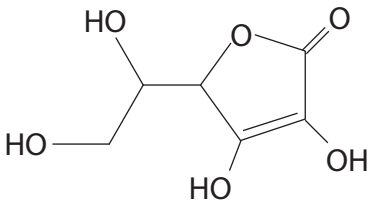
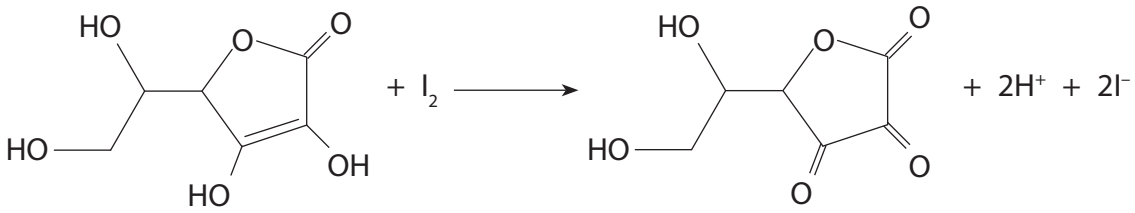
1 Vitamin C (L-ascorbic acid) is present in fresh fruit and vegetables although prolonged cooking destroys it. The structure of ascorbic acid, $C_6H_8O_6$, is shown below.



(a) The amount of ascorbic acid present in a sample is determined by reacting it with a known amount of iodine. The excess iodine is then measured by titration with a solution of sodium thiosulfate, using a starch indicator. The equations for the reactions are given below.



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

Four 500 mg vitamin C tablets were dissolved in distilled water and the solution made up to 250 cm^3 in a volumetric flask. A 25.0 cm^3 portion of this solution was added to an iodine solution containing 2.00×10^{-3} moles of iodine. The resulting mixture was titrated with sodium thiosulfate solution of concentration 0.0631 mol dm^{-3}. The titration was repeated and the mean (average) titre was 27.85 cm^3.

(i) State the type of chemical change undergone by ascorbic acid when it reacts with iodine.

(1)

.....

(ii) State the colour of the solution in the flask just before the starch is added to the titration mixture and state the colour change at the end-point of the titration.

(2)

.....

.....

.....

(iii) Calculate the percentage by mass of ascorbic acid in the tablets. The molar mass of ascorbic acid is 176 g mol^{-1}.

(5)

(iv) Explain why using four tablets in 250 cm^3 of solution gives a more accurate result than two tablets in 250 cm^3.

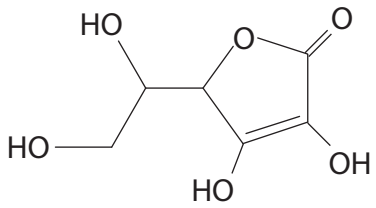
(1)

.....

.....

.....

(b) The structure of ascorbic acid is shown again below. Vitamin C is one of the optical isomers of this structure.



(i) Mark on this diagram the two chiral centres of this molecule.

(2)

(ii) How might you show that vitamin C is a single optical isomer and not a racemic mixture of the optical isomers of ascorbic acid?

(2)

.....

.....

.....

.....

(iii) Despite its name, ascorbic acid is not a carboxylic acid but it does contain an ester group. Suggest what happens to destroy vitamin C on prolonged cooking.

(1)

.....

.....

(Total for Question = 14 marks)

2 (a) An impure sample of sodium hydrogencarbonate, $NaHCO_3$, of mass 0.227 g, was reacted with an excess of hydrochloric acid. The volume of carbon dioxide evolved was measured at room temperature and pressure and found to be 58.4 cm^3.

$$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$$

The molar volume of any gas at the temperature and pressure of the experiment is 24 dm^3 mol^{-1}. The molar mass of sodium hydrogencarbonate is 84 g mol^{-1}.

(i) Calculate the number of moles of carbon dioxide given off.

(1)

(ii) Calculate the mass of sodium hydrogencarbonate present in the impure sample.

(2)

(iii) Calculate the percentage purity of the sodium hydrogencarbonate. Give your answer to two significant figures.

(2)

(b) (i) The total error in reading the gas syringe is ±0.4 cm^3. Calculate the percentage error in measuring the gas volume of 58.4 cm^3.

(1)

(ii) Suggest why the carbon dioxide should not be collected over water in this experiment.

