Questions

Q1.

The properties of elements and their compounds are determined by their structure and bonding.

(i) In a dry container, a fluoride of silver reacts with sulfur to produce disulfur difluoride. Complete the equation for this reaction. State symbols are not required.

(1)

$$S_8 + \ldots\ldots AgF_2 \rightarrow \ldots\ldots S_2F_2 + \ldots\ldots AgF$$

(ii) Explain, by using the oxidation numbers of **all** the atoms, whether or not this is a redox reaction.

(3)

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(Total for question = 4 marks)

Q2.

This question is about some redox reactions of chlorine, bromine and iodine.

Chlorine undergoes disproportionation when it reacts with **hot** aqueous sodium hydroxide solution.

(i) Complete the ionic equation for this reaction. State symbols are not required.

(1)

(ii) Explain, in terms of oxidation numbers, why this is a disproportionation reaction.

(2)

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(Total for question = 3 marks)

Q3.

This is a question about chromium(III) and chromium(VI) compounds.

The chromium(III) complex, $[Cr(OH)_6]^{3-}$, can be oxidised to chromate(VI) ions, CrO_4^{2-}, by hydrogen peroxide solution.

(i) Deduce the oxidation half-equation for this reaction, which takes place in alkaline conditions.
State symbols are not required.

(2)

(ii) If the solution of chromate(VI) ions is then acidified, the colour of the solution changes to orange as dichromate(VI) ions form.

Write the equation for this change. State symbols are not required.

(1)

(iii) In acidic conditions, dichromate(VI) ions can also be reduced to chromium(III) ions using hydrogen peroxide.

The value of $E^{\ominus}_{cell}$ cell = + 0.65 V for which the cell diagram is

$$Pt(s) \mid H_2O_2(aq), [2H^+(aq)+O_2(g)] \,\|\, [Cr_2O_7^{2-}(aq)+14H^+(aq)], [2Cr^{3+}(aq)+7H_2O(l)] \mid Pt(s)$$

Deduce from the cell diagram the oxidation and the reduction half-equations, and thus the overall equation for this reaction.
State symbols are not required.

(3)

(Total for question = 6 marks)

Q4.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

This question is about the compound potassium bromate, $KBrO_3$.

These bromate ions react with bromide ions in acidic solution.

$$BrO_3^-(aq) + 5Br^-(aq) + 6H^+(aq) \rightarrow 3Br_2(aq) + 3H_2O(l)$$

(i) Explain, in terms of oxidation numbers, whether or not this is a disproportionation reaction.

(2)

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(ii) What is the overall order of this reaction?

(1)

- ☒ **A** 3
- ☒ **B** 6
- ☒ **C** 12
- ☒ **D** cannot tell from this information

(Total for question = 3 marks)

Q5.

This question is about the elements in Group 2 of the Periodic Table.

Calcium reacts with chlorine.

$$Ca(s) + Cl_2(g) \rightarrow CaCl_2(s)$$

Explain, in terms of electrons, why this is a redox reaction.

(2)

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(Total for question = 2 marks)

Q6.

Tablets containing potassium manganate(VII), $KMnO_4$, are dissolved in water forming an antiseptic solution to treat skin conditions. The manufacturers claim that each tablet contains 400 mg of $KMnO_4$.

To check the claim, the titration procedure outlined was carried out.

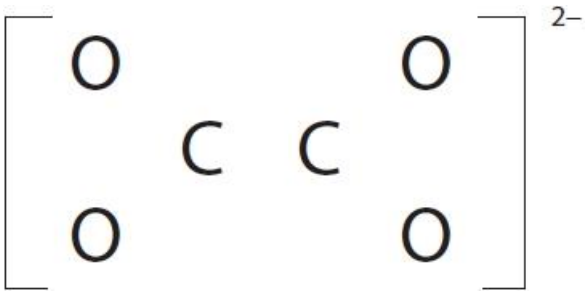
- Five tablets were dissolved in distilled water to make 100.0 cm^3 of solution.
- Some of the $KMnO_4$ solution was used to fill a burette.
- 25.0 cm^3 of sodium ethanedioate solution, $Na_2C_2O_4(aq)$, of concentration 0.200 mol dm^{-3}, was added to a conical flask and warmed.
- Sulfuric acid, of concentration 2 mol dm^{-3}, was also added to the conical flask.
- The $KMnO_4$ solution was added to the flask from the burette, until the end-point.

The equation for the reaction between MnO_4^- ions from the $KMnO_4$ and $C_2O_4^{2-}$ ions from the sodium ethanedioate solution is shown.

$$16H^+(aq) + 2MnO_4^-(aq) + 5C_2O_4^{2-}(aq) \rightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(l)$$

(i) Complete the dot-and-cross diagram for the ethanedioate ion.
Show the outer electrons only.

(2)



(ii) Determine the oxidation number of carbon in the ethanedioate ion, $C_2O_4^{2-}$.

(1)

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(Total for question = 3 marks)

Q7.

This question is about some reactions of chlorine and hydrogen chloride.

Chlorine can be produced by reacting concentrated hydrochloric acid with manganese(IV) oxide.

The equation for this reaction is

$$4HCl(aq) + MnO_2(s) \rightarrow MnCl_2(aq) + Cl_2(g) + 2H_2O(l)$$

(i) Deduce the half-equation for the formation of chlorine.

(1)

(ii) A student reacted 5.0 cm^3 of 5.0 mol dm^{-3} hydrochloric acid with an excess of manganese(IV) oxide. 70 cm^3 of chlorine gas was produced.

