



Candidate Name

Candidate Number

Centre Name

Centre Number

Paper 3: Chemistry

For Examination December 2023

(2 hours)

It is necessary to respond on the answer sheets provided alongside this question paper. Additionally, you must have a soft pencil (preferably of type B or HB), a clean eraser and a dark blue or black pen.

INSTRUCTIONS:

- You must write your name, candidate number, centre name and centre number on the answer sheets in the designated spaces.
- Attempt all the questions from using a dark blue or black pen.
- It is important to follow the instructions provided on the answer sheets.
- Do not use correction fluid.
- Avoid writing on any bar codes.
- There is a list of data values and a periodic table at the back for your use.

INFORMATION:

The number of marks assigned for every question or its parts is indicated within brackets []

Section A (Multiple Choice)

For each question there are four possible answers **A**, **B**, **C** and **D**. Choose the **one** you consider to be correct.

Use of the Data Booklet may be appropriate for some questions.

- 1 Ethene can be oxidised to form epoxyethane, C₂H₄O.



Which set of conditions gives the greatest yield of epoxyethane at equilibrium?

	pressure	temperature / °C
A	high	100
B	high	200
C	low	100
D	low	200

- 2 Cobalt can form the positive ion Co(NH₃)₄Cl₂⁺.

What is the oxidation number of cobalt in this ion?

- A** +1 **B** +2 **C** +3 **D** +6

- 3 When considering one molecule of ethene, which row describes both the hybridisation of the atomic orbitals in the carbon atoms and the overall bonding?

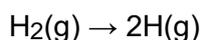
	hybridisation	bonding
A	sp ²	4 σ bonds 1 π bond
B	sp ²	5 σ bonds 1 π bond
C	sp ³	4 σ bonds 1 π bond
D	sp ³	5 σ bonds 1 π bond

- 4 10 cm³ of ethane is burned in 45 cm³ of oxygen at a pressure of 101 kPa and a temperature of 200 °C. Complete combustion takes place.

What is the total volume of gas present when the reaction is complete, measured under the same conditions?

- A** 30 cm³ **B** 50 cm³ **C** 55 cm³ **D** 60 cm³

5 Two reactions are shown.

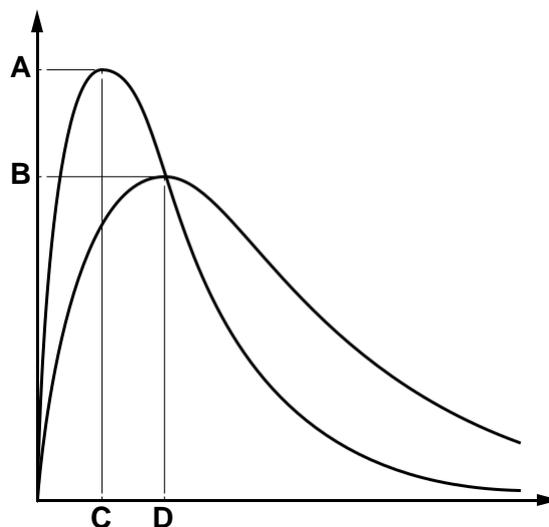


If molar amounts are used, how can the two energy changes associated with these reactions be described?

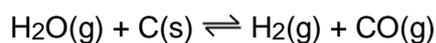
- A enthalpy of atomisation and enthalpy of combustion
- B enthalpy of atomisation and enthalpy of formation
- C bond energy and enthalpy of combustion
- D bond energy and enthalpy of formation

6 The diagram shows the Boltzmann energy distribution curves for molecules of a sample of a gas at two different temperatures.

Which letter on the axes represents the most probable energy for molecules of the same sample of gas at the **lower** temperature?



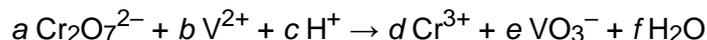
7 What are the units of K_p for the reaction shown?



- A Pa^{-1}
- B Pa
- C Pa^2
- D no units

- 8 In this question you should use changes in oxidation numbers to balance a chemical equation.

Acidified potassium dichromate(VI) solution can oxidise a solution of V^{2+} ions. The equation for this reaction is shown.



What is the ratio $a : b$ in the correctly balanced equation?

