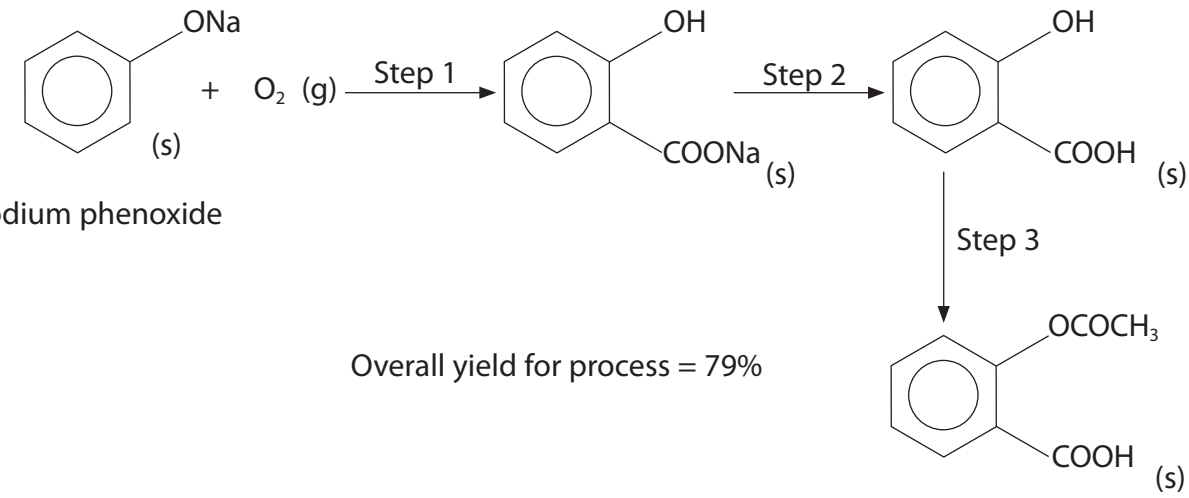
1 Aspirin can be manufactured from sodium phenoxide using the process shown below.



Sodium phenoxide

Overall yield for process = 79%

Aspirin

(a) Explain **one** effect of an increase in pressure on the reaction in Step 1.

(2)

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(b) The overall yield for this process is 79%.

Calculate the mass, in tonnes, of aspirin that would be formed from 2.5 tonnes of sodium phenoxide. Give your answer to **two** significant figures.

[Molar masses / g mol^{-1}: sodium phenoxide = 116; aspirin = 180]

(3)

(c) Classify the reaction type in Step 3 and suggest a suitable reagent.

(2)

Reaction type .....

Reagent .....

(Total for Question = marks)

2 In an experiment to make crystals of hydrated copper(II) nitrate, a sample of 5.60 g of copper(II) oxide was added to 50 cm^3 of 2.50 mol dm^{-3} nitric acid. The following reaction occurred.

$$CuO(s) + 2HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + H_2O(l)$$

(a) Calculate the number of moles of each reactant present, and use this to show that the copper(II) oxide was in excess.

The molar mass of copper(II) oxide, CuO, is 79.5 g mol^{-1}.

(3)

Moles of copper(II) oxide added

Moles of nitric acid used

The copper(II) oxide is in excess because .....

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(b) The copper(II) nitrate solution was heated gently to concentrate it, and then left to crystallize. The mass of hydrated copper(II) nitrate crystals, $Cu(NO_3)_2.6H_2O$, obtained was 12.52 g.

Calculate the percentage yield.

The molar mass of $Cu(NO_3)_2.6H_2O$ is 295.6 g mol^{-1}.

(3)

(c) Give **one** reason why the percentage yield is less than 100%, even though the nitric acid was completely reacted.

(1)

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*(d) (i) The nitrate ion, NO_3^-, contains both covalent and dative covalent bonds.

What is the difference between these types of bond?