The teacher said the expected percentage yield of the experiment is 75 %.
Determine whether the student achieved the expected percentage yield.
[Molar volume of a gas at r.t.p. = 24 000 cm^3 mol^{-1}]

(4)

(Total for question = 5 marks)

Q8.

This question is about redox reactions.

Name the ion with formula PO_3^{3-} . Include the relevant oxidation number.

(1)

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(Total for question = 1 mark)

Q9.

This question is about redox reactions.

Manganese(IV) oxide, MnO_2 , and manganate(VII) ions, MnO_4^- , react in alkaline solution to form manganate(VI) ions, MnO_4^{2-} .

(i) Write the **ionic** equation for this reaction.

State symbols are not required.

(2)

(ii) Give a reason why this reaction is **not** disproportionation.

(1)

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(Total for question = 3 marks)

Q10.

This question is about redox chemistry.

(i) Write an ionic half-equation for the reduction of chlorine molecules to chloride ions.

State symbols are not required.

(1)

(ii) Write an ionic half-equation for the oxidation of chlorine molecules to chlorate(I) ions in the presence of cold, aqueous hydroxide ions.

State symbols are not required.

(1)

(iii) Combine the two equations in (i) and (ii) to give the ionic equation for the reaction of chlorine molecules with cold, aqueous hydroxide ions.

(1)

(iv) Use your answer to (iii) to explain why the reaction is described as a **disproportionation** reaction.

(2)

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(Total for question = 5 marks)

Q11.

This question is about chlorine.

Write the formula of potassium chlorate(V).

(1)

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(Total for question = 1 mark)

Q12.

This question is about transition metals.

In which of these complex ions does the transition metal have the oxidation number +3?

(1)

- ☒ **A** $[Ag(CN)_2]^-$
- ☒ **B** $[CuCl_4]^{2-}$
- ☒ **C** $[Fe(CN)_6]^{3-}$
- ☒ **D** $[Ni(EDTA)]^{2-}$

(Total for question = 1 mark)

Q13.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

The halogens are elements in Group 7 of the Periodic Table.

Sodium chlorate(I) is a bleaching agent.

(i) Sodium chlorate(I) can be made by the reaction of chlorine with sodium hydroxide.

Show, by using oxidation numbers, that this reaction is disproportionation.

$$2NaOH + Cl_2 \rightarrow NaClO + NaCl + H_2O$$

(2)

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(ii) A different bleaching agent can be made by the reaction of chlorine with sodium hydroxide under different conditions.

Balance this equation.

$$.....NaOH + ...Cl_2 \rightarrow NaClO_3 + ...NaCl + ...H_2O$$

(1)

(iii) What conditions are required for the reaction in (b)(ii)?

(1)

- ☒ **A** cold and dilute alkali
- ☒ **B** cold and concentrated alkali
- ☒ **C** hot alkali
- ☒ **D** excess chlorine

(Total for question = 4 marks)

Q14.

This question is about the reactions of the halogens and their salts.

The reaction that occurs between chlorine and sodium hydroxide depends on the temperature.

(i) At room temperature the reaction that occurs is

$$Cl_2 + NaOH \rightarrow NaClO + NaCl$$

Explain, with reference to oxidation numbers, why this is a disproportionation reaction.

(2)

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(ii) With hot sodium hydroxide solution, a different disproportionation reaction occurs. Sodium chlorate(V) is one of the products.

Complete the equation for this reaction. State symbols are not required.

(2)

..... Cl_2^+ ..... NaOH →

(Total for question = 4 marks)

Q15.

Chlorine and iodine are in the same group in the Periodic Table.
Members of the same group sometimes react in different ways.
Iodine and chlorine react differently with thiosulfate ions, $S_2O_3^{2-}$
Iodine gives $S_4O_6^{2-}$, whilst chlorine gives SO_4^{2-}.
(i) Complete the table by identifying the oxidation numbers of sulfur in the three sulfur-containing ions.

(2)

Ion	Oxidation number of sulfur
$S_2O_3^{2-}$	
SO_4^{2-}	
$S_4O_6^{2-}$	

(ii) The equation for the reaction of iodine with thiosulfate ions is

$$2S_2O_3^{2-} + I_2 \rightarrow 2I^- + S_4O_6^{2-}$$

State, in terms of electrons, why iodine is classified as an oxidising agent in this reaction.

(1)

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(iii) Use your answer to (i) to show that chlorine is a stronger oxidising agent than iodine.

(1)

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(iv) Chlorine reacts in aqueous solution with $S_2O_3^{2-}$ to give SO_4^{2-}.

The ionic half-equation for the reaction of chlorine is

$$Cl_2 + 2e^- \rightarrow 2Cl^-$$

Write the ionic half-equation for the reaction of aqueous $S_2O_3^{2-}$ to give SO_4^{2-}.
State symbols are not required.

(2)

(v) Use your answer to (iv) and the half-equation for chlorine, to write the overall ionic equation for the reaction between chlorine and thiosulfate ions.

State symbols are not required.

(1)

(Total for question = 7 marks)

Q16.

This question is about the properties of transition elements, their ions and their complexes.

Give the oxidation state of vanadium in the compound NH_4VO_3.

(1)

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(Total for question = 1 mark)

Q17.

This question is about halogens and redox reactions.

Use these electrode potentials to answer the following questions.