- A** 1:1 **B** 1:2 **C** 2:1 **D** 4:1

- 9 A sample of argon gas has a mass of 0.20 g, at a pressure of 100 000 Pa and a temperature of 12 °C.

Which volume does the gas occupy?

- A** $1.2 \times 10^{-4} \text{ cm}^3$
B 5.0 cm^3
C 59 cm^3
D 119 cm^3

- 10 In which pair does each species have the same number of unpaired electrons?

- A** Al and Cu^{2+}
B Ca and Cr^{3+}
C Ca and Ni^{2+}
D Fe^{3+} and O^{2-}

- 11 A sample of solid ammonium chloride decomposes on heating.



A total of 2.4×10^{21} molecules of gas is formed.

How many hydrogen atoms are present in the gaseous products?

- A** 1.2×10^{21} **B** 2.4×10^{21} **C** 4.8×10^{21} **D** 9.6×10^{21}

- 12 A white powder is a mixture of sodium chloride and sodium iodide. It is dissolved in water in a test-tube. An excess of aqueous silver nitrate is added to the test-tube. A precipitate, X, is observed.

An excess of concentrated ammonia is then added to the test-tube containing X. After the test-tube has been shaken, a precipitate, Y, is observed.

Which statement about X or Y is correct?

- A X is a pure white colour.
 - B X is pure silver iodide.
 - C Y is pure silver chloride.
 - D Y is yellow.
- 13 6.90 g of an ammonium salt is heated with an excess of aqueous sodium hydroxide. The volume of ammonia produced, measured under room conditions, is 2.51 dm³.

Which ammonium salt is used?

- A ammonium carbonate ($M_r = 96.0$)
 - B ammonium chloride ($M_r = 53.5$)
 - C ammonium nitrate ($M_r = 80.0$)
 - D ammonium sulfate ($M_r = 132.1$)
- 14 An excess of MgO is shaken with water. The resulting mixture is filtered into test-tube P.
An excess of BaO is shaken with water. The resulting mixture is filtered into test-tube Q.
- Which oxide reacts more readily with water and which filtrate has the **lower** pH?

	oxide reacts more readily with water	test-tube with filtrate of lower pH
A	BaO	P
B	BaO	Q
C	MgO	P
D	MgO	Q

15 Element Z has a giant structure.

The chloride of Z reacts with water to give a solution with a pH less than 5.

Which pair shows two elements which could be Z?

- A aluminium, magnesium
- B aluminium, silicon
- C phosphorus, magnesium
- D phosphorus, silicon

16 Sodium, aluminium and silicon are three elements in Period 3. Each element forms an oxide.

Which row has three correct properties of these oxides?

	sodium oxide	aluminium oxide	silicon dioxide
A	basic	basic	amphoteric
B	giant ionic	giant ionic	simple molecular
C	high melting point	low melting point	high melting point
D	reacts with water	no reaction with water	no reaction with water

17 0.25 g of anhydrous magnesium nitrate is heated strongly until it completely decomposes.

What is the total volume of gas produced, measured under room conditions?

- A 40 cm³ B 81 cm³ C 101 cm³ D 202 cm³

18 Astatine, At, is below iodine in Group 17 of the Periodic Table.

Which statement is most likely to be correct?

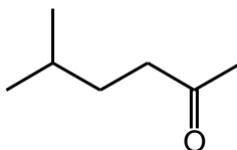
- A AgAt(s) reacts with an excess of dilute aqueous ammonia to form a solution of a soluble complex.
- B Astatine and KCl(aq) react to form KAt(aq) and chlorine.
- C KAt(aq) and dilute sulfuric acid react to form HAt(g).
- D NaAt(s) and concentrated sulfuric acid react to form astatine.

