1



Explain why the boiling point of HF is much higher than the boiling point of the other hydrogen halides.

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.....

(2 marks)

(b) There is an increase in boiling point moving from HCl to HI.

Explain this trend in boiling points of the hydrogen halides.

.....

.....

(2 marks)

7 (a) A student dissolves the oxides of potassium and selenium in water and tests the resulting solutions with litmus paper.

Explain what the student would expect to observe.

(3 marks)

(b) Magnesium and silicon(V) oxides melt at high temperatures, unlike phosphorus(V) oxide and sulfur trioxide, which do so at lower temperatures.

State whether each of the four oxides would conduct electricity in their molten state.

(2 marks)

(c) For the solutions formed by dissolving the oxides in water in part (b), identify each as acidic, alkaline, or neutral.

(2 marks)

(d) Write equations for each of the reactions when the oxides of magnesium, phosphorus, and sulfur in part b) are dissolved in water.

(3 marks)

8 (a) Sodium oxide and silicon dioxide are two compounds of period 3 elements that react with water. Write equations for their separate reactions with water.

.....

.....

(2 marks)

(b) Suggest the pH of the resulting solutions when both sodium oxide and phosphorus(V) oxide react with water.

.....

.....

(2 marks)

(c) Aluminium oxide can react as both an acid and as a base.

i) State the name given to this type of oxide.

[1]

ii) Write an equation for the reaction of aluminium oxide with hydrochloric acid.

[1]

iii) State whether aluminium oxide is behaving as an acid or base in this reaction.

[1]

.....

.....

.....

(3 marks)

(d) Outline the acid-base nature of the oxides of the elements in period 3 from sodium to chlorine

.....

.....

.....

(3 marks)

9 (a) Potassium is an element found in group 1 of the periodic table.

State how potassium reacts with water and write a balanced equation for the reaction including state symbols.

.....

.....

(2 marks)

(b) A student has a sample of lithium and sodium which he drops into a beaker of distilled water.

Compare the reactivity of lithium and sodium with water and state what the student would see in each reaction.

.....

.....

.....

(3 marks)

(c) The student continues to react various group 1 metals with water and observes a change in reactivity as they move down the group.

Explain the trend in reactivity that would be observed.

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.....

.....

(3 marks)

(d) From only the first three elements in each of Group 1 and Group 17, state which Group 1 element and Group 17 element would show the most vigorous reaction when they react together.

Write a balanced equation for the reaction.

.....

.....

(2 marks)

10 (a) Chlorine is a greenish-yellow gas, bromine is a dark red liquid, and iodine is a dark grey solid.

State and explain the property which most directly causes these differences in volatility.

(3 marks)

(b) Explain why Cl_2 rather than Br_2 would react more vigorously with a solution of I^-.

(2 marks)

(c) Describe what happens when aqueous bromine solution is added to separate solutions of sodium chloride and sodium iodide.

Include balanced equations for any reactions that occur.

(3 marks)

(d) Astatine, At, is the rarest naturally occurring element in the Earth's crust. Before it was discovered in 1940 scientists could only predict its existence and properties.

Suggest the basis for these predictions.

(2 marks)

11 (a) Explain why transition metals exhibit variable oxidation states compared to the elements in Group 1.

(2 marks)

(b) Transition metal compounds and ions are often coloured. For example, $[Cr(H_2O)_6]^{3+}$ is green.

Explain why $[Cr(H_2O)_6]^{3+}$ and other complex ions are coloured.

(3 marks)

(c) Water acts as a ligand when it reacts with zinc and cobalt ions, forming the complexes $[Zn(H_2O)_4]^{2+}$ and $[Co(H_2O)_6]^{2+}$

Explain how water acts as a ligand in forming these complexes and predict the shape of $[Co(H_2O)_6]^{2+}$.

(3 marks)

(d) Explain why solutions containing $[Co(H_2O)_6]^{2+}$ are coloured but solutions containing $[Zn(H_2O)_4]^{2+}$ are not.

.....