(2)

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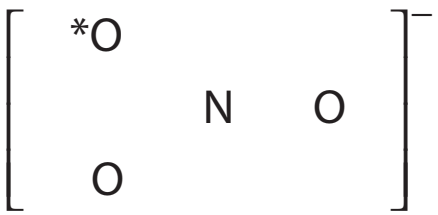
(ii) Complete the dot and cross diagram to show the bonding in the nitrate ion. Only the outer electron shells for each atom need to be shown.

Represent the nitrogen electrons with crosses (×), and oxygen electrons with dots, (•). The symbol * on the diagram represents the extra electron giving the ion its charge.

(3)



(Total for Question = marks)

3 Brand **X** is unlike many conventional toilet cleaners in that it does not contain bleach, but instead contains hydrochloric acid. The label states that the toilet cleaner contains 9 g of HCl per 100 cm^3 of the toilet cleaner.

An industrial technician was given the task of checking the validity of this statement. Using 25.0 cm^3 portions of the toilet cleaner, the technician carried out a titration using 2.50 mol dm^{-3} sodium hydroxide solution and obtained the following results.

Titration	Trial	1	2
Final Volume /cm^3	25.00	49.60	24.50
Initial Volume /cm^3	0.00	25.00	0.00
Volume Added /cm^3			

(a) (i) Complete the table and calculate the mean titre by selecting the appropriate results.

(1)

(ii) Write the equation for the titration reaction. State symbols are not required.

(1)

(iii) Calculate the number of moles of sodium hydroxide that reacted.

(1)

(iv) Hence state the number of moles of hydrochloric acid that reacted with the sodium hydroxide.

(1)

(v) Calculate the mass of HCl present in 100 cm^3 of the toilet cleaner. Give your answer to 3 significant figures.

(2)

(vi) Using the technician's results, comment on the validity of the manufacturer's statement that the toilet cleaner contained 9 g of HCl per 100 cm^3. Justify your answer.

(1)

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(vii) Explain why titrations involving the use of a 2.50 mol dm^{-3} sodium hydroxide solution would **not** be advisable in a school or college laboratory.

(1)

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(b) Conventional toilet cleaners contain a bleaching agent. Chloric(I) acid, HOCl, is one such substance.

Draw the dot and cross diagram for chloric(I) acid. Show outer electrons only.

(1)

(c) The instructions for the use of Brand **X** state that the toilet cleaner should not be used with bleaching agents.

Complete the equation for the reaction between the hydrochloric acid in the toilet cleaner and the chloric(I) acid in the bleaching agent. Give a reason why this reaction is to be avoided in accordance with the instructions for the use of the toilet cleaner.

(2)

Equation $HCl + HOCl \rightarrow$

Reason .....

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(d) Another bleaching agent is sodium chlorate(I), NaClO, which can be purchased as a solution. It can also be obtained by bubbling chlorine gas into sodium hydroxide solution.

(i) Give the oxidation numbers of the chlorine-containing species in the equation below and classify the reaction as a result of your answer.

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

Oxidation Number ....

(2)

Type of reaction .....

(ii) State how the reaction conditions would need to be changed in order to produce sodium chlorate(V) instead of sodium chlorate(I).

(1)

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(iii) Give the equation for the reaction between chlorine and sodium hydroxide solution that forms sodium chlorate(V) as one of the products. State symbols are not required.

(2)

(Total for Question = marks)

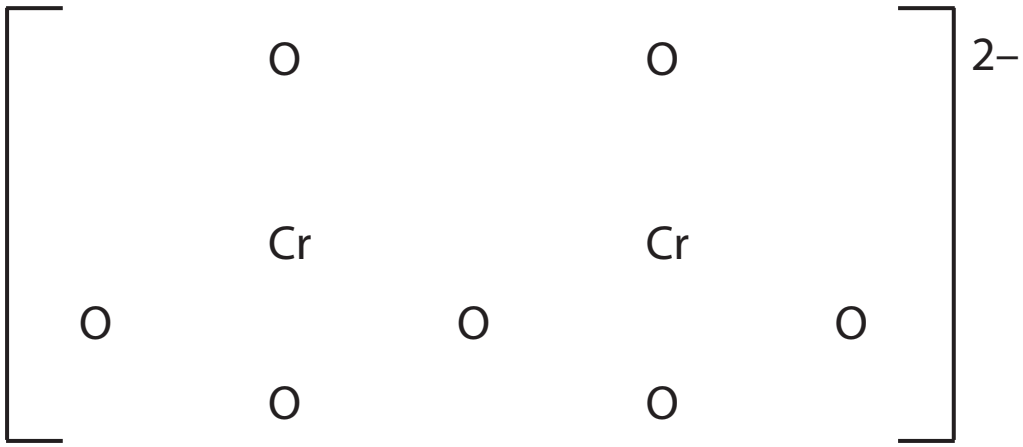
4 Potassium dichromate(VI), $K_2Cr_2O_7$, can be used to accurately determine the concentration of other chemicals, such as sodium thiosulfate, $Na_2S_2O_3$.