19 What is the order of increasing melting point of the three chlorides shown?



	lowest melting point	→	highest melting point
A	CCl_4		MgCl_2
B	MgCl_2		PCl_5
C	MgCl_2		CCl_4
D	PCl_5		MgCl_2

20 The skeletal formula of compound X is shown.



Which row is correct?

	molecular formula of X	observation on addition of X to Fehling's reagent
A	$\text{C}_7\text{H}_{14}\text{O}$	no change
B	$\text{C}_7\text{H}_{14}\text{O}$	red precipitate forms
C	$\text{C}_7\text{H}_{16}\text{O}$	no change
D	$\text{C}_7\text{H}_{16}\text{O}$	red precipitate forms

21 Which statement is correct?

- A** 2,2-dimethylpropanoic acid is an isomer of propyl methanoate.
- B** 2-methylbutan-2-ol is an isomer of hexan-3-ol.
- C** 3-methylbutan-2-one is an isomer of pentanal.
- D** 3,3-dimethylbutan-2-one is an isomer of pentan-3-one.

22 But-1-ene and but-2-ene are treated separately with cold, dilute acidified manganate(VII) ions.

Four students, W, X, Y and Z, make statements about these alkenes and the diols formed from them.

- W One diol contains two primary alcohol groups.
- X One diol contains a primary and a secondary alcohol group.
- Y One diol contains two secondary alcohol groups.
- Z Both alkenes exhibit *cis-trans* isomerism.

Which two students are correct?

- A** W and Y **B** W and Z **C** X and Y **D** X and Z

23 2-bromo-2-methylpentane is a tertiary halogenoalkane.

Which organic products are formed when 2-bromo-2-methylpentane reacts with a hot concentrated ethanoic solution of sodium hydroxide?

- A** 2-methylpent-1-ene only
- B** 2-methylpent-1-ene and 2-methylpent-2-ene
- C** 2-methylpent-2-ene only
- D** 2-methylpent-2-ene and 4-methylpent-2-ene

24 Poly(propene) is an addition polymer.

What are the C–C–C bond angles along its polymer chain?

- A** They are all 109°.
- B** Half of them are 109° and half are 120°.
- C** Half of them are 90° and half are 180°.
- D** They are all 120°.

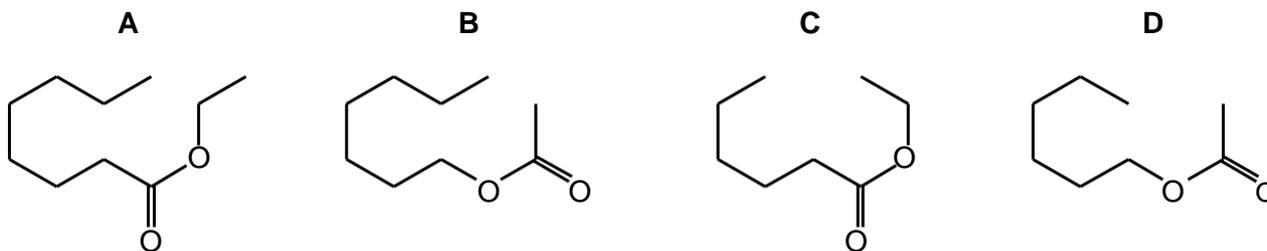
25 An alcohol has the molecular formula C₅H₁₂O. It has several isomers.

Which isomer forms a yellow precipitate with alkaline aqueous iodine? **A** 2,2-dimethylpropan-1-ol

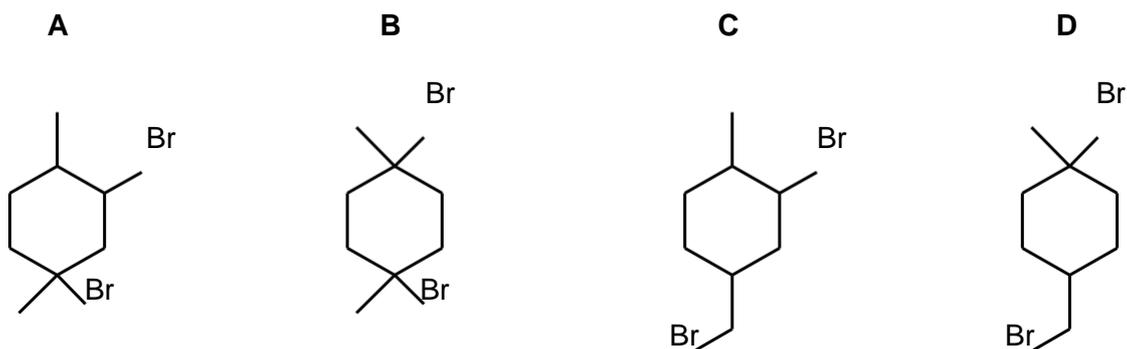
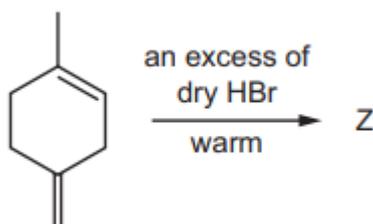
- B** 2-methylbutan-2-ol
- C** 3-methylbutan-2-ol
- D** pentan-3-ol