(4 marks)

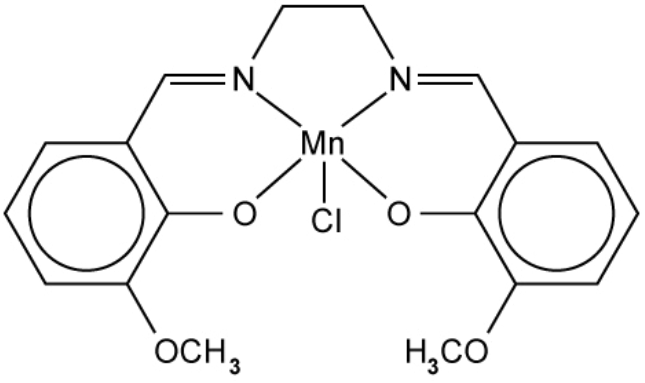
12 (a) Complete **Table 1** below to show the oxidation state of the **transition element.**

Table 1

Ion	$[Cu(Cl_4)]^{2-}$	$[Fe(H_2O)_6]^{3+}$	$Cr_2O_7^{2-}$
Oxidation state			

(3 marks)

(b) EUK-134 is a complex ion of manganese(III) used in skin care products to protect against UV damage as it has antioxidant properties.



i) State the electron configuration of the manganese(III) ion in the complex shown above.

[1]

ii) State the name given to species that bond to a central metal ion, and identify the type of bond present.

[2]

(3 marks)

(c) Transition metals have certain characteristic properties.

State **two** properties that are involved in EUK-134 rapidly decreasing the concentration of oxidising agents.

.....

.....

(2 marks)

13 (a) A characteristic property of transition elements, like chromium, is that they form coloured compounds. Explain why $Ni^{2+}(aq)$ is green but $Sc^{3+}(aq)$ is colourless.

(5 marks)

(b) The colour intensity of solutions of complex ions is one method of determining the concentration of transition metal ions. Excess aqueous ammonia is sometimes added before measuring the absorption of copper(II) ions.

Describe why the addition of excess ammonia to aqueous copper(II) ions causes the shade of the blue colour to change.

(3 marks)

(c) Increasing the concentration of chloride ions in an aqueous solution of vanadium(III) chloride causes the vanadium complex to change from $[V(H_2O)_6]^{3+}$ to $[VCl(H_2O)_5]^{2+}$ to $[VCl_2(H_2O)_4]^{+}$

Outline what would happen to the wavelength at which the vanadium complex ions would absorb light as the concentration of chloride ions is increased.

(2 marks)

(d) Ferrocyanide salts, $[Fe(CN)_6]^{4-}$, are used in the production of Prussian blue, which was the first modern synthetic pigment.

i) Deduce the oxidation number of iron in $[Fe(CN)_6]^{4-}$.

[1]

ii) Draw the abbreviated orbital diagram for the **iron ion in $[Fe(CN)_6]^{4-}$** using the arrow-in-box notation to represent electrons.

[1]

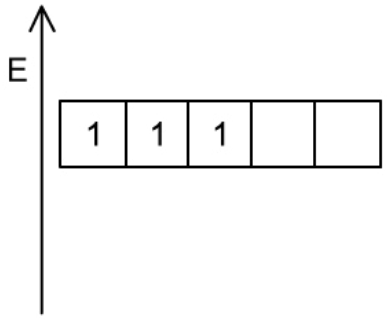
.....

.....

(2 marks)

14 (a) The energy level diagram showing the electrons in the five 3d orbitals of a chromium atom is shown in the figure below.

Draw the completed diagram showing the d orbitals in $[Cr(H_2O)_6]^{3+}$ after splitting.



.....

(1 mark)

(b) State and explain what happens to the splitting of the d orbitals if the ligand is changed from H_2O to NH_3.

.....

.....

(2 marks)

(c) Explain, in terms of acid-base theories, what type of a reaction is the formation of $[Fe(H_2O)_6]^{2+}$ from Fe^{2+} and water.

.....

.....

