Kirkcaldy High School

Chemistry

Advanced Higher

# Unit 4 – Researching Chemistry

TUTORIAL QUESTIONS

(a) Weighing by difference and gravimetric analysis

1. A 1.00 l sample of polluted water was analysed for lead (II) ions, Pb^{2+}, by adding an excess of sodium sulfate to it. The mass of lead (II) sulfate that precipitated out was 229.8 mg. Calculate the concentration of lead (II) ions in mg l-1 present in the initial sample of polluted water.

2. A chemist added an excess of sodium sulphate to a solution of a soluble barium compound to precipitate all the barium as barium sulphate, $BaSO_4$. Calculate the mass (in grams) of Ba^{2+} ions in 458 mg of compound if a solution of the sample produces 513 mg of barium sulphate.

3. Before 1947, 'silver' coins were made from an alloy of silver, copper and nickel. To determine the metal composition, a coin weighing 10.00 g was dissolved in nitric acid and the resulting solution diluted to 1000 cm^3 in a standard flask. A 100 cm^3 portion was treated in the following way. Hydrochloric acid (0.20 mol l–1) was added to this solution until precipitation of silver(I) chloride was complete. The precipitate was recovered by filtration. It was washed and dried and found to weigh 0.60 g.

   (a)

   (i) Calculate the percentage by mass of silver in the coin.
   (ii) How could you tell when precipitation was complete?

   (b) The filtrate was treated to reduce the copper(II) ions to copper(I) ions. Ammonium thiocyanate solution was added to precipitate the copper as copper(I) thiocyanate:

$$Cu^+(aq) + CNS^-(aq) \rightarrow CuCNS(s)$$
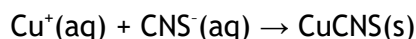
   After filtration, drying and weighing, the precipitate was found to weigh 0.31 g. Calculate the percentage by mass of copper in the coin.

4. An anhydrous salt is known to be a mixture of magnesium chloride and magnesium nitrate. To determine the composition of the mixture, the following procedure was carried out. 4.50 g of the salt was dissolved in water and the solution made up to 500 cm^3 in a standard flask. A slight excess of silver(I) nitrate solution was then added to 100 cm^3 of this solution and the resulting precipitate recovered by filtration. The precipitate was washed, dried and its mass found to be 2.01 g.

   (a) Explain how you would check that an excess of silver(I) nitrate had been added?
   (b) Calculate the percentage by mass of magnesium chloride in the mixture.
   (c) A variation of this method involved titrating the salt solution with standard silver(I) nitrate solution using a suitable indicator. Calculate the volume of 0.10 mol l^{-1} silver(I) nitrate solution would be required to react completely with 25 cm^3 of the salt solution?
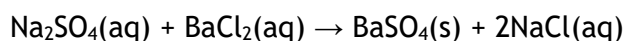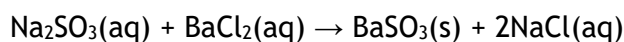
5. Crystals of hydrated sodium carbonate left exposed to the atmosphere gradually lose some of their water of crystallisation. The formula of the crystals may be given by $Na_2CO_3.xH_2O$, where x has a numerical value between 0 and 10. 16.0 g of the crystals was dissolved in water and made up to 250 cm^3 of solution in a standard flask. To determine the value of x in the formula, 25 cm^3 of the sodium carbonate solution was titrated with 1.0 mol l^{-1} hydrochloric acid. 15.0 cm^3 of the acid was required for neutralisation.

(a) Calculate the mass of sodium carbonate (Na_2CO_3) in 16.0 g of the crystals.
(b) Find the value of x in the formula $Na_2CO_3.xH_2O$

6. Sodium sulphite is a reducing agent that is oxidised to sodium sulphate by atmospheric oxygen. In order to determine its purity, a sample of sodium sulphite was analysed as follows.
5.02 g of the sample was dissolved in water and made up to 250 cm^3 in a standard flask. 50 cm^3 of the solution was pipetted into a beaker and treated with excess barium chloride solution to precipitate all the sulphite and sulphate ions as their barium salts, as shown in the equations below:

$$Na_2SO_3(aq) + BaCl_2(aq) \rightarrow BaSO_3(s) + 2NaCl(aq)$$
$$Na_2SO_4(aq) + BaCl_2(aq) \rightarrow BaSO_4(s) + 2NaCl(aq)$$

