SECTION B

*Answer **one** question. Write your answers in the boxes provided.*

4. Group 7 of the periodic table contains a number of reactive elements such as chlorine, bromine and iodine.

(a) (i) Describe the colour change that occurs when aqueous chlorine is added to aqueous sodium bromide. *[1]*

pale yellow to an orange-brown

(ii) Outline, with the help of a chemical equation, why this reaction occurs. *[2]*

(phases not needed!)

$Cl_2(aq) + 2Br^-(aq) \rightarrow 2Cl^-(aq) + Br_2(aq)$

chlorine is more reactive (i.e., a stronger oxydizing agent) than bromine.

(b) The colour change in the reaction between aqueous chlorine and aqueous sodium iodide is very similar, but it differs with an excess of aqueous chlorine. Describe the appearance of the reaction mixture when **excess** aqueous chlorine has been added to aqueous sodium iodide. *[1]*

* The excess Cl_2 will promote the formation of I_2 which would appear as a *solid forming within a colorless solution.

* $Cl_2 + 2I^- \rightarrow 2Cl^- + I_2(s)$

* violet

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(Question 4 continued)

(c) Bleaches in which chlorine is the active ingredient are the most common, although some environmental groups have concerns about their use. In aqueous chlorine the equilibrium below produces chloric(I) acid (hypochlorous acid), HOCl, the active bleach.

$$Cl_2(aq) + H_2O(l) \rightleftharpoons HOCl(aq) + H^+(aq) + Cl^-(aq)$$

(i) Chloric(I) acid is a weak acid, but hydrochloric acid is a strong acid. Outline how this is indicated in the equation above. *[1]*

The H^+ and Cl^- are dissociated, whereas HOCl is still in its molecular form.

(ii) State a balanced equation for the reaction of chloric(I) acid with water. *[1]*

states not needed!

$HClO(aq) + H_2O(l) \rightleftharpoons ClO^-(aq) + H_3O^+(aq)$

must include double arrows! (always for weak acids)

(iii) Outline, in terms of the equilibrium above, why it is dangerous to use an acidic toilet cleaner in combination with this kind of bleach. *[2]*

Adding an acid would shift the reaction to the left, producing Cl_2 which is very toxic.

(iv) Suggest why a covalent molecule, such as chloric(I) acid, is readily soluble in water. *[2]*

HClO is a very polar molecule and capable of hydrogen bonding to water.

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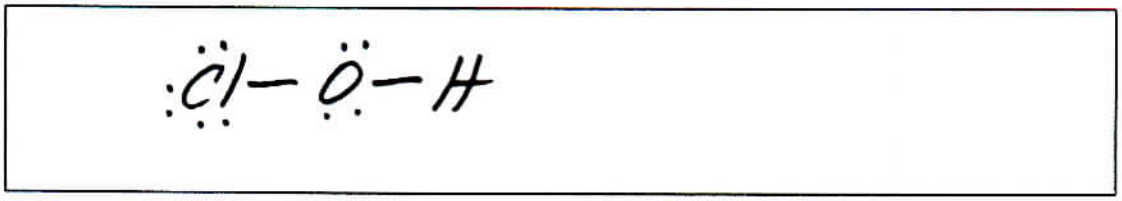
(Question 4 continued)

(v) Draw the Lewis (electron dot) structure of chloric(I) acid. *[1]*



(vi) Predict the H–O–Cl bond angle in this molecule and explain this in terms of the valence shell electron pair repulsion (VSEPR) theory. *[3]*

104.5°
The 4 electron pairs are tetrahedrally arranged around the oxygen, but the two lone pairs repel greater than the two bonding (shared) pairs.

(d) Aqueous sodium chlorate(I), NaOCl, the most common active ingredient in chlorine based bleaches, oxidizes coloured materials to colourless products while being reduced to the chloride ion. It will also oxidize sulfur dioxide to the sulfate ion.

(i) Deduce the coefficients required to balance the half-equations given below. *[2]*

$$\_\_ ClO^- + \underline{2}\, H^+ + \underline{2}\, e^- \rightleftharpoons \_\_ H_2O + \_\_ Cl^-$$

$$\_\_ SO_4^{2-} + \underline{4}\, H^+ + \underline{2}\, e^- \rightleftharpoons \_\_ SO_2 + \underline{2}\, H_2O$$

Recall: charge needs to balance too!

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(Question 4 continued)

(ii) State the initial and final oxidation numbers of both chlorine and sulfur in the equations in part (i). *[2]*

Must include signs! (+ or −)

Element	Initial oxidation number	Final oxidation number
Chlorine	+1	−1
Sulfur	+6	+4

(iii) Use the half-equations to deduce the balanced equation for the reaction between the chlorate(I) ion and sulfur dioxide. *[2]*

$ClO^- + SO_2 + H_2O \rightleftharpoons SO_4^{2-} + 2H^+ + Cl^-$

[Done by reversing the second reaction and cancelling like terms (H^+, e^-, H_2O)]

HL (e) A chemist considered preparing a copper(I) salt by reacting copper metal with the corresponding copper(II) salt according to the equation below.

$$Cu^{2+}(aq) + Cu(s) \rightarrow 2Cu^{+}(aq)$$

(i) Using data from Table 24 of the Data Booklet, calculate the cell potential for this reaction. *[2]*

$Cu^{2+} + e^- \rightarrow Cu^+ \quad E^\ominus = +0.15$

$Cu \rightarrow Cu^+ + e^- \quad E^\ominus = -0.52$

$-0.37\,V$

(ii) Use this result to predict, with a reason, whether this reaction will be spontaneous. *[1]*

Not spontaneous, $E^\ominus$ is negative.