26 When compound X is heated under reflux with aqueous sodium hydroxide solution two products are formed: sodium ethanoate and hexan-1-ol.

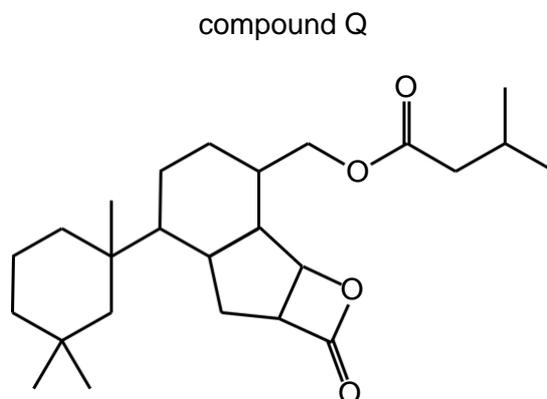
What is compound X?



27 What is the major product Z of the following reaction?



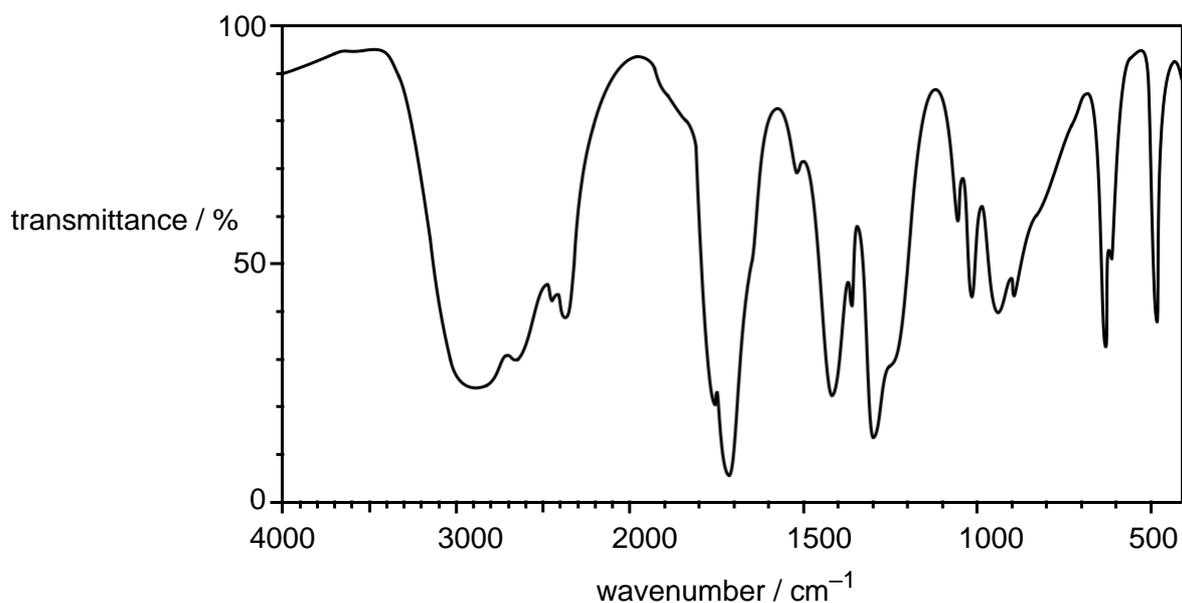
28 The structure of compound Q is shown.



How many chiral centres are present in a molecule of Q?

- A 4 B 5 C 6 D 7

29 Compound X has the infra-red spectrum shown.



What could be the identity of compound X?