(2 marks)

(d) The complex ion $[Ni(NH_3)_6]^{2+}$ is blue and $[Ni(H_2O)_6]^{2+}$ is green

Explain why the $[Ni(H_2O)_6]^{2+}$ complex ion is coloured and outline why changing the identity of the ligand changes the colour of the ion.

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(4 marks)

15 (a) Dilute copper(II) chloride solution is light blue, while copper(I) chloride is colourless.

Describe how the blue colour is produced in the copper(II) chloride. Refer to Section 15 of the Data Booklet.

(4 marks)

(b) Explain why the copper(I) chloride is colourless.

(2 marks)

(c) When excess ammonia is added to copper(II) chloride solution, the dark blue complex ion, $[Cu(NH_3)_4(H_2O)_2]^{2+}$, forms.

State the molecular geometry of this complex ion and the bond angles within it.

(2 marks)

(d) Outline the relationship between the Brønsted–Lowry and Lewis definitions of a base, referring to the ligands in the complex ion $[CuCl_4]^{2-}$.

(3 marks)

Hard Questions

1 (a) This question refers to the elements in the first three periods of the Periodic Table.

Select an element from the first three periods that fits each of the following descriptions.

i) The element with the highest first ionisation energy

[1]

ii) The element that forms a 1− ion with the same electron configuration as helium

[1]

iii) An element which forms a compound with hydrogen in which the element has an oxidation number of −4

[1]

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.....

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(3 marks)

(b) This question is about the elements which have atomic numbers 33 to 37.

The first ionisation energies of these elements are shown in the table below.

Element	As	Se	Br	Kr	Rb
Ionisation energy value in kJ /mol^{-1}	947	941	1340	1351	403

i) Suggest the formulae of the hydrides of arsenic and selenium

[2]

ii) Explain why the first ionisation energy of rubidium is lower than that of krypton

[2]

iii)

State which of the elements, arsenic to rubidium, has atoms with the smallest atomic radius

[1]

(5 marks)

(c) The first 3 elements of Period 3 show a general increase in melting point.

Explain this trend in melting point across these Period 3 elements.

(3 marks)

(d) This question is about hydrogen, the element with the atomic number $Z = 1$.

Hydrogen can be placed in several different positions in periodic tables. One is immediately above lithium in Group 1 as shown in section 6 of the data booklet. Another is in the centre of the first row.

Evaluate the position of hydrogen when it is placed immediately above lithium and state **one** reason in favour and **two** against.

(3 marks)

2 (a) This question is about Period 4 of the Periodic Table.

State and explain which of K^+ and Ca^{2+} is the smaller ion.

.....

.....

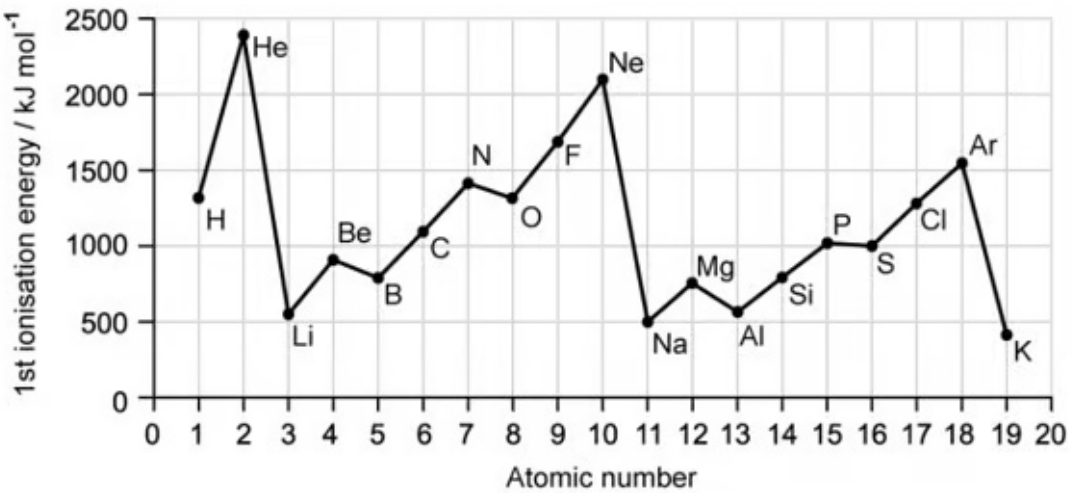
(2 marks)

(b) Write the electron configuration for a Ca^+ ion.

