IB · DP · Chemistry

1 hour 10 questions

Structured Questions

How Much? The Amount of Chemical Change

Balancing Equations / Reacting Mass Calculations / Avogadro's Law & Molar Volume of Gas / Concentration Calculations / Limiting & Excess Reactants / Percentage Yield Calculations / Atom Economy

Easy (3 questions)	/24
Medium (3 questions)	/25
Hard (4 questions)	/40
Total Marks	**/89**

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Easy Questions

1 (a) In a firework, solid potassium nitrate, KNO_3, decomposes to form solid potassium nitrite, KNO_2, and oxygen, O_2.

i) Write a balanced symbol equation for this reaction. [1]

ii) Use section 7 of the data booklet to calculate the amount, in g, of potassium nitrate, KNO_3, required to make 1.5 g of oxygen. Give your answer to 2 significant figures. [3]

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(4 marks)

(b) Use section 2 of the data booklet to calculate the volume of gas at STP, in dm^3, that is produced in the reaction outlined in part (a). Give your answer to 2 significant figures.

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(1 mark)

(c) Potassium can form a superoxide, KO_2 (s), which will react with carbon dioxide, CO_2 (g), to produce potassium carbonate, K_2CO_3 (s) and oxygen, O_2 (g), as shown in the equation below.

$$4KO_2\,(s) + 2CO_2\,(g) \rightarrow 2K_2CO_3\,(s) + 3O_2\,(g)$$

i) Calculate the amount, in moles, of 5.00 g of potassium superoxide. Give your answer to 3 significant figures.

[1]

ii) Calculate the amount, in moles, and therefore volume, in dm^3, of carbon dioxide which will react with the superoxide. Give your answer to 3 significant figures. [2]

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(3 marks)

(d) A student calculated that 4.86 g of potassium carbonate, KCO_3, should be produced during the reaction outlined in part (c), 2.61 g of potassium carbonate, KCO_3, was produced when the experiment was carried out. Calculate the percentage yield for the production of potassium carbonate. Give your answer to 2 decimal places.

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(1 mark)

2 (a) A student carried out a series of titration experiments. Their results from their experiments are shown in the table below.

Titration	**Rough**	**1**	**2**	**3**
Final reading / cm^3	25.45	21.95	43.65	22.10
Initial reading / cm^3	0.00	0.05	21.90	0.10
Titre / cm^3	25.45	21.90	21.75	22.00

Calculate the mean titre using the concordant results. Give your answer to 2 decimal places.

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(2 marks)

(b) The student added 0.10 mol dm^{-3} hydrochloric acid, HCl (aq), to the burette and performed the titration using a 25.00 cm^3 sample of an unknown carbonate solution. The equation for the neutralisation reaction is shown below.

$$M_2CO_3\,(aq) + 2HCl\,(aq) \rightarrow 2MCl\,(aq) + CO_2\,(g) + H_2O\,(l)$$

i) Using your answer to part (a), calculate the amount, in moles, of hydrochloric acid used. Give your answer to 2 decimal places.

[1]

ii) Calculate the amount, in moles, of the aqueous carbonate solution. Give your answer to 2 decimal places.

[1]

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(2 marks)

(c) Using your answer to part (b) (i) determine the concentration in mol dm^{-3} of the aqueous carbonate. Give your answer to 2 decimal places.

(1 mark)

(d) The student used 1.38 g of the unknown carbonate to make up a 250 cm^3 standard solution for the titration outlined in part (a). Using section 6 of the data booklet, prove that the unknown carbonate is potassium carbonate, K_2CO_3.

Calculate the amount, in moles, of K_2CO_3 .....

Calculate the concentration in, mol dm^{-3}, of K_2CO_3 solution .....

(4 marks)

3 (a) 3.75 g of zinc oxide, ZnO (s), was added to 150 cm^3 of 1.00 mol dm^{-3} of sulfuric acid (aq) producing a salt. Write a balanced symbol equation for this reaction.

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(1 mark)

(b) Using the equation in part (a) and section 7 of the data booklet, calculate the limiting reagent in the reaction. Give your answer to 2 significant figures.

