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 + ...AgF_2 → .....S_2F_2 + ...AgF

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

(3)

.....

.....

.....

.....

.....

.....

.....

(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)

..... Cl_2 + ... OH^- → ..... Cl^- + ... ClO_3^- + ... H_2O

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

(2)

.....

.....

.....

.....

.....

.....

(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)

.....

.....

.....

.....

.....

.....

(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)

.....

.....

.....

.....

.....

.....

(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.

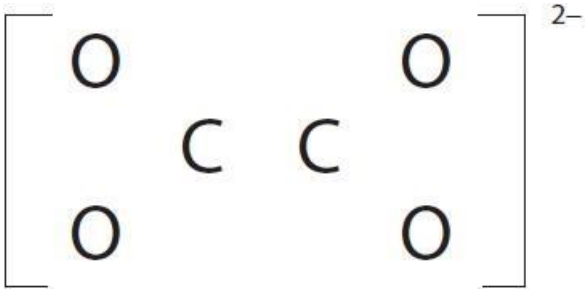
- Five tablets were dissolved in distilled water to make 100.0 cm^3 of solution.
- Some of the $KMnO_4$ solution was used to fill a burette.
- 25.0 cm^3 of sodium ethanedioate solution, $Na_2C_2O_4(aq)$, of concentration 0.200 mol dm^{-3}, was added to a conical flask and warmed.
- Sulfuric acid, of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

.....

(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)

.....

(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)

.....

.....

.....

.....

(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)

.....

.....

.....

(Total for question = 5 marks)

Q11.

This question is about chlorine.

Write the formula of potassium chlorate(V).

(1)

.....

(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)

.....

.....

(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)

.....

.....

.....

.....

.....

.....

(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 $\rightarrow$

(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)

.....

.....

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

(1)

.....

.....

(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)

.....

(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)

.....

.....

.....

.....

.....

.....

(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.

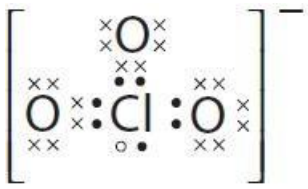
$$3Cl_2 + 6KOH \rightarrow 5KCl + KClO_3 + 3H_2O$$

(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)

.....

.....

.....

.....

.....

.....

.....

.....

(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)

.....

.....

.....

.....

.....

.....

.....

.....

.....

(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)

.....

.....

(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)

.....

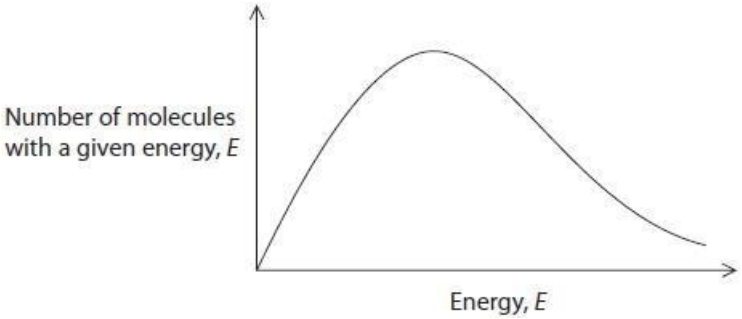
.....

.....

.....

.....

(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)

.....

.....

.....

.....

.....

.....

(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)

.....

.....

.....

(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)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(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)

.....

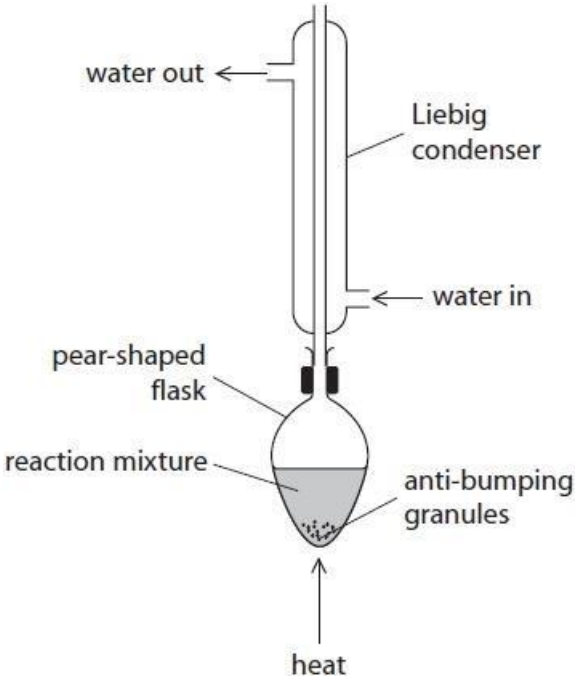
.....

(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)

.....

.....

.....

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

State the oxidation number of chromium in $Na_2Cr_2O_7$.

(1)

.....

(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)

.....

.....

.....

(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)

.....

.....

(Total for question = 7 marks)