.....

(1 mark)

(c) The first ionisation energies of the elements H to K are shown below.



State and explain the trend in first ionisation energies shown by the elements with the atomic numbers 2, 10 and 18.

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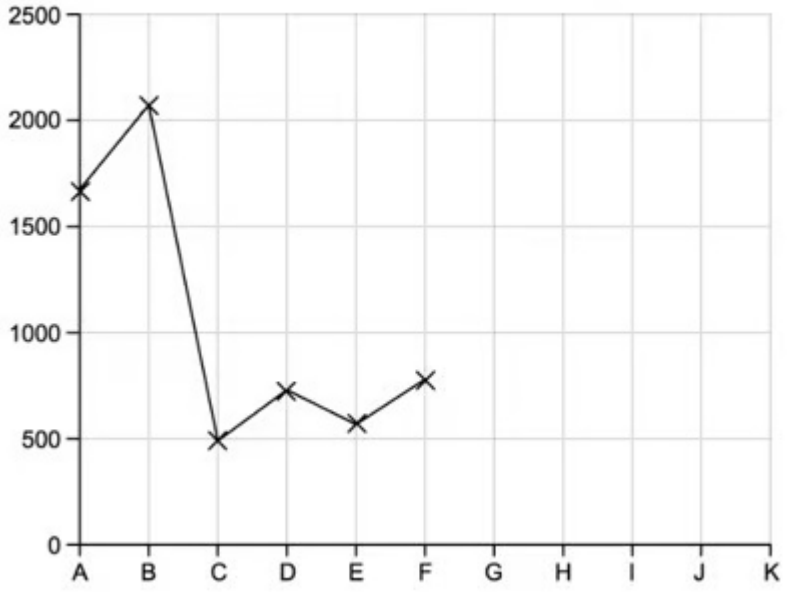
(4 marks)

3 (a) Electrons in atoms occupy orbitals.

The figure below shows the first ionisation energies for six consecutive elements labelled **A**–**F**.



Complete the graph of the first ionisation energies for the next five elements.

(3 marks)

(b) Explain why the value of the first ionisation energy for D is greater than for C.

(2 marks)

(c) The sequence of the first three elements in the Periodic Table is hydrogen, helium and then lithium.

Explain why the first ionisation energy of hydrogen is less than that of helium but greater than that of lithium.

(4 marks)

4 (a) First ionisation energies decrease down groups in the Periodic Table.

Explain this trend and the effect on the reactivity of groups containing metals.

(3 marks)

(b) The ionisation energy values show a general increase across period 4 from gallium to krypton.

State and explain how selenium deviates from this trend.

(3 marks)

(c) Give one other element from period 2 or 3 which also deviates from this general trend, similar to selenium.

(1 mark)

(d) State and explain the trends in electronegativity down group 2 and across period 3.

(6 marks)

5 (a) Describe the trends in first ionisation energy and atomic radius as you move up Group 1.

.....

(1 mark)

Explain the connection between first ionisation energy and atomic radius seen in the alkali metals.

.....

.....

(b) **(2 marks)**

(c) Potassium reacts with water to form hydrogen gas. Using sections 1 and 2 of the data booklet, determine the volume, in cm^3, of hydrogen gas that could theoretically be produced at 273 K and 1.01105 Pa when 0.0587 g of potassium reacts with excess water.

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(3 marks)

6 (a) Write equations for the separate reactions of lithium oxide and carbon dioxide with excess water and differentiate between the solutions formed.

Lithium oxide.....

Carbon dioxide.....

Differentiation.....

.....

.....

.....

(3 marks)

(b) Suggest why it is surprising that dinitrogen monoxide dissolves in water to give a neutral solution.

.....

(1 mark)

(c) Calcium carbide reacts with water to form ethyne, C_2H_2, and one other product.