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(3 marks)

(c) Use your answer to part (b) and section 7 of the data booklet to calculate the amount, in grams, of the salt produced. Give your answer to 3 significant figures.

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(1 mark)

(d) Calculate the amount, in moles, of the excess reactant left over at the end of the reaction. Give your answer to 2 decimal places.

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(1 mark)

Medium Questions

1 (a) An analysis of a 2.54 g antacid tablet containing $Mg(OH)_2$ was carried out by titration using 40.00 cm^3 of 1.25 $moldm^{-3}$ sulfuric acid. The acid was in excess.

i) Write an equation for the reaction.

[1]

ii) Determine the amount, in mol, of sulfuric acid.

[1]

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(2 marks)

(b) The excess sulfuric acid reacted with 21.45 cm^3 of 1.51 $moldm^{-3}$ NaOH.
Determine the amount of excess acid present.

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(2 marks)

(c) Calculate the amount of sulfuric acid that reacted with the $Mg(OH)_2$

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(1 mark)

(d) Determine the mass of $Mg(OH)_2$ that was present in the tablet.

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(1 mark)

(e) Determine the percentage mass of $Mg(OH)_2$ that was present in the tablet.

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(1 mark)

2 (a) The chlorine level in a swimming pool should lie between 1.0 and 3.0 ppm. Explain the meaning of ppm and express this concentration range in moldm^{-3}.

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(2 marks)

(b) The amount of dissolved chlorine can be analysed by reacting with excess iodide ions under acidic conditions, and titrating the liberated iodine against standard sodium thiosulfate solution in a two-step process:

$$Cl_2\,(aq) + 2I^-\,(aq) \text{ " } 2Cl^-\,(aq) + I_2\,(aq)$$

$$I_2\,(aq) + 2S_2O_3^{2-}\,(aq) \text{ " } 2I^-\,(aq) + S_4O_6^{2-}\,(aq)$$

A 25.0 mL sample of chlorine water was analysed and the volume of 0.120 moldm^{-3} sodium thiosulfate solution, $Na_2S_2O_3$, needed to react with the iodine was recorded in **Table 1**.

Table 1

Volume of $Na_2S_2O_3$	**I**	**II**	**III**
Initial burette reading / *mL* ± 0.05	1.05	23.40	2.10
Final burette reading / *mL* ± 0.05	23.40	45.70	24.50
Titre / *mL*			

Calculate the mean titre and determine the number of moles of sodium thiosulfate that reacted.

(2 marks)

(c) Determine the amount of chlorine, in mol, present in the sample of chlorine water.

(1 mark)

(d) Calculate the concentration of the chlorine water in $moldm^{-3}$ and in gdm^{-3}.

(2 marks)

3 (a) Aluminium will react with copper(II) sulfate solution according to the following equation:

$$2Al\ (s) + 3CuSO_4\ (aq)\ "\ \ 3Cu\ (s) + Al_2(SO_4)_3\ (aq)$$

The reaction is quite slow at room temperature, but when chloride ions in the form of hydrochloric acid are added, the rate increases significantly. The chloride ions catalyse the reaction.

An experiment was carried out to determine the yield of the reaction. A student made a solution of aqueous copper(II) sulfate by dissolving 2.00 g of copper(II) sulfate pentahydrate, $CuSO_4.5H_2O$ (M_r 249.72 g mol^{-1}) in 10.0 mL of distilled water in a small beaker.

To this solution she added 0.25 g of aluminium foil followed by 2.0 mL of 6.0 mol dm^{-3} hydrochloric acid.

After the reaction was complete, she collected, dried, and weighed the copper that was produced.

She recorded the measurements in **Table 1** below.

Table 1

	Mass / ± 0.01 g
Initial mass of copper sulfate	2.00
Mass of aluminium foil used	0.25
Mass of empty beaker	42.18
Mass of beaker with dry copper	42.61

Use the data to show that the copper sulfate is the limiting reagent in the experiment and calculate the mass of aluminium in excess.

(4 marks)

(b) Calculate the actual yield and the percentage yield of copper in the experiment.

