1 Chlorine is used to prevent the growth of bacteria in swimming pool water. It reacts as shown below.

$$Cl_2(aq) + H_2O(l) \rightleftharpoons HCl(aq) + HClO(aq)$$

(a) (i) By giving appropriate oxidation numbers, explain why this is a disproportionation reaction.

(3)

....

....

....

....

....

....

(ii) State and explain the effect on the position of equilibrium if concentrated hydrochloric acid is added to a sample of chlorinated swimming pool water.

(2)

....

....

....

....

(b) In a similar reaction, chlorine reacts with sodium hydroxide to make household bleach.

$$Cl_2(aq) + 2NaOH(aq) \rightarrow NaCl(aq) + NaClO(aq) + H_2O(l)$$

The concentration of NaClO in diluted bleach was measured by titration. A 25.0 cm^3 sample of bleach was pipetted into a conical flask. Approximately 1.5 g of solid potassium iodide and 10 cm^3 of hydrochloric acid with concentration 2.00 mol dm^{-3} were added. Each mole of ClO^-, from the NaClO in the solution of bleach, produced one mole of iodine, I_2, which was titrated with sodium thiosulfate solution.

(i) Complete the ionic half-equations below for the reaction of ClO^- with acidified potassium iodide by balancing them and **adding electrons** where required.

(2)

$$ClO^- + \ldots\ldots H^+ \rightarrow Cl^- + H_2O$$

$$\ldots\ldots I^- \rightarrow I_2$$

(ii) Use your answer to (a)(i) to write the overall ionic equation for the reaction between ClO^- and I^- ions in acidic conditions.

(1)

(iii) The iodine in the sample required a mean (average) titre of 24.20 cm^3 of 0.0500 mol dm^{-3} sodium thiosulfate solution. Thiosulfate ions react with iodine as shown below.

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

Calculate the number of moles of iodine in the solution.

(2)

(iv) What is the number of moles of ClO^- ions in the sample of diluted bleach?

(1)

(v) Hence calculate the concentration, in mol dm^{-3}, of ClO^- in the diluted bleach.

(1)

(vi) 1.5 g of potassium iodide, KI, contains 9.04×10^{-3} mol of I^-. Use your answers to (b)(ii) and (b)(iv) to show by calculation why this amount was suitable.

(2)

....

....

(vii) A student carrying out this titration measured the mean (average) titre as 24.50 cm^3.

What is the percentage difference in this student's titre, compared with the accurate value of 24.20 cm^3?

(1)

(viii) The difference between the student's mean titre and the accurate value was **not** due to the limitations in the accuracy of the measuring instruments.

Suggest one possible reason for this difference.

(1)

....

....

....

(c) Suggest **one** damaging effect to the upper atmosphere which could be caused by the presence of chlorine compounds.

(1)

....

....

(Total for Question = 17 marks)

2 (a) Coral reefs are produced by living organisms and predominantly made up of calcium carbonate. It has been suggested that coral reefs will be damaged by global warming because of the increased acidity of the oceans due to higher concentrations of carbon dioxide.

(i) Write a chemical equation to show how the presence of carbon dioxide in water results in the formation of carbonic acid. State symbols are **not** required.

(1)

(ii) Write the **ionic** equation to show how acids react with carbonates.
State symbols are **not** required.

(2)

(b) One method of determining the proportion of calcium carbonate in a coral is to dissolve a known mass of the coral in excess acid and measure the volume of carbon dioxide formed.

In such an experiment, 1.13 g of coral was dissolved in 25 cm^3 of hydrochloric acid (an excess) in a conical flask. When the reaction was complete, 224 cm^3 of carbon dioxide had been collected over water using a 250 cm^3 measuring cylinder.

(i) Draw a labelled diagram of the apparatus that could be used to carry out this experiment.

(2)

(ii) Suggest how you would mix the acid and the coral to ensure that no carbon dioxide escaped from the apparatus.

(1)

....

....

....

(iii) Calculate the number of moles of carbon dioxide collected in the experiment.

[The molar volume of any gas is 24 000 cm^3 mol ^{1} at room temperature and pressure.]

(1)

(iv) Complete the equation below for the reaction between calcium carbonate and hydrochloric acid by inserting the missing state symbols.

(1)

$$CaCO_3(\ldots\ldots\ldots) + 2HCl(\ldots\ldots\ldots) \rightarrow CaCl_2(\ldots\ldots\ldots) + H_2O(l) + CO_2(\ldots\ldots\ldots)$$

(v) Calculate the mass of 1 mol of calcium carbonate.

[Assume relative atomic masses: Ca 40, C 12, O 16.]

(1)

(vi) Use your data and the equation in (iv) to calculate the mass of calcium carbo in the sample and the percentage by mass of calcium carbonate in the coral. Give your final answer to **three** significant figures.

(2)

(vii) When this experiment is repeated, the results are inconsistent. Suggest a reason for this other than errors in the procedure, measurements or calculations.

(1)

....

....

(Total for Question 12 marks)

3 The leaves of the rhubarb plant contain ethanedioic acid, $(COOH)_2$, a toxic white soluble solid. The acid is readily oxidized by potassium manganate(VII) under acidic conditions. A sample of 250 g of rhubarb leaves was finely chopped then soaked in warm water to release any ethanedioic acid present. The mixture was then filtered and made up to a volume of 500 cm^3 using distilled water. 10.0 cm^3 of the solution was then titrated with 0.0100 mol dm^{-3} acidified potassium manganate(VII) solution from a burette, requiring 11.30 cm^3 to completely oxidize the sample.

(a) (i) Write the half equation for the oxidation of ethanedioic acid to form carbon dioxide, and the half equation for the reduction of manganate(VII) ions, MnO_4^-, in acidic solution to form manganese(II) ions. State symbols are **not** required.

(2)

(ii) Use your answers to (a)(i) to write the overall equation for the reaction, showing that the ratio of ethanedioic acid to manganate(VII) ions in the full equation is 5 : 2. State symbols are **not** required.

(1)

*(iii) Calculate the % by mass of the ethanedioic acid present in the leaves, giving your final answer to **two** decimal places.

(5)

(iv) What is the level of accuracy of a burette in each reading? Use your answer to calculate the percentage error in the titre volume of 11.30 cm^3.

(2)

(v) Suggest **two** reasons, other than the accuracy of the equipment used for measurements, why the results obtained in this experiment may be considered unreliable.

(2)

....

....

....

....

(vi) A student risk assessment for this experiment suggested wearing gloves, but a supervisor said that this was unnecessary. Why do you think this precaution was suggested by the student and why was it rejected by the supervisor?

(2)

....

....

....

....

....

(vii) An aqueous solution of MnO_4^- ions contained a small amount of chloride ions, Cl^-, as an impurity. Use this fact, and items 70 and 85 from page 16 of the data booklet, to suggest why this solution went cloudy after a time.

(2)

....

....

....

....

(b) An aqueous solution containing Mn^{2+} ions is pale pink in colour due to the presence of the complex ion $[Mn(H_2O)_6]^{2+}(aq)$.

(i) Complete the electronic configuration of the Mn^{2+} ion.

(1)

$1s^2$ ....

(ii) What shape would you expect this complex ion to be?

(1)

....

(Total for Question 18 marks)