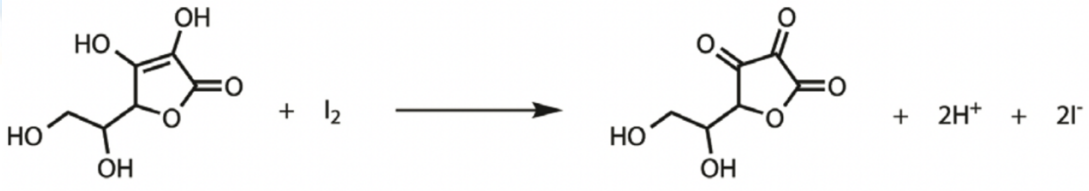
SL HL Paper 3 Section A Data Response (5) with worked answers

The Royal Society of Chemistry has introduced a global experiment for school students to determine the amount of vitamin C in various fruits.

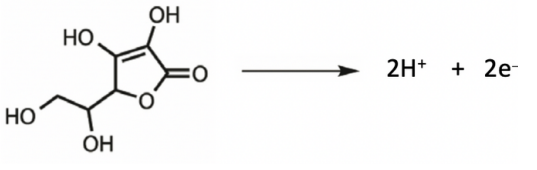
Students first determine how many drops of a given iodine solution are required to react with a known amount of vitamin C by calibrating the iodine solution with a known amount of vitamin C using starch as an indicator.
All the Vitamin C content is then extracted from a selected fruit and the number of drops of the standardised iodine solution required to react with the vitamin C is determined. The amount of vitamin C in mg g^{-1} in the selected fruit is then calculated.
The relevant equation for the reaction in aqueous solution is:



ascorbic acid (vitamin c) dehydroascorbic acid

The molar mass of vitamin C = 176.12 g mol^{-1}

(a) (i) Deduce the two half-equations for the oxidation of vitamin C and the reduction of iodine in aqueous solution. ***[2]***



[1]

$I_2 + 2e^- \rightarrow 2I^-$ ***[1]***

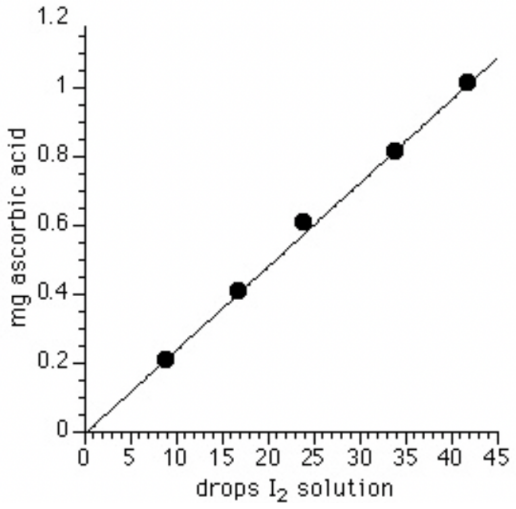
(Underlying chemistry concepts can be found in 9.1 Oxidation & reduction.)

(ii) Explain why vitamin C is soluble in water. ***[1]***

It contains polar –OH groups which can form hydrogen bonds with water molecules. ***[1]***

(Underlying chemistry concepts can be found in 4.4 Intermolecular forces.)

(b) A student in a particular school obtained the following calibration curve:



She found that epper required 82 drops of the iodine solution

(i) Deduce the concentration of vitamin C in mg g^{-1} of the fresh red pepper. ***[2]***

3.04 g required 82 drops so 1.00 g would require 82 ÷ 3.04 = 27 drops ***[1]***
Interpolation of the graph gives 0.65 mg of vitamin C, so the concentration in fresh red pepper is 0.65 mg g^{-1} ***[1]***

(Underlying chemistry concepts can be found in 11.2 Graphical techniques.)

(ii) It was determined that 103 drops of the iodine solution had a total volume of 1.00 cm^3. Calculate the concentration of the iodine solution in mol dm^{-3}. ***[2]***

27 drops of iodine solution reacts with 0.65 mg of vitamin C
M(vitamin C) = 176.12 g mol^{-1} so one drop reacts with 0.65 ÷ (1000 x 176.12 x 27) = 1.37 x 10^{-7} mol of vitamin C ***[1]***
One mol of vitamin C reacts with one mol of iodine
Amount of iodine in one drop = 1.37 x 10^{-7} mol, and there are 103 x 1000 drops in one dm^3
Concentration of iodine solution = 103 x 1000 x 1.37 x 10^{-7} = 0.014 mol dm^{-3}. ***[1]***

(Underlying chemistry concepts can be found in 1.2 The mole & Avogadro's constant.)

(c) Iodine can be formed by the reaction between iodide and iodate ions in acidic solution:

$I^-(aq) + IO_3^-(aq) + 6H^+(aq) \rightarrow 3I_2(aq) + 3H_2O(l)$

This redox reaction is known as a disproportionation reaction as iodine is simultaneously oxidised (from -1 to zero) and reduced (from +5 to zero).

Iodine is insoluble in water but it does dissolve in a solution of potassium iodide as it forms the complex triiodide ion, I_3^-.

$I_2(aq) + I^-(aq) \longrightarrow I_3^-(aq)$

Discuss whether this reaction between iodine and iodide ions can also be considered to be a disproportionation reaction. ***[2]***

Applying the rules for determining oxidation states gives an average oxidation state of – 1/3 for iodine in the I_3^- ion. Assuming this is the correct value then disproportionation has occurred as I in I_2 has been reduced from zero to – 1/3 and oxidised from – 1 in the iodide ion to – 1/3. ***[1]***
The rules do not take into account the fact that iodine is bonded to itself in the I_3^- ion and also assume falsely that the covalent bonds in a complex ion behave as if they are ionic. Some chemists regard the I_3^- ion as being a mixture of iodine and iodide. If this is assumed then no redox reaction is occurring. ***[1]***

(Underlying chemistry concepts can be found in 9.1 Oxidation & reduction and The Nature of Science.)