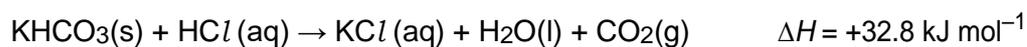
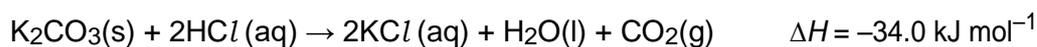
- A ethanoic acid
 - B ethanol
 - C ethylethanoate
 - D propanone
- 30 Which reaction produces an organic anion with a good yield?
- A heating ethanenitrile under reflux with dilute sodium hydroxide
 - B heating ethanenitrile under reflux with dilute sulfuric acid
 - C heating ethane with sodium metal
 - D heating ethanol under reflux with dilute sodium hydroxide
- 31 Which particle has equal numbers of protons and neutrons and an electronic structure of $1s^2 2s^2 2p^6 3s^2 3p^6$?
- A $^{39}_{18}\text{Ar}$
 - B $^{40}_{20}\text{Ca}^{2+}$
 - C $^{16}_8\text{O}^{2-}$
 - D $^{32}_{16}\text{S}$
- 32 Which molecule contains six bonding electrons?
- A NCl_3
 - B H_2S
 - C C_2H_4
 - D SF_6

33 Solid carbon dioxide, CO₂, is similar to solid iodine, I₂, in its structure.

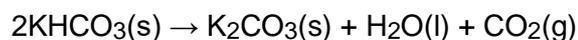
Which statement about solid CO₂ and solid SiO₂ is correct?

- A Both solid CO₂ and solid SiO₂ exist in a lattice structure.
- B Both solid CO₂ and solid SiO₂ have a simple molecular structure.
- C Both solid CO₂ and solid SiO₂ have atoms joined by single covalent bonds.
- D Both solid CO₂ and solid SiO₂ change spontaneously to gas at s.t.p..

34 The enthalpy changes of two reactions are shown.

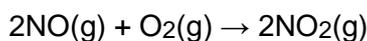
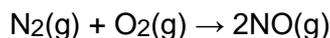


What is the enthalpy change for the reaction shown?



- A -31.6 kJ mol⁻¹
- B 1.2 kJ mol⁻¹
- C 66.8 kJ mol⁻¹
- D 99.6 kJ mol⁻¹

- 35 Nitrogen reacts with oxygen to form nitrogen monoxide, NO, and nitrogen dioxide, NO₂. Nitrogen dioxide reacts with water and with hydroxide ions.



What can be deduced using **only** the information from these equations?

- A HNO₂ is a strong acid.
B HNO₃ is a weak acid.
C NO₂ is a neutral gas.
D NO is a reducing agent.
- 36 Which solution has the lowest pH value?
A 0.01 mol dm⁻³ butanoic acid
B 0.01 mol dm⁻³ ethanoic acid
C 0.01 mol dm⁻³ hydrochloric acid
D 0.01 mol dm⁻³ sulfuric acid
- 37 The element sulfur produces a mass spectrum with the following peaks.

<i>m / e</i> value of peak	relative abundance
7	95.02
8	0.76
9	4.20
8	0.02

Which relative atomic mass of sulfur can be calculated from these data, given to four significant figures?

- A 32.07 B 32.08 C 32.09 D 32.10
- 38 What is the electronic configuration of an isolated Ni²⁺ ion?
A 1s²2s²2p⁶3s²3p⁶3d⁶4s² B 1s²2s²2p⁶3s²3p⁶3d⁷4s¹ C 1s²2s²2p⁶3s²3p⁶3d¹⁰4s²
D 1s²2s²2p⁶3s²3p⁶3d⁸

39 At 200 °C aluminium chloride is a gas with $M_r = 267$.

What is the number of covalent bonds, dative covalent bonds and lone pairs of electrons in one molecule of aluminium chloride at 200 °C?

	covalent bonds	dative covalent bonds	lone pairs
A	6	2	0
B	6	2	16
C	6	2	18
D	3	0	9

40 When solid $KClO_3$ is heated in the absence of air, a mixture of two chlorine compounds in the mole ratio of 3 : 1 is formed. Chlorine is the only element whose oxidation number changes in this reaction.

What could be the oxidation numbers of chlorine in the two compounds that are formed?