Electrode reaction	$E^{\ominus}$ / V
$I_2(aq) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$Br_2(aq) + 2e^- \rightleftharpoons 2Br^-(aq)$	+1.09
$MnO_2(s) + 4H^+(aq) + 2e^- \rightleftharpoons Mn^{2+}(aq) + 2H_2O(l)$	+1.23
$Cl_2(aq) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	+1.51

(i) Which species will oxidise $Fe^{2+}(aq)$ to $Fe^{3+}(aq)$?

(1)

☒ **A** $Br_2(aq)$

☒ **B** $Cl^-(aq)$

☒ **C** $I_2(aq)$

☒ **D** $Mn^{2+}(aq)$

(ii) Write the ionic equation and calculate the $E^{\ominus}_{cell}$ for the reaction between MnO_4^- ions and Br^- ions in acidic solution.
State symbols are not required.

(3)

(Total for question = 4 marks)

Q18.

This question is about some reactions of chlorine and hydrogen chloride.

Chlorine reacts with hot concentrated aqueous sodium hydroxide to produce sodium chlorate(V) as one of the products.

The equation for this reaction is

$$3Cl_2 + 6NaOH \rightarrow 5NaCl + NaClO_3 + 3H_2O$$

(i) Explain, using oxidation numbers, why this is a disproportionation reaction.

(2)

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(ii) Calculate the atom economy, by mass, of sodium chlorate(V) in this reaction.

(3)

(Total for question = 5 marks)

Q19.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

This question is about chlorine and its compounds.

Potassium chlorate(V) can be produced by passing chlorine gas into hot, concentrated potassium hydroxide solution.

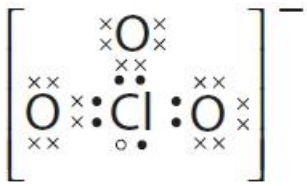
$$3Cl_2 + 6KOH \rightarrow 5KCl + KClO_3 + 3H_2O$$

(i) This reaction is an example of

(1)

- ☒ **A** oxidation only
- ☒ **B** reduction only
- ☒ **C** disproportionation
- ☒ **D** decomposition

(ii) A dot-and-cross diagram for the chlorate(V) ion (ClO_3^-) is shown.



Key
• = chlorine electrons
○ = an added electron
× = oxygen electrons

Predict the shape and bond angle (O—Cl—O) of the chlorate(V) ion. Justify your answer.

(4)

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(Total for question = 5 marks)

Q20.

This question is about chlorine and its compounds.

(i) The following reaction occurs when potassium chlorate(V) is heated at a suitable temperature.
Complete the equation by balancing it.
State symbols are not required.

..... $KClO_3$ → ..... KCl + ... $KClO_4$

(1)

(ii) The table shows some properties of potassium chloride and potassium chlorate(VII).

	Potassium chloride KCl	Potassium chlorate(VII) $KClO_4$
Solubility in water (mol/100 g)	4.81×10^{-1}	1.29×10^{-2}
Solubility in ethanol (mol/100 g)	2.9×10^{-4}	8.7×10^{-6}

Devise a brief method to show how the compounds produced in the decomposition of potassium chlorate(V) could most effectively be separated.
Use information from the table.

(3)

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(Total for question = 4 marks)

Q21.

Many vehicles are fitted with airbags which provide a gas-filled safety cushion to protect the occupant of the vehicle if there is a crash.

(a) The first reaction in airbags is the thermal decomposition of sodium azide, NaN_3, to form sodium and nitrogen gas.

(i) Write the equation for this decomposition of sodium azide.
State symbols are not required.

(1)

(ii) In the reaction in (i), a typical airbag is inflated by about 67 dm^3 of gas.
Calculate the **minimum mass** of sodium azide, in grams, needed to produce this volume of gas. Use the Ideal Gas Equation and give your answer to an appropriate number of significant figures.
For the purpose of this calculation, assume that the temperature is 300 °C and the pressure is 140 000 Pa.

(4)

(b) The second reaction in the airbag is between the sodium produced in the reaction (a)(i) and potassium nitrate.

$$\_\_\_\_Na + \_\_\_\_KNO_3 \rightarrow \_\_\_\_K_2O + \_\_\_\_Na_2O + \_\_\_\_N_2$$

Balance the above equation, justifying your answer in terms of the changes in oxidation numbers.

(3)

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(c) The third reaction in the airbag is between the metal oxides and silicon dioxide.

State the type of reaction taking place and justify why this reaction is necessary.

(3)

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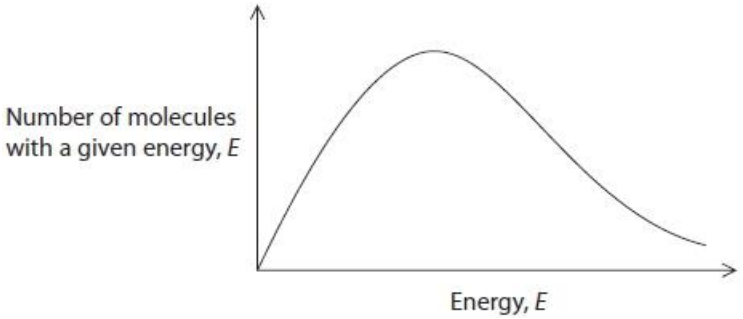
(d) The Maxwell-Boltzmann distribution diagram shows the molecular energies for the gaseous system immediately after the airbag has been deployed.



What is the change in shape of the curve when the airbag **cools**?