The mixed precipitate was then filtered off, washed with water and dried in an oven to constant mass. Excess dilute hydrochloric acid was added to the precipitate to dissolve the barium sulphite. The untreated barium sulphate was then filtered off, washed with water and dried in an oven to constant mass:

$$\text{mass of mixed precipitate} = 1.69 \text{ g}$$
$$\text{mass of barium sulphate} = 0.60 \text{ g}$$

(a) Calculate the number of moles of barium sulphite in the mixed precipitate.
(b) Calculate the percentage by mass of sodium sulphite in the sample.
(c) Analysis of sodium sulphite may also be carried out by a volumetric technique using acidified potassium permanganate solution. Give two reasons why acidified potassium permanganate would be a suitable reagent for this analysis.

7. Nickel (II) ions react quantitatively with dimethylglyoxime ($C_4H_8O_2N_2$) forming a complex which precipitates out as a red solid. The equation for the reaction and the structure of the complex are shown below.

$$Ni^{2+} + 2C_4H_8O_2N_2 \longrightarrow Ni(C_4H_7O_2N_2)_2 + 2H^+$$
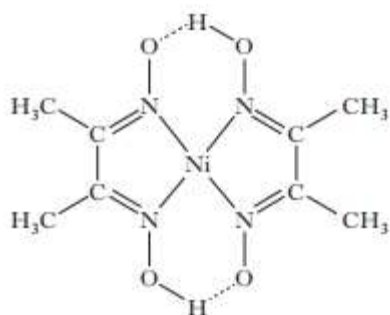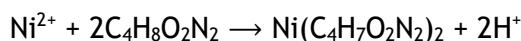
Relative formula mass = 288·7

When 0·968 g of an impure sample of nickel(II) sulfate, $NiSO_4.7H_2O$, was dissolved in water and reacted with dimethylglyoxime. 0·942 g of the red precipitate was formed.

(a) Calculate the percentage, by mass, of nickel in the impure sample of nickel(II) sulfate

(b) The dicarboxylic acid, oxalic acid, has molecular formula $H_2C_2O_4$. It can be prepared by reacting calcium oxalate with sulfuric acid.

$$H_2SO_4(aq) + CaC_2O_4(s) + xH_2O(l) \longrightarrow CaSO_4.xH_2O(s) + H_2C_2O_4(aq)$$
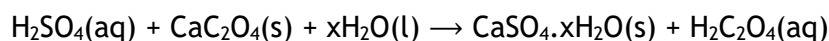
4·94 g of $CaSO_4.xH2O$ was dehydrated to produce 3·89 g of $CaSO_4$. Determine the value of x.

8. Aspirin is one of the most widely used drugs in our society. Aspirin works as a pain killer by binding to a specific enzyme and blocking its use in biological pathways which lead to the production of pain. Aspirin can be prepared by reacting 2-hydroxybenzoic acid ($C_7H_6O_3$), with ethanoic anhydride in acidic conditions.
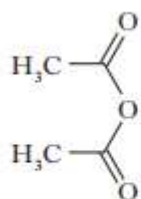

ethanoic anhydride   aspirin
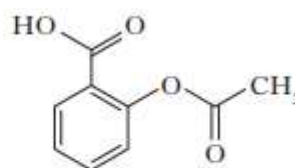
The percentage yield for this reaction is 67%.

Calculate the minimum mass of 2-hydroxybenzoic acid required to produce 5·00g of aspirin.

9. A gravimetric analysis of a water sample must be carried out to determine the mass of Ag+ ions present.

   (a) List 3 aqueous solutions that would be suitable to mix with the test sample to perform the analysis

   (b) Explain if adding a solution of potassium nitrate be of any benefit to the analysis.

   (c) After completing the analysis, the silver solid formed is sparingly soluble. Explain how this might affect the analysis results?