- A** +3 and -1 **B** +6 and +4 **C** +7 and -1 **D** +7 and +1

Section B (Short- and extended- responses)

Question One

One reason for the wide variety of organic compounds is isomerism, either structural isomerism or stereoisomerism.

(i) Explain the meaning of the term *structural isomerism*.

.....
.....
..... [2]

(ii) Explain the meaning of the term *stereoisomerism*.

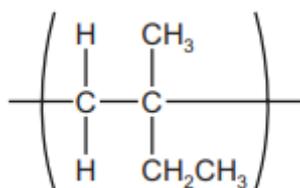
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.....
..... [2]

(iii) Pent-1-ene, $\text{CH}_2=\text{CH}(\text{CH}_2)_2\text{CH}_3$, does not show stereoisomerism.

a. Give **two** reasons why pent-1-ene does **not** show stereoisomerism.

reason 1
.....
reason 2
..... [2]

- iv. A structural isomer of pent-1-ene is used as the monomer to form a polymer. The repeat unit of this polymer is shown.



Draw the **displayed** formula of the monomer used to make this polymer.

Give the name of the monomer.

.....

[2]

- v. A different structural isomer of pent-1-ene shows geometrical isomerism. Draw the structure of **one** of the two geometrical isomers with the formula C_5H_{10} . Give the full name of this isomer.

.....

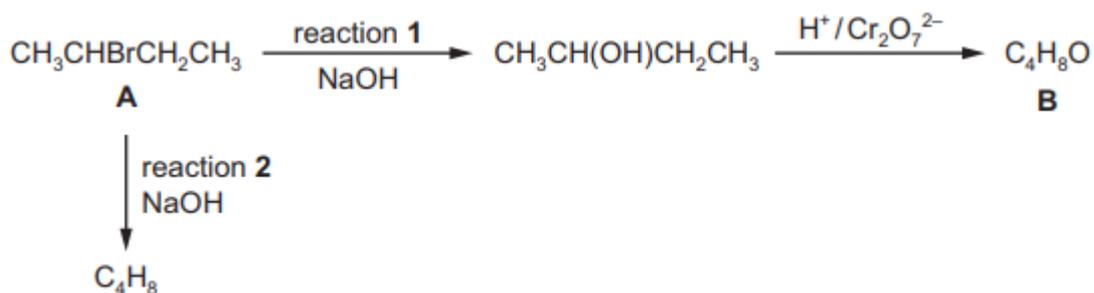
[2]

[Total: 10]

Question Two

A is $\text{CH}_3\text{CHBrCH}_2\text{CH}_3$.

Some reactions of A are shown.



i) Name A.

..... [1]

ii) Name the class of compound to which B belongs.

..... [1]

iii) There are three structural isomers of A.

Draw the structures of these three isomers of A.

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[2]

iv) Reaction 1 occurs by two different mechanisms at the same time.

These mechanisms are referred to as $\text{S}_{\text{N}}1$ and $\text{S}_{\text{N}}2$.

State what the letters 'S' and 'N' represent in the abbreviation $\text{S}_{\text{N}}1$.

S

N

[1]

v) Complete the S_N1 mechanism for reaction 1.



Include the structure of the intermediate and all necessary charges, dipoles, lone pairs and curly arrows.

[3]

The S_N1 mechanism for reaction 1 is repeated using CH₃CHClCH₂CH₃ or CH₃CHI CH₂CH₃ in place of the CH₃CHBrCH₂CH₃.

State and explain how the rates of these two reactions will compare with the rate of the original reaction using CH₃CHBrCH₂CH₃.

.....

.....

.....

.....

..... [3]

vi) Reaction 2 uses the same reagent as reaction 1, but under different conditions.

State **two** differences in the conditions needed to ensure that reaction 2 is more likely to take place than reaction 1 when this reagent is added.

.....

.....

..... [2]

[Total: 13]

Question Three

The elements in Group 17, the halogens, show trends in both their chemical and physical properties. The elements and their compounds have a wide variety of uses.

At room temperature fluorine and chlorine are gases, bromine is a liquid and iodine is a solid.

- i) State the trend in the volatility of the Group 17 elements down the group.

..... [1]

- ii) Explain this trend.

.....

.....