(1)

- ☒ **A** the peak would shift to the left and be higher
- ☒ **B** the peak would shift to the left and be lower
- ☒ **C** the peak would shift to the right and be higher
- ☒ **D** the peak would shift to the right and be lower

(Total for question = 12 marks)

Q22.

Magnesium nitrate decomposes on heating as shown by the equation.

$$2Mg(NO_3)_2 \rightarrow 2MgO + 4NO_2 + O_2$$

Explain, in terms of all the relevant oxidation numbers, why this is a redox reaction.

(3)

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(Total for question = 3 marks)

Q23.

This question is about the reactions of the halogens and their salts.

The potassium halides react with concentrated sulfuric acid to form hydrogen halides.

(i) The equation for this reaction for potassium chloride can be written

$$KCl + H_2SO_4 \rightarrow HCl + KHSO_4$$

The hydrogen chloride does not react further.
State why this reaction is not a redox reaction.

(1)

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(ii) On descending Group 7, the hydrogen halides become better reducing agents.

Explain how the reactions of potassium chloride, potassium bromide and potassium iodide with concentrated sulfuric acid provide evidence for this statement.
No explanation of the trend is required.

(3)

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(Total for question = 4 marks)

Q24.

This question is about redox reactions.

State what happens to a reducing agent during a reaction, in terms of oxidation number **and** electrons.

(1)

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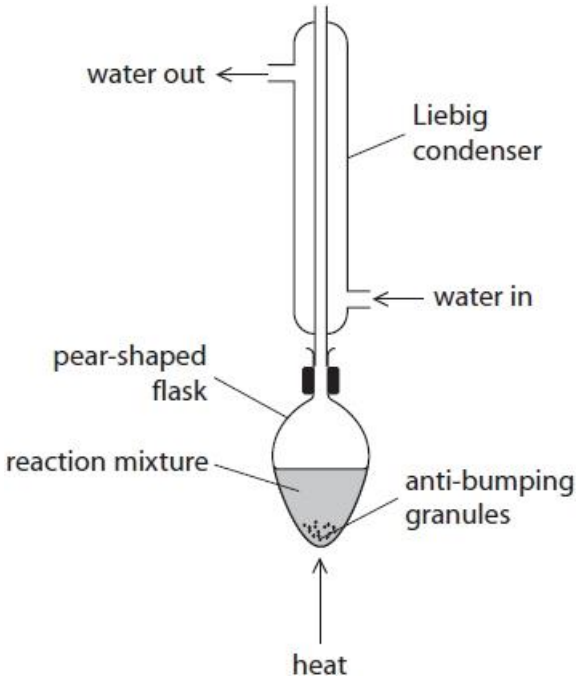
(Total for question = 1 mark)

Q25.

Propanal can be produced from the oxidation of propan-1-ol.

(i) A student assembled the apparatus shown for this oxidation.



Explain why the use of this apparatus would give a very low yield of propanal.

(2)

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(ii) The oxidising agent is acidified $Na_2Cr_2O_7$.

State the oxidation number of chromium in $Na_2Cr_2O_7$.

(1)

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(iii) Complete the ionic half-equation for the oxidation of propan-1-ol.

(1)

$$CH_3CH_2CH_2OH \rightarrow CH_3CH_2CHO + ...H^+ + ...e^-$$

(iv) State how the use of anti-bumping granules gives smoother boiling.

(1)

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(v) Another student used the correct apparatus for this oxidation. 1.50 g of propan-1-ol produced 0.609 g of propanal.

Calculate the percentage yield of propanal by mass.

(3)

(Total for question = 8 marks)

Q26.

This question is about transition metals and transition metal complexes.

Aqueous vanadium(II) chloride, $VCl_2(aq)$, can be oxidised by bubbling gaseous chlorine, $Cl_2(g)$, through the solution in the absence of air.

40.0 cm^3 of 0.100 mol dm^{-3} VCl_2 solution was oxidised by 144 cm^3 of chlorine gas, at room temperature and pressure (r.t.p.).
The chlorine was reduced to chloride ions, according to the half-equation

$$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$$

[Molar volume of a gas at r.t.p. = 24.0 dm^3 mol^{-1}]

(i) Use these data to calculate the final oxidation state of vanadium.
You **must** show your working.

(5)

(ii) State the initial and final colours you would see as the chlorine bubbles through the aqueous vanadium(II) chloride, $VCl_2(aq)$.

(2)

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(Total for question = 7 marks)

Mark Scheme

Q1.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	$S_8 + 8AgF_2 \rightarrow 4S_2F_2 + 8AgF$	Allow multiples	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: • the oxidation number of sulfur increases from 0 to +1 and so is oxidation **(1)** • the oxidation number of silver decreases from +2 to +1 and so is reduction **(1)** • fluorine does not change from −1 **and** it is a redox reaction **(1)**	Check for any oxidation numbers which may be written near the equation if not given on the lines provided. Omission of reduction and oxidation scores max 1 for MP1 and MP2	(3)

Q2.

Question Number	Answer	Additional Guidance	Mark
(i)	• balanced equation	Example of equation $3Cl_2 + 6OH^- \rightarrow 5Cl^- + ClO_3^- + 3H_2O$ Allow multiples Ignore state symbols even if incorrect	(1)

Question Number	Answer	Additional Guidance	Mark
(ii) Clip with (i)	An explanation that makes reference to the following points: • oxidation number for chlorine changes from 0 to -1 so it is **reduced** **(1)** • oxidation number for chlorine changes from 0 to +5 so it is **oxidised** **(1)**	Ignore general definitions of disproportionation Accept oxidation numbers and their changes shown with equation Allow 1 out of 2 marks for three correct oxidation numbers of the chlorine	(2)

Q3.