10. To determine the composition of an old coin containing silver, copper and nickel, a student dissolved the coin of mass 10·04 g in nitric acid. The resulting solution was diluted with deionised water to 1000 cm^3 in a standard flask.
    0·2mol l^{-1} hydrochloric acid was added to 100 cm^3 of this solution until precipitation of silver(I) chloride was complete. After filtration, the precipitate was washed and dried and found to have a mass of 0·620 g.

    (a) Calculate the percentage, by mass, of silver in the coin.

    (b) Suggest how the student would test that no silver(I) ions remained in the solution.

    (c) The filtrate was treated to reduce the copper(II) ions to copper(I) ions. Ammonium thiocyanate solution was added to precipitate the copper as copper(I) thiocyanate.

$$Cu^+(aq) + CNS^-(aq) \longrightarrow Cu^+CNS^-(s)$$
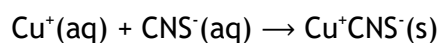
    After filtration, drying and weighing, the precipitate was found to weigh 0·320 g.
   Calculate the percentage, by mass, of copper in the coin.

(n) Using a separating funnel and solvent extraction

1. An aqueous solution of iodine was shaken with cyclohexane until equilibrium was established. Some solid iodine was added to the test tube and the contents shaken until equilibrium was re-established. Which line in the table shows the effects caused by the addition of the solid iodine?

	Concentration of iodine in water	Concentration of iodine in cyclohexane	Partition coefficient
A	increases	increases	No change
B	increases	increases	Increases
C	No change	increases	No change
D	increases	No change	increases

2. Iodine was added to 50 cm³ of two immiscible solvents X and Y as shown. After shaking, the following equilibrium was established

I_2 in 50 cm³ of solvent X

I_2 in 50 cm³ of solvent Y

$$I_2(Y) \rightleftharpoons I_2(X)$$
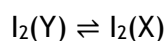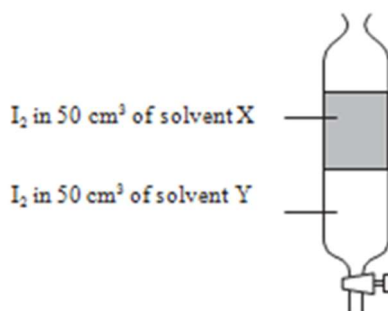
An extra 10 cm3 of solvent X was added, the mixture shaken and equilibrium re-established. Which of the following statements is correct?

A. The concentration of I_2 in Y increases.

B. The concentration of I_2 in Y decreases.

C. The equilibrium constant increases.

D. The equilibrium constant decreases.

3. An monoprotic organic acid can be extracted from a reaction mixture using ethoxyethane. 100 cm^3 of ethoxyethane were added to 500 cm^3 of an aqueous organic acid and the mixture shaken. After being allowed to settle, two immiscible layers formed.

(a) What piece of apparatus would be used to separate both layers?

(b) The following equilibrium was established

organic acid (aqueous) $\rightleftharpoons$ organic acid (ethoxyethane)
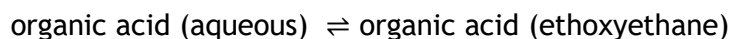
25 0 cm^3 of the ethoxyethane layer required 22·7 cm^3 of 0·10 mol l-1 NaOH solution to neutralise it.

25·0 cm^3 of the aqueous layer was neutralised by 8·25 cm^3 of 0·10 mol l-1 NaOH solution.

Calculate the equilibrium constant for the system.