(1)

.....

.....

(Total for Question 7 marks)

3 Chlorine disinfectants are essentially solutions containing chlorine molecules and chlorate(I) ions in an equilibrium summarised by the equation

$$Cl_2(aq) + H_2O(l) \rightleftharpoons 2H^+(aq) + ClO^-(aq) + Cl^-(aq) \qquad \textbf{Equation 1}$$

The chlorine content of a disinfectant was determined using the following procedure.

1. 10.0 cm^3 of the disinfectant was transferred to a 250 cm^3 volumetric flask.

2. Approximately 20 cm^3 of nitric acid and 20 cm^3 potassium iodide solution (both in excess) were added to the volumetric flask.

3. The solution in the volumetric flask was made up to the mark with distilled water and then mixed thoroughly.

4. 10.0 cm^3 portions of the solution in the volumetric flask were titrated against a solution of sodium thiosulfate, concentration 0.109 mol dm^{-3}. Starch solution was added near the end-point of the titration and the mean (average) titre was 27.35 cm^3.

The equations for the reactions involved in this procedure are

$$Cl_2(aq) + 2I^-(aq) \rightarrow I_2(aq) + 2Cl^-(aq) \qquad \textbf{Equation}$$

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq) \qquad \textbf{Equation 3}$$

(a) (i) Calculate the number of moles of sodium thiosulfate used in the titration.

(2)

(ii) Calculate the number of moles of iodine, I_2, that reacted in the titration (step 4).

(1)

(iii) Hence state the number of moles of chlorine, Cl_2, in 10.0 cm^3 of the solution in the volumetric flask.

(1)

(iv) Calculate the concentration of chlorine, in mol dm^{-3}, in the **original** disinfectant.

(2)

(b) **Equation 1** is an example of a disproportionation reaction. Define the term 'disproportionation' and explain, by considering the relevant oxidation numbers, why this reaction is a disproportionation.

(3)

.....

.....

.....

.....

.....

(c) State the colours of the titration solution just before the starch solution is added, after the starch solution is added and the colour change at the end-point of the reaction.

(2)

Colour just before adding the starch .....

Colour after adding the starch .....

Colour at the end-point .....

(Total for Question 11 marks)

4 The ingredients list on the label of a commercial indigestion remedy states that each tablet contains 680 mg of calcium carbonate.

To check this, the following experiment was carried out.

One tablet was crushed. 50.0 cm^3 of 1.00 mol dm^{-3} hydrochloric acid, an excess, was then added and the mixture was transferred to a volumetric flask. The volume was made up to exactly 100 cm^3 with distilled water. 10.0 cm^3 of this solution was titrated with 0.300 mol dm^{-3} sodium hydroxide solution. The following results were obtained.

Run	Rough	1	2
Final burette reading / cm^3	21.80	33.20	44.40
Initial burette reading / cm^3	10.00	21.80	33.20
Volume added / cm^3	11.80	11.40	11.20

(a) (i) What should be used to crush the tablet?

(1)

.....

(ii) Name a suitable indicator for the titration. State the colour change you would expect to see.

(2)

Indicator .....

Colour change from ..... to .....

(b) (i) Select appropriate readings and calculate the mean titre.

(1)

(ii) Calculate the number of moles of sodium hydroxide used.

(1)

(iii) Use your answer to (ii) to write down the number of moles of hydrochloric acid left in 10.0 cm^3 of the solution used in the titration.

(1)

(iv) Calculate the number of moles of hydrochloric acid left in 100 cm^3 of solution.

(1)

(v) 50.0 cm^3 of 1.00 mol dm^{-3} hydrochloric acid contains 0.0500 mol of hydrochloric acid.

Use this and your answer to (iv) to calculate the number of moles of hydrochloric acid that reacted with the indigestion tablet.

(1)

(vi) The equation for the reaction between hydrochloric acid and calcium carbonate is:

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

Use this, and your answer to (v), to calculate the number of moles of calcium carbonate in one tablet.

(1)

(vii) Calculate the mass of calcium carbonate in one tablet.

[Assume that the molar mass of $CaCO_3$ is 100 g mol^{-1}]

(1)

(viii) Suggest a reason, other than experimental error, why your value differs from the value given on the label.

(1)

.....

.....

.....

.....

(Total for Question 11 marks)