Question Number	Answer	Additional Guidance	Mark
(i)	• four correct species **(1)** • balancing and the correct number of electrons **(1)**	An example of equation $[Cr(OH)_6]^{3-} + 2OH^- \rightarrow CrO_4^{2-} + 4H_2O + 3e^-$ Accept multiples	**(2)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• equation	An example of equation $2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$ Accept $\rightleftharpoons$ / multiples	**(1)**

Question Number	Answer	Additional Guidance	Mark
(iii)	• oxidation half equation **(1)** • reduction half equation **(1)** • overall equation **(1)**	$H_2O_2 \rightarrow 2H^+ + O_2 + 2e^-$ $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ $Cr_2O_7^{2-} + 8H^+ + 3H_2O_2 \rightarrow 2Cr^{3+} + 7H_2O + 3O_2$ for M3 do not award if H^+/ e^- left on both sides Accept multiples Allow $\rightleftharpoons$ Ignore state symbols even if incorrect Oxidation and reduction half equations scores (2) if not identified but in correct order Award (1) only for M1 and M2 if half equations are not in correct order No TE on incorrect half equations	**(3)**

Q4.

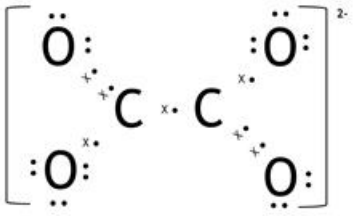
Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • oxidation numbers of Br identified as (+)5 for BrO_3^-, −1 for Br^- and 0 for Br_2 **(1)** • this is not disproportionation because: two different species of bromine / reactants are oxidised and reduced / not one species oxidised and reduced **or** only one species containing bromine is produced / two different species containing bromine in two different oxidation states are not produced **(1)**	These may be shown in the equation Allow 5+ / V / 1− / −I Do not award any change in oxidation numbers of oxygen and or hydrogen Allow bromine is oxidised and reduced in the reverse reaction Allow this is reverse disproportionation / comproportionation	**(2)**

Question number	Answer	Mark
(ii)	**The only correct answer is D** (cannot tell from this information) ***A*** *is incorrect because there are 3 reactant species but the overall order of a reaction can only be determined by experiment* ***B*** *is incorrect because there is 1 bromate ion and 5 bromide ions but the overall order of a reaction can only be determined by experiment* ***C*** *is incorrect because there are 12 reactant particles but the overall order of a reaction can only be determined by experiment*	**(1)**

Q5.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • calcium is oxidised as it loses electrons **(1)** • Chlorine / Cl_2 / Cl is reduced as it gains electron(s) **(1)**	Allow $Ca \rightarrow Ca^{2+} + 2e^-$ / $Ca - 2e^- \rightarrow Ca^{2+}$ **and** oxidation Do not allow calcium loses 1 electron Allow $Cl_2 + 2e^- \rightarrow 2Cl^-$ **and** reduction	**(2)**

Q6.

Question Number	Answer	Additional Guidance	Mark
(i)	• double C=O bond on left and right hand side **(1)** • rest of diagram **(1)**		**(2)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• (+) 3	Allow 3+ / +III / III+ / III / three Ignore working out Do not award ±3	**(1)**

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• half-equation	Example of half-equation $2Cl^- \rightarrow Cl_2 + 2e^{(-)}$ Allow multiples Allow $2Cl^- - 2e^{(-)} \rightarrow Cl_2$ Ignore state symbols even if incorrect DNA reverse equation	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • calculation of moles of HCl **(1)** • calculation of theoretical moles of Cl_2 produced **(1)** • calculation of theoretical volume of Cl_2 **(1)** • calculation of % yield **and** comparison with expected yield **(1)**	Example of calculation $(5.0 \times 5.0) \div 1000 = 0.025 / 2.5 \times 10^{-2}$ (mol) $0.025 \div 4 = 0.00625 / 6.25 \times 10^{-3}$ (mol) $0.00625 \times 24000 = 150$ (cm^3) % yield = (70÷150) x 100 = 46.7/47(%) **and** less than expected / did not achieve expected yield / expected yield is 75% of 150 =112.5 cm^3 Allow calculation of actual moles of Cl_2 for MP3, then calculation of yield based on moles for MP4: $70 \div 24000 = 2.9167 \times 10^{-3}$ (mol) then % yield and comparison for MP4 $(2.9167 \times 10^{-3} \div 0.00625) \times 100 =$ 46.7/47(%) Ignore SF except 1 Allow TE at each stage	(4)

Q8.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• phosphate(III) (ion)	Name **and** oxidation number are required Allow gap between name and oxidation number Allow phosphate and +3 Ignore missing brackets around oxidation number Do not award phosphorus / trioxide / phosphite(III)	**(1)**

Q9.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• MnO_2, MnO_4^-, OH^- and MnO_4^{2-} species correct in a single equation **(1)**	Example of equation $MnO_2 + 2MnO_4^- + 4OH^- \rightarrow 3MnO_4^{2-} + 2H_2O$ Ignore state symbols, even if incorrect Do not award M1 if H^+ is on the left	**(2)**
	• H_2O on right **and** balancing **(1)**	Allow cancelled electrons Allow multiples	