..... [2]

- iii) Iodine, I_2 , can be displaced from $NaI(aq)$, by chlorine, Cl_2 . Write an equation for this reaction.

..... [1]

- iv) Silver nitrate solution, $AgNO_3(aq)$, is added to separate solutions of NaI and $NaCl$. Precipitates form. An excess of aqueous ammonia is then added to both precipitates.

- a. Complete the table to give the colour and name of the precipitate formed in each reaction and the effect of the addition of an excess of aqueous ammonia to each of the precipitates formed.

	$NaI(aq) + AgNO_3(aq)$	$NaCl(aq) + AgNO_3(aq)$
colour of precipitate		
name of precipitate		
effect of addition of an excess of aqueous ammonia to the precipitate		

[3]

- v) Write an ionic equation, including state symbols, to show the reaction occurring when $AgNO_3(aq)$ is added to $NaI(aq)$.

..... [1]

- vi) Solid NaI reacts with concentrated sulfuric acid to form purple fumes of $I_2(g)$ and hydrogen sulfide gas, $H_2S(g)$.

However, when solid NaCl reacts with concentrated sulfuric acid the only gas produced is $HCl(g)$.

Explain the difference in the reactions of concentrated sulfuric acid with NaI and with NaCl. Your answer should refer to the role of the sulfuric acid in each reaction.

.....
.....
.....
.....
.....
..... [3]

- vii) Chlorine is commonly used in water purification. When chlorine is added to water it reacts to produce a mixture of acids, one of which is chloric(I) acid, $HClO$, a powerful oxidising agent.

a. Explain the meaning of the term *oxidising agent*, in terms of electron transfer.

.....
.....
..... [1]

- viii) Suggest an equation for this reaction of chlorine with water.

..... [1]

- ix) Write an equation for the reaction of chlorine with **hot** aqueous sodium hydroxide. Use oxidation numbers to explain why this is a redox reaction.

equation
.....
..... [2]

[Total: 15]

Part C (Practical Based Skills)

A student carries out some tests on four aqueous solutions **A**, **B**, **C** and **D**. One of the solutions is aqueous barium chloride, $\text{BaCl}_2(\text{aq})$.

The student is asked to add **A** to samples of **B**, **C** and **D** in separate test tubes, a **small** amount at a time, until there is no further change.

The container of solution **A** has a hazard label.



- (i) Identify the hazard indicated by this label. [1]

-
- (ii) Describe how you would add small amounts of **A** until there is no further change. Name the apparatus you would use. [3]

.....

.....

.....

.....

.....

.....

- (iii) **B** is a blue solution. When **A** is added to **B**, the mixture first turns green and then gradually turns yellow.

Give the **formula** of the cation in **B**. [1]

-
- (iv) When **A** is added to **C**, vigorous effervescence occurs and the gas produced turns limewater cloudy.

Identify, by name or formula, the gas produced. [1]

(v) Suggest the identity, by name or formula, of the anion in **C**.

[1]

.....

(vi) Identify **A** by name or formula. Justify your answer.

[3]

.....

.....

.....

.....

.....

.....

(vii) When **A** is added to **D** no change is seen.
A small amount of this mixture is added to **B** and a white precipitate forms.
Suggest what can be deduced about solutions **B** and **D**.

[2]

Solution **B**

.....

Solution **D**

.....

[Total: 12]

Table: Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g ⁻¹ K ⁻¹)

The Periodic Table of Elements

		Group															
1	2											13	14	15	16	17	18
		Key															
		atomic number name atomic symbol relative atomic mass										1 H hydrogen 1.0					
3 Li lithium 6.9	4 Be beryllium 9.0											5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3											13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium -	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs caesium 132.9	56 Ba barium 137.3	57-71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium -	85 At astatine -	86 Rn radon -
87 Fr francium -	88 Ra radium -	89-103 actinoids	104 Rf rutherfordium -	105 Db dubnium -	106 Sg seaborgium -	107 Bh bohrium -	108 Hs hassium -	109 Mt meitnerium -	110 Ds darmstadtium -	111 Rg roentgenium -	112 Cn copernicium -	113 Nh nihonium -	114 Fl flerovium -	115 Mc moscovium -	116 Lv livermorium -	117 Ts tennessine -	118 Og oganeson -