Estimate the pH of the resultant solution.

.....

(1 mark)

7 (a) Impurities cause phosphine to ignite spontaneously in the air to form an oxide of phosphorus and water.

The oxide formed in the reaction with air contains 56.3 % phosphorus by mass. Determine the empirical formula of the oxide, showing your method.

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.....

.....

(3 marks)

(b) The molar mass of the oxide is approximately 220 g mol^{-1}. Determine the molecular formula of the oxide.

.....

(1 mark)

(c) State the equation for the reaction of this oxide of phosphorus with water.

.....

(1 mark)

(d) Predict how dissolving an oxide of phosphorus would affect the electrical conductivity of water.

.....

(1 mark)

8 (a) When chromium(III) sulfate dissolves in water, a green solution containing the $[Cr(H_2O)_6]^{3+}$ ion forms.

i) State the bond angles found in this complex ion.

[1]

ii) Explain why the chromium(III) complex ion is coloured.

[3]

.....

.....

.....

.....

(4 marks)

(b) Vanadium(V) oxide is the catalyst used in the Contact process as shown by the reactions:

$$SO_2\,(g) + V_2O_5\,(s) \rightarrow SO_3\,(g) + V_2O_4\,(s)$$

$$V_2O_4\,(s) + ½O_2\,(g) \rightarrow V_2O_5\,(s)$$

i) Explain, using the equations, why V_2O_5 is a catalyst.

[1]

ii) Explain why V_2O_5 can act as a catalyst in this reaction.

[1]

.....

.....

(2 marks)

(c) Excess ammonia is added to a solution of Cu^{2+} ions resulting in the substitution of 4 ligands.

Explain why this reaction results in a shift in the wavelength of light absorbed by the Cu^{2+} complex.

.....

(1 mark)

9 (a) Iron is a transition element that forms several ions with iron in different oxidation states.

Deduce the condensed electron configuration of the iron cation that can form the complex ion $[Fe(CN)_6]^{4-}$.

.....

(1 mark)

(b) Co(III) has the same electron configuration as the iron cation in part(a).

Explain why, despite this, solutions of the two ions are different colours.

.....

.....

(2 marks)

(c) Rhenium forms salts containing the perrhenate(VII) ion, ReO_4^-.

Suggest why the existence of salts containing an ion with this formula could be predicted. Refer to section 7 of the data booklet.

.....

(1 mark)

(d) Rhenium is used with platinum to speed up reactions used in the production of gasoline.

Predict **two** other chemical properties you would expect rhenium to have, given its position in the periodic table.

.....

.....

(2 marks)

10 (a) 1,2-diaminoethane is a bidentate ligand which can form a complex with $[Co(NH_3)_4(H_2O)_2]^{2+}$. In this reaction, only the ammonia molecules are replaced.

i) Write an equation for this reaction.

[1]

ii) State the molecular geometry of the complex formed.

[1]

.....

.....

(2 marks)

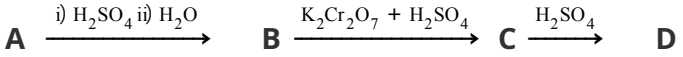
(b) Explain why Ti forms variable oxidation states, but Ca only occurs in the +2 oxidation state.

.....

.....

(2 marks)

11 (a) The following three step synthesis route was carried out:



Reactant **A** is a hydrocarbon containing 85.71% carbon and shows 4 peaks in a ^1H NMR spectrum. Deduce the identity of A.

.....

.....

(2 marks)

(b) Intermediate **B** shows a fragment at m/z 43 in the mass spectrum and has a molecular ion at m/z 74.

Deduce the identity of **B**, giving a reason.

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.....

(2 marks)

(c) The question is about intermediate **C** in the synthesis.

i) Suggest an identity for intermediate **C**.

[1]

ii) State the reaction conditions for the conversion of **B** to **C**.

[1]

.....

.....

(2 marks)

(d) Deduce the identify of the reaction product, **D**, and give one piece of spectral data that would support your answer.

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(2 marks)