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	An answer that makes reference to: • 2 different species are oxidised and reduced (to form the same species) **or** there is not 1 species that is being oxidised and reduced **or** 2 different oxidation states are not produced from one oxidation state **or** only 1 oxidation state / +6 is formed as a product **or** Mn changes from +4 and +7 to +6 (only)	This mark can be awarded even if (i) is incorrect Allow manganate(VI) / MnO_4^{2-} is oxidised and reduced in the reverse reaction Allow Mn in the same species is not being oxidised and reduced Ignore just 'Mn is not simultaneously oxidised and reduced' Ignore this is reverse disproportionation / comproportionation Do not award O / H is oxidised / reduced Do not award molecules / compounds for species	(1)

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	$Cl_2 + 2e^{(-)} \rightarrow 2Cl^-$	Allow multiples Ignore state symbols even if incorrect	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	$Cl_2 + 4OH^- \rightarrow 2ClO^- + 2H_2O + 2e^{(-)}$	Allow multiples $Cl_2 + 2OH^- \rightarrow 2ClO^- + 2H^+ + 2e^{(-)}$ Ignore state symbols even if incorrect	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	$Cl_2 + 2OH^- \rightarrow Cl^- + ClO^- + H_2O$	Allow multiples Ignore state symbols even if incorrect Do not award mark if electrons are un-cancelled	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
(iv)	An explanation that makes reference to the following points: • (disproportionation is simultaneous) oxidation and reduction of an element (in the same species) **(1)** • chlorine changes from 0 to -1 **and** +1 **(1)**	 Allow statement that chlorine is oxidised **and** reduced This can be shown on the equation in (iii)	**(2)**

Q11.

Question Number	Answer	Additional Guidance	Mark
	• $KClO_3$	Allow $K^+ClO_3^-$	(1)

Q12.

Question Number	Answer	Mark
	The only correct answer is C ***A*** *is not correct because it is +1 not +3* ***B*** *is not correct because it is +2 not +3* ***D*** *is not correct because it is +2 not +3*	**(1)**

Q13.

Question Number	Answer	Additional Guidance	Mark
(i)	• chlorine is oxidised **and** from 0 to +1 (in NaClO) **(1)** • chlorine is reduced **and** from 0 to -1 (in NaCl) **(1)**	Check the equation Allow (1) for three correct oxidation numbers if no other mark is awarded. Allow (1) max for general definition of disproportionation	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	• equation	$6\,NaOH + 3\,Cl_2 \rightarrow NaClO_3 + 5\,NaCl + 3\,H_2O$ Allow multiples	(1)

Question Number	Answer	Mark
(iii)	**The only correct answer is C** (hot alkali) **A** *is not correct because high temperature is required* **B** *is not correct because high temperature is required* **D** *is not correct because high temperature and not excess chlorine is required*	(1)

Q14.

Question Number	Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following points: • chlorine / Cl_2 is simultaneously oxidised and reduced (1) • the oxidation number of chlorine changes from 0 to –I and (+)I / 0 to –1 and (+)1 / increases by 1 and decreases by 1 (1)	Allow oxidation numbers underneath or above the equation	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	• substances correct in equation (1) • equation is balanced (1)	<u>Example of equation</u> $3Cl_2 + 6NaOH \rightarrow NaClO_3 + 5NaCl + 3H_2O$ Ignore state symbols even if incorrect	(2)

Q15.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	Any two correct **(1)** Third also correct **(1)**	<table><tr><th>Ion</th><th>Oxidation number of sulfur</th></tr><tr><td>$S_2O_3^{2-}$</td><td>+2 / 2+ / +II / II+</td></tr><tr><td>SO_4^{2-}</td><td>+6 / 6+ / +VI / VI+</td></tr><tr><td>$S_4O_6^{2-}$</td><td>+2.5 / 2.5+ / $+\frac{10}{4}$ / $\frac{10}{4}+$</td></tr></table>Allow any equivalent fractions e.g. 5/2+ Penalise missing + once only	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to: • gain of electrons (by iodine / I_2)	Allow thiosulfate ion has lost electrons / sulfur has lost electrons Ignore reference to oxidation numbers	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to: • chlorine oxidises sulfur (from +2) to +6 whereas iodine only oxidises sulfur (from +2) to +2.5	Allow chlorine causes a greater increase in oxidation number (than iodine) OR chlorine causes loss of more electrons (from sulfur than iodine) Do not award chlorine gains more electrons Award mark for a greater increase in oxidation number, even if the stated oxidation numbers are incorrect	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(iv)	• correct species **(1)** • balancing of correct species **(1)**	Example of equation $S_2O_3^{2-} + 5H_2O \rightarrow 2SO_4^{2-} + 10H^+ + 8e^-$ Allow for one mark: $S_2O_3^{2-} + 10OH^- \rightarrow 2SO_4^{2-} + 5H_2O + 8e^-$ Ignore state symbols even if incorrect	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(v)	• correct equation	Example of equation $4Cl_2 + S_2O_3^{2-} + 5H_2O \rightarrow 8Cl^- + 2SO_4^{2-} + 10H^+$ Allow HCl in place of H^+ and Cl^- as long as balanced ($8HCl + 2H^+$) Allow $4Cl_2 + S_2O_3^{2-} + 10OH^- \rightarrow 8Cl^- + 2SO_4^{2-} + 5H_2O$ From $S_2O_3^{2-} + 10OH^- \rightarrow 2SO_4^{2-} + 5H_2O + 8e^-$ in (b)(iv) Do not award equations with electrons not cancelled Ignore state symbols even if incorrect	**(1)**

Q16.