6

(o) Stoichiometric Calculations

1. Calculate the percentage of each of the elements present in the following compounds.

   (a) SO_2

   (b) CH_4

   (c) MgO

   (d) CuSO4

   (e) sodium hydroxide

   (f) potassium sulphate

   (g) calcium carbonate

   (h) carbon tetrachloride

2. Nitrogen is an element essential for plant growth. Which of the following fertilisers is richest in nitrogen?

   (a) ammonium sulphate

   (b) sodium nitrate

   (c) ammonium nitrate

3. Calculate the mass of nitrogen in 1 Kg of ammonium nitrate
4. Calculate the mass of potassium in 500 g of potassium sulphate.
5. Calculate the mass of phosphorus in 2 Kg of sodium phosphate.
6. Cyclohexanol can be converted into cyclohexene or cyclohexanone using different reagents as outlined below.
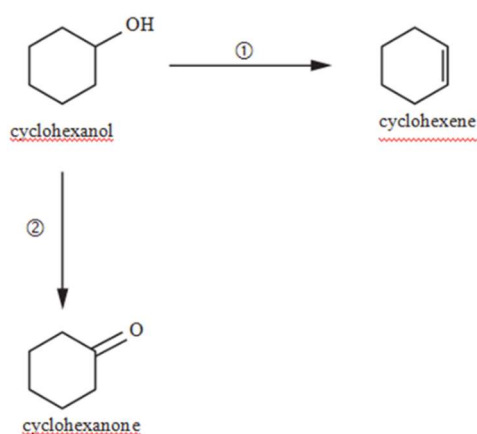

In an experiment, a student obtained 3·14 g of cyclohexene from 4·36 g of cyclohexanol.

   (a) Calculate the percentage yield.
   (b) Give a reason why the yield is not 100%.

7. Sir Isaac Newton was thought to have suffered from mercury poisoning and when his hair was analysed the level of mercury was found to be 73 ppm. The unit ppm stands for parts per million and refers to 1mg per kg. Calculate the number of moles of mercury in a $1 \cdot 0 \times 10^{-6}$ g sample of Newton's hair

8. $4 \cdot 94$ g of $CaSO_4.xH_2O$ was dehydrated to produce $3 \cdot 89$ g of $CaSO_4$. Determine the value of x.

9. Aspirin is one of the most widely used drugs in our society. It can be prepared by reacting 2-hydroxybenzoic acid ($C_7H_6O_3$), with ethanoic anhydride in acidic conditions.
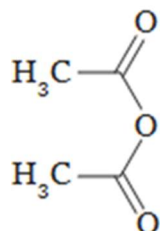
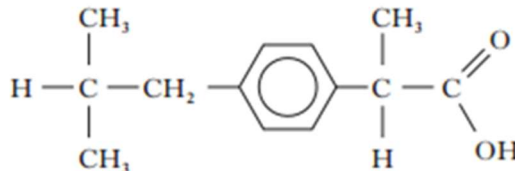ethanoic anhydride   aspirin
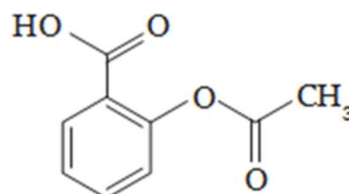
The percentage yield for this reaction is 67%.

Calculate the minimum mass of ethanoic anhydride required to produce 5·00g of aspirin?

10. Ibuprofen is one of the most commonly used non-steroidal anti-inflammatory drugs (NSAIDs). The structure of ibuprofen is shown below.

ibuprofen

The percentage yield of the final purified product is 57%. Suggest a reason why the yield is less than 100 %.

11. Calculate the empirical formula for the following compounds from their percentage compositions.

(a) 75 % carbon, 25 % hydrogen
(b) 27.3 % carbon, 72.7 % oxygen
(c) 83 % nitrogen, 17 % hydrogen
(d) 52 % carbon, 13 % hydrogen, 35 % oxygen
(e) 32 % sodium, 23 % sulphur, 45 % oxygen
(f) 60 % potassium, 19 % carbon, 22 % nitrogen

12. From the following information obtained by experiment, calculate the empirical formula of each of the metal oxides.

   (a) 2.25 g iron reacts with 0.68 g oxygen
   (b) 0.6 g magnesium burns to give 0.95 g magnesium oxide
   (c) 3.0 g titanium combines with 2.0 g oxygen
   (d) 40 g copper oxide is reduced to form 32 g copper
   (e) 36 g copper oxide is reduced to form 32 g copper

13. A container when empty weighed 5.20g. Lead oxide was added and the weight of the container plus lead oxide was 7.60g. After reduction with hydrogen, the weight of the container plus lead metal was 7.28g. Calculate the empirical formula of the lead oxide.