(a) The dichromate(VI) ion has two chromium atoms sharing one oxygen to give two tetrahedral units. Each chromium atom uses six electrons in bonding and expands its outer shell to accommodate a total of 12 electrons.

Complete the dot and cross diagram for this ion below. Only show outer shell electrons.

Use **x** for chromium electrons and • for oxygen electrons. Use the symbol * to represent the extra electrons which give the ion its charge.

(3)



(b) Four chemistry students were given a solution of sodium thiosulfate with a concentration of **approximately** 0.1 mol dm^{-3} and asked to determine its **exact** concentration using potassium dichromate(VI) solution. They were each given separate tasks to carry out as described below.

(i) The first student was given the task of making up a potassium dichromate(VI) solution. A mass of 14.71 g of $K_2Cr_2O_7$ was weighed out, dissolved in deionized water, the volume made up to 250 cm^3 in a volumetric flask and the mixture shaken.

Calculate the concentration of this potassium dichromate(VI) solution, in mol dm^{-3}.

Use the Periodic Table as a source of data.

(2)

(ii) The second student was asked to calculate the mass of potassium iodide that would be required to add to 0.00250 mol of potassium dichromate(VI) to ensure complete reaction. The equation for the reaction is

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6I^-(aq) \rightarrow 2Cr^{3+}(aq) + 3I_2(aq) + 7H_2O(l)$$

Calculate the minimum mass of potassium iodide, KI, required and hence suggest a suitable mass to use if the potassium iodide is to be in excess.

You **must** show your working and your mass should be reasonable.

(2)

Minimum mass required ..... g

Suitable mass to use ..... g

(iii) The third student was given the following equation.

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

This student was asked to estimate the titration reading at the end-point if a solution that contained 0.00260 mol of iodine was in the conical flask and the concentration of sodium thiosulfate was about 0.16 mol dm^{-3}.

Calculate the volume of sodium thiosulfate solution, in cm^3, that would have been added at the end-point of the titration.

(2)

*(iv) The fourth student was given the following experimental information.

0.1 g of potassium dichromate(VI) was dissolved in a total volume of 25.00 cm^3. An excess of potassium iodide and acid was added and then used in a titration with the sodium thiosulfate solution of concentration approximately 0.1 mol dm^{-3}. The titre was 25.15 cm^3.

The student suggested that the greatest uncertainty in the result arose from the mass that was measured and that the procedure was unreliable.

Explain why these views were justified. No calculation is required.

(2)

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(c) (i) Acidified sodium dichromate(VI) solution is commonly used for the oxidation of alcohols. It is important not to use hydrochloric acid in this reagent mixture because the chloride ions are oxidized to chlorine.

Write the ionic half-equation for the oxidation of chloride ions. State symbols are not required.

(1)

(ii) Fumes of hydrogen chloride gas can be identified by bringing the fumes into contact with another gas, **X**. Identify gas **X** and state the observation you would make.

(2)

Gas **X** .....

Observation .....

(d) Potassium bromide can be distinguished from potassium chloride by its reaction with silver nitrate solution, followed by the addition of aqueous ammonia solution.

State what you would see on the addition of silver nitrate solution to potassium bromide solution.

How could both dilute and concentrated ammonia be used to confirm that silver bromide is formed, rather than silver chloride?

(3)

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(Total for Question = marks)