Question Number	Acceptable Answers	Additional Guidance	Mark
	+5	Allow 5+ / +V / V+ / (V) / 5 Do not award V^+	**(1)**

Q17.

Question Number	Answer	Mark
(i)	**The only correct answer is A** ***B*** *is not correct because* Cl^- *is not an oxidising agent* ***C*** *is not correct because* I_2 *is not a powerful enough oxidising agent* ***D*** *is not correct because* Mn^{2+} is not an oxidising agent	**(1)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• all species on correct sides of equation **and** no electrons / electrons cancelled **(1)** • balancing correct species **(1)** • $E^{\ominus}_{cell}$ value **(1)**	Example of ionic equation $2MnO_4^- + 16H^+ + 10Br^- \rightarrow 2Mn^{2+} + 8H_2O + 5Br_2$ Allow ⇌ Allow correct species if shown in working with half-equations but slip made in final equation e.g. charge missing Ignore state symbols Allow multiples Allow M2 for almost correct species $E^{\ominus}_{cell}$ (= 1.51 – 1.09) = (+)0.42 (V) No TE on incorrect equation	**(3)**

Q18.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following points • recognises/states that disproportionation reactions contain one element that is both reduced and oxidised **(1)** • identifies the relevant oxidation number changes in chlorine **(1)**	Allow answers in terms of just Chlorine i.e. Chlorine is both oxidised and reduced Do not award: Chlorine **molecule** both oxidised and reduced Cl changes from 0 in Cl_2 to -1 in NaCl **and** 0 in Cl_2 to +5 in $NaClO_3$ Allow oxidation numbers shown on equation	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points • all molar masses correct **(1)** • correct use of multiples **(1)** • calculation of atom economy **(1)**	<u>Example of calculation</u> $NaClO_3$ = 106.5 NaCl = 58.5 H_2O = 18 Allow calculation of molar masses of left-hand side Cl_2 = 71, NaOH = 40 (5 x 58.5 and 1 x 106.5 and 3 x 18) or (3 x 71 and 6 x 40) M1 and M2 may be combined: total molar mass = 453 = 106.5 x 100 ÷ ((5 x 58.5) + 106.5 + (3 x 18)) = 23.51% Ignore SF except 1 SF TE on molar masses and multiples	**(3)**

Q19.

Question Number	Answer	Mark
(i)	**The only correct answer is C** (Disproportionation) ***A** is not correct because oxidation and reduction are occurring* ***B** is not correct because oxidation and reduction are occurring* ***D** is not correct because two reactants are involved*	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • (trigonal) pyramidal **(1)** • (predicted bond angle) 107° **(1)** • three groups / three pairs of bonding electrons and one lone pair **OR** lone pair – bond pair repulsion > bond pair – bond pair repulsion **(1)** • (electron pairs / groups repel to positions of) minimum repulsion / maximum separation **(1)**	For M1, this shape must be **named** Allow answers in the range 106.5° to 107.5° (allow actual value 110°) Allow M2 on an annotated diagram Allow 'regions' for 'groups' or 'pairs' Allow statements such as "lone pair repulsion greater than bond pair repulsion"	**(4)**

Q20.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• **4** $KClO_3$ → **1** KCl + **3** $KClO_4$	Allow just KCl with no number in front Allow multiples	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • use of **water only** as solvent **(1)** • add the mixture of solids / products to any one of the following : water only **or** ethanol only **or** a water plus ethanol mixture **or** water followed by ethanol **or** ethanol followed by water **(1)** • **filter** off the undissolved potassium chlorate(VII) $KClO_4$ **(1)**	Use of separating funnel or electrolysis scores (0) overall NB: If water **only** used as the solvent, both M1 and M2 are awarded Allow 'insoluble solid' / 'less soluble solid' / 'the precipitate' for $KClO_4$ Allow salt for solid	**(3)**

Q21.

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(i)	correct equation	Example of equation: $2NaN_3 \rightarrow 2Na + 3N_2$ Allow multiples Ignore state symbols even if incorrect	**(1)**

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(ii)	• conversion of volume and temperature to correct units **(1)** • rearrangement of ideal gas equation so $n=pV \div RT$ and calculation of $n(N_2)$ in moles **(1)** • evaluation of $n(NaN_3)$ **(1)** • answer converted into mass to 2/3 SF **(1)** Allow TE at each stage	Example of calculation: 67 dm^3 = 0.067 m^3, 300°C = 573 K $n(N_2) = \frac{140\,000 \times 0.067}{8.31 \times 573}$ = 1.9699.....(mol) $n(NaN_3)$ = (2/3 x 1.9699.....=) 1.313.... (mol) m= (1.313 .... x 65 = 85.3629..=) = 85.4 / 85 (g) Correct answer without working scores (4)	**(4)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)	An answer that makes reference to the following points: • Nitrogen (is reduced) from +5 to 0 **(1)** • Sodium (is oxidised) from 0 to +1 **(1)** • Balanced equation **(1)**	Look for oxidation numbers annotated on the equation Do not award potassium oxidised Penalise omission of "+" sign, once only Example of balanced equation: **10**Na +**2**$KNO_3 \rightarrow K_2O$+ **5**Na_2O + N_2 Allow multiples	**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(c)	An answer that makes reference to the following points: • Neutralisation reaction / acid base reaction **(1)** • Sodium and/or potassium oxides are caustic / corrosive **(1)** • Salts (silicates) formed are inert / unreactive **(1)**	Allow salt formation Allow "metal oxides" Ignore "harmful" / "alkaline" Allow "not harmful"/ "not caustic" Ignore "neutral"	**(3)**