14. The results from a reduction of copper oxide are as follows:

   mass of empty tube 15.80 g
   mass of tube + copper oxide 16.16 g
   mass of tube + copper 16.12 g

   Calculate the empirical formula for the copper oxide

15. Meldrum's acid is a chemical named after the Scotsman, Andrew N. Meldrum who was the first to produce it. Microanalysis showed that Meldrum's acid has a composition, by mass, of 50 % C, 5.6 % H, 44 4% O. Use the percentage composition to calculate the empirical formula of Meldrum's acid.

(p) Volumetric Analysis

1. What volume of $0{\cdot}5$ mol l^{-1} sodium carbonate is required to make, by dilution with water, one litre of a solution with a Na+(aq) ion concentration of $0{\cdot}2$ mol l^{-1}?

   A. 100 cm^3
   B. 200 cm^3
   C. 300 cm^3
   D. 400 cm^3

2. Which of the following aqueous solutions contains the greatest number of negatively charged ions?

   A. 500 cm^3 0.10 mol l^{-1} Na_2SO_4(aq)
   B. 250 cm^3 0.12 mol l^{-1} $BaCl_2$(aq)
   C. 300 cm^3 0.15 mol l^{-1} KI(aq)
   D. 400 cm^3 0.10mol l^{-1} $Zn(NO_3)_2$(aq)

3. What volume of $0{\cdot}25$ mol l^{-1} calcium nitrate is required to make, by dilution with water, 500 cm^3 of a solution with a nitrate ion concentration of $0{\cdot}1$ mol l^{-1}?

   A. 50cm^3
   B. 100cm^3
   C. 200cm^3
   D. 400cm^3

4. What volume of water needs to be added to 25 cm^3 of 0.2 mol l^{-1} calcium chloride solution to produce a solution with a chloride ion concentration of 0.2 mol l^{-1}?

   A. 25cm^3
   B. 50cm^3
   C. 75cm^3
   D. 100cm^3

5. What volume of 0.2 mol l^{-1} potassium sulphate is required to make, by dilution with water, one litre of a solution with a potassium ion concentration of 0.1 mol l^{-1}?

   A. 100 cm^3
   B. 250 cm^3
   C. 400 cm^3
   D. 500 cm^3

6. What volume of 0·5 mol l^{-1} sodium carbonate is required to make, by dilution with water, one litre of a solution with a $Na^+(aq)$ ion concentration of 0·2 mol l^{-1}?

   A. 100 cm^3
   B. 200 cm^3
   C. 300 cm^3
   D. 400 cm^3

7. Which of the following aqueous solutions contains the greatest number of negatively charged ions?

   A. 500 cm^3 0.10 mol l^{-1} $Na_2SO_4(aq)$
   B. 250 cm^3 0.12 mol l^{-1} $BaCl_2(aq)$
   C. 300 cm^3 0.15 mol l^{-1} $KI(aq)$
   D. 400 cm^3 0.10 mol l^{-1} $Zn(NO_3)_2(aq)$

8. What volume of 0·25 mol l^{-1} calcium nitrate is required to make, by dilution with water, 500 cm^3 of a solution with a nitrate ion concentration of 0·1 mol l^{-1}?

   A. 50cm^3
   B. 100cm^3
   C. 200cm^3
   D. 400cm^3

9. What volume of water needs to be added to 25 cm^3 of 0.2 mol l^{-1} calcium chloride solution to produce a solution with a chloride ion concentration of 0.2 mol l^{-1}?

   A. 25 cm^3
   B. 50 cm^3
   C. 75 cm^3
   D. 100 cm^3

10. What volume of 0.2 mol l^{-1} potassium sulphate is required to make, by dilution with water, one litre of a solution with apotassium ion concentration of 0.1 mol l^{-1}?

   A. 100 cm^3
   B. 250 cm^3
   C. 400 cm^3
   D. 500 cm^3

11. What volume of 0·2 mol l $^{-1}$ potassium sulfate is required to make, by dilution with water, one litre of a solution with a potassium ion concentration of 0·1 mol l^{-1}?

