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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]

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

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(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]

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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]*

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

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(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]*

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

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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]*

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(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]*

$$\_\_ClO^- + \_\_H^+ + \_\_e^- \rightleftharpoons \_\_H_2O + \_\_Cl^-$$

$$\_\_SO_4^{2-} + \_\_H^+ + \_\_e^- \rightleftharpoons \_\_SO_2 + \_\_H_2O$$

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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]*

Element	Initial oxidation number	Final oxidation number
Chlorine		
Sulfur		

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

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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]*

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

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