Question Number	Acceptable Answer	Mark
(d)	The only correct answer is **A** ***B*** *is incorrect because the peak would shift to the left and be higher* ***C*** *is incorrect because the peak would shift to the left not to the right* ***D*** *is incorrect because the peak would be shift to the left not to the right*	**(1)**

Q22.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • N changes from (+)5 to (+)4 **(1)** • O changes from −2 to 0 (in O_2) **(1)** • so nitrogen / N is reduced (as the oxidation number has decreased) **and** oxygen / O (in forming O_2) is oxidised (as the oxidation number has increased) **(1)**	These numbers may be written under the formulae in the equation Allow oxidation numbers written as 5+, 4+, 2− Ignore unchanged oxidation numbers of magnesium and oxygen Allow this mark if incorrect / missing oxidation numbers in M1 and M2 Ignore general statement about redox Ignore redox explained in terms of electron gain or loss	**(3)**

Q23.

Question Number	Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following point: • the oxidation number / state does not change for any element	Accept there is no transfer of electrons	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: • (because) sulfur in sulfuric acid is reduced further by hydrogen iodide than hydrogen bromide (and hydrogen chloride) (1) • SO_2 / S(IV) produced in the reaction with HBr (1) • more negative oxidation states of sulfur / S / H_2S / S^{2-} are produced in the reaction with HI	Mark independently Allow potassium salt / halide ion for hydrogen halide May be shown in an equation, but ignore incorrect state symbols and/or balancing May be shown in an equation, but ignore incorrect state symbols and/or balancing	(3)

Q24.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• (a reducing agent) increases in oxidation number **and** loses electron(s)	Allow oxidation number becomes more positive / gets larger Allow donates / gives electrons / number of electrons decreases Ignore a reducing agent decreases the oxidation number of another substance	**(1)**

Q25.

Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to • propanal is condensed back (to the pear-shaped flask) **(1)** • so propanal is (further) oxidised (to propanoic acid) or propanal is more readily oxidised than propan-1-ol **(1)**	Allow aldehyde for propanal Allow 'apparatus is reflux' Allow propanal is not being removed /distilled off (from the oxidising agent) Ignore just 'reacts further' Do not award reference to propanal being completely oxidised	**(2)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• (+)VI	Allow (+) six / (+)6 / six (+) / 6(+)	**(1)**

Question Number	Answer	Additional Guidance	Mark
(iii)	• balanced equation	Example of equation $CH_3CH_2CH_2OH \rightarrow CH_3CH_2CHO + 2H^+ + 2e^-$	**(1)**

Question Number	Answer	Additional Guidance	Mark
(iv)	• provides a surface for bubbles to form / enables smaller bubbles to form / provides nucleation sites for bubbles or to prevent large bubbles forming	Allow distribution of heat more evenly / to prevent superheating Ignore mixing / to stop bumping / spitting / explosion / liquid splashing out / vigorous reaction / loss of reactants Do not award reference to large gas molecules	**(1)**

Question Number	Answer	Additional Guidance	Mark
(v)	• (**M1**) evaluation of number of moles of propan-1-ol **(1)** Method one using masses for percentage calculation • (**M2**) evaluation of maximum mass of propanal **(1)** • (**M3**) percentage yield **(1)** or Method two using moles for percentage calculation • (**M2**) evaluation of actual moles of propanal **(1)** • (**M3**) percentage yield **(1)**	<u>Example of calculation</u> n(propan-1-ol) = (1.50 ÷ 60) = 0.025 (mol) n(propan-1-ol) = n(propanal) max m(propanal) = (0.025 x 58) = 1.45 (g) %Yield = ((0.609 ÷ 1.45) x 100) = 42 % n(propanal) = (0.609 ÷ 58) = 0.0105 (mol) %Yield =((0.0105 ÷ 0.025) x 100) = 42 % Allow TE at each stage Ignore SF except 1SF Penalise incorrect M_r values once only Correct answer without working scores (3)	**(3)**

Q26.

Question Number	Answer	Additional guidance	Mark
(i)	• calculation of moles of $VCl_2(aq)$ **(1)** • calculation of moles of $Cl_2(g)$ **(1)** • deduction of whole number ratio of V^{2+} : Cl_2 **(1)** • deduction of electrons lost per vanadium ion **(1)** • deduction of final oxidation number of V **(1)**	Example of calculation $(40/1000) \times 0.100 = 4 \times 10^{-3} / 0.004$ (mol) $(144/24000) = 6 \times 10^{-3} / 0.006$ (mol) $2V^{2+} : 3Cl_2$ allow $V^{2+} : 1.5Cl_2$ 6 electrons lost by $2V^{2+}$, so 3 lost per V^{2+}, (+)5 Allow TE throughout Correct answer with no working scores M5 only	**(5)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• purple / lilac / violet **(1)** • to yellow (solution) **(1)**	Ignore references to blue / green / turquoise or similar, as intermediate colours, regardless of order If no final oxidation state given in (d)(i) do not award M2 Allow lavender / mauve for M1 Mark consequentially from (d)(i) Do not award colourless Use list principle for additional inappropriate intermediate colours e.g. red / pink For consequential marking from (d)(i) V(IV) – blue ; V(III) – green If both colours are given but the wrong way round, allow 1 mark out of 2	**(2)**