    A. 100 cm^3
   B. 250 cm^3
    C. 400 cm^3
    D. 500 cm^3

12. Which of the following techniques could be used to purify an impure sample of solid benzoic acid?

   A. Refluxing
   B. Distillation
   C. Recrystallisation
   D. Thin layer chromatography

13. 5·0 cm^3 of a solution of hydrochloric acid was diluted to exactly 250 cm^3 with water. The pH of this diluted solution was 2·00. The concentration of the original undiluted solution, in mol l^{-1}, was

   A. $2·0 \times 10^{-2}$
   B. $4·0 \times 10^{-2}$
   C. $4·0 \times 10^{-1}$
   D. $5·0 \times 10^{-1}$

14. Calculate the volume (in cm^3) of 0.250 mol l^{-1} nitric acid which will be completely neutralised by 44.8 cm^3 of 0.150 mol l^{-1} of sodium carbonate in the following reaction

$$2HNO_3(aq) + Na_2CO_3(aq) \rightarrow 2NaNO_3(aq) + H_2O(l) + CO_2(g)$$
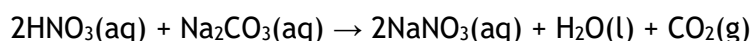
15. Calculate the volume (in cm^3) of 1 mol l^{-1} sodium hydroxide which is required to neutralise 35 cm^3 of 0.175 mol l^{-1} sulfuric acid

16. Calculate the volume (in cm^3) of 0.375 mol l^{-1} nickel (II) sulphate is required to react with 45.7 cm^3 of 0.265 mol l^{-1} sodium phosphate solution

17. Brass is an alloy consisting mainly of copper and zinc. To determine the percentage of copper in a sample of brass, 2.63 g of the brass was dissolved in concentrated nitric acid and the solution diluted to 250 cm^3 in a standard flask. Excess potassium iodide was added to 25.0 cm3 of this solution, iodine being produced according to the equation:

$$2Cu^{2+}(aq) + 4I^{-}(aq) \rightarrow 2CuI(s) + I_2(aq)$$
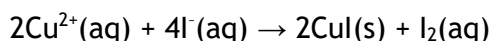
The iodine formed was titrated with 0.10 mol l^{-1} sodium thiosulfate solution, Na$_2$S$_2$O$_3$(aq), the volume required for complete reaction being 24.8 cm^3.
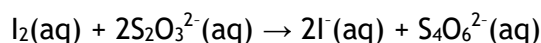
$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^{-}(aq) + S_4O_6^{2-}(aq)$$
$$\text{Orange/brown colourless}$$

(a) Which species in the first equation is oxidised?
(b) How could the end-point for the titration be made more obvious?
(c) How many moles of sodium thiosulphate were required in the titration?
(d) Calculate the percentage by mass of copper in the sample of brass.

18. 1.8 g of iron (II) ammonium sulphate, $Fe(NH_4)_2(SO_4)_2.6H_2O$, was dissolved in 35 cm^3 of distilled water. The solution was then diluted to 50 cm^3 using dilute sulphuric acid. The final solution was titrated against potassium permanganate solution and 40 cm^3 of the potassium permanganate solution was required to reach the end-point at which all the iron(II) had been converted to iron(III). Calculate the concentration of the potassium permanganate solution.

19. The manganese content of a steel paperclip can be determined by oxidising the manganese firstly into manganese (II) ions and then to the purple permanganate ion. Colorimetry is then used to find the concentration of the permanganate ion, from which the percentage manganese in the steel paperclip can be determined.

   (a) What data must be collected to allow the calibration graph to be drawn?
   (b) In a determination, the manganese in 0·245 g of steel was oxidised to permanganate ions and the solution made up to 100 cm^3 in a standard flask. The absorbance of the solution was measured as 0·26. Use this information and the following calibration graph to calculate the percentage of manganese in this sample of steel.
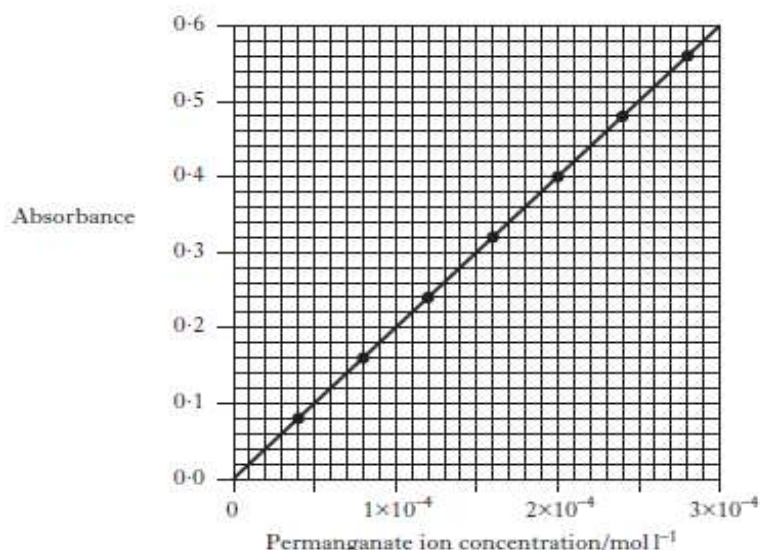
   (c) State one of the characteristics of a primary standard.
   (d) As part of an AH Chemistry investigation, a student had to prepare a standard solution of sodium carbonate. Outline how the student would prepare this standard solution from pure sodium carbonate.

20. Outline how 250 cm^3 of 0·20 mol l^{-1} sodium carbonate solution would be prepared from a standard 1·00 mol l^{-1} sodium carbonate solution.

21. The equation for the reaction between oxalic acid solution and sodium hydroxide solution is

$$H_2C_2O_4(aq) + 2NaOH(aq) \longrightarrow Na_2C_2O_4(aq) + 2H_2O(l)$$
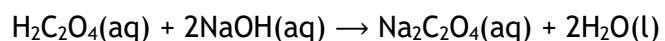
A student used a standard solution of 0.0563 mol l^{-1} oxalic acid to standardise 20.0 cm^3 of approximately 0.1 mol l^{-1} sodium hydroxide solution. The raw results for the titration are given in the table.

	1st attempt	2nd attempt	3rd attempt
Final burette reading/cm^3	17·2	33·8	16·6
Initial burette reading/cm^3	0·0	17·2	0·1
Titre/cm^3	17·2	16·6	16·5

(a) Calculate the accurate concentration of the sodium hydroxide solution

(b) Oxalic acid is a primary standard but sodium hydroxide is not.   State one characteristic of sodium hydroxide that makes it unsuitable as a primary standard.

22. "Complexometric Determination of Nickel using EDTA" has two main stages.

Stage 1: Preparation of nickel(II) sulphate solution.

Stage 2: Titration of the nickel(II) sulphate solution with EDTA.

The instructions for Stage 1 are shown below.

1. Accurately weigh out approximately 2·6 g of hydrated nickel(II) sulphate, $NiSO_4.6H_2O$.

2. Transfer the hydrated nickel salt to a 100 cm^3 beaker, add 25 cm^3 of deionised water and stir to dissolve the solid.

3. Transfer the solution to a 100 cm^3 standard flask.

4.

5.

6. Stopper the flask and invert it several times to ensure the contents are thoroughly mixed.

(a) Complete the instructions for steps 4 and 5.

(b) In Stage 2, 25·0 cm^3 of the nickel(II) sulphate solution were titrated against 0·110 mol l^{-1} EDTA solution. The results of the titrations are shown below

	1st attempt	2nd attempt	3rd attempt
Initial burette reading/cm^3	2.00	25.9	10.0
Final burette reading/cm^3	25.9	49.4	33.6
Titre/cm^3	23.9	23.5	23.6

The equation for the reaction is represented by

$$Ni^{2+}(aq) + [EDTA]^{4-}(aq) \rightarrow Ni[EDTA]^{2-}(aq)$$
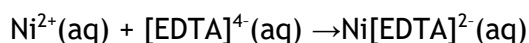
(i) Name the indicator used to detect the end-point of the titration in this experiment

(ii) EDTA acts as a hexadentate ligand. Name the shape of the complex ion Ni[EDTA]$^{2-}$?

(c) The accurate mass of the nickel(II) sulphate used was 2·656 g. Calculate the percentage by mass of nickel present in the hydrated salt from these experimental results.