(3 marks)

(c) Determine the percentage uncertainty in the mass of copper produced, and the overall percentage error for the experiment.

(2 marks)

(d) Discuss the impact on the percentage yield of copper from the following systematic errors:

i) The copper collected is not fully dried out before the beaker is weighed.

[1]

ii) The student misread the instructions and used 1.0 mL of hydrochloric acid.

[1]

(2 marks)

Hard Questions

1 (a) Citric acid, $C_6H_8O_7$, is present in lemon juice and is classed as a weak acid. 10.00 cm^3 of citric acid is reacted with sodium hydroxide, NaOH (aq) , with a concentration of 12.0 g dm^{-3} to form sodium citrate, $Na_3C_6H_5O_7$, and water. 32.10 cm^3 of sodium hydroxide was required to react with the lemon juice.

State the balanced equation for this reaction.

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(1 mark)

(b) Calculate the mass, in grams, of sodium hydroxide that reacted with the lemon juice.

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(1 mark)

(c) Determine the concentration, in mol dm^{-3}, of citric acid in the sample of lemon juice.

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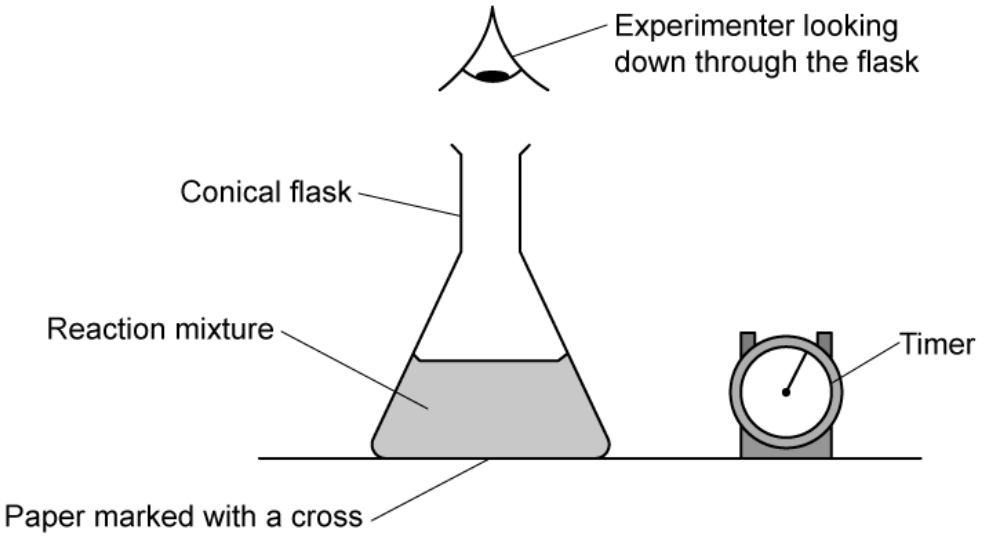
(3 marks)

2 (a) A group of students investigated the rate of reaction between sodium thiosulfate and hydrochloric acid by measuring the amount of time taken for a cross marked on a piece of paper to become obscured by a yellow precipitate.

$$Na_2S_2O_3\ (aq) + 2HCl\ (aq) \rightarrow 2NaCl\ (aq) + SO_2\ (g) + H_2O\ (l) + S\ (s)$$



Initially they measured out 15.00 cm^3 of 0.900 mol dm^{-3} hydrochloric acid and then added 40.00 cm^3 of 0.0150 mol dm^{-3} aqueous sodium thiosulfate.

The mark on the paper was obscured 38 seconds after the solutions were mixed.

Their teacher made up 3.00 dm^3 of sodium thiosulfate solution using sodium thiosulfate pentahydrate crystals, $Na_2S_2O_3 \cdot 5H_2O$.

Calculate the required mass, in grams, of these crystals. Give your answer to 2 decimal places.

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(3 marks)

(b) Using sections 2 and 4 of the Data booklet, calculate the volume of gas produced, in dm^3, in this reaction if it were collected at a temperature of 300 K and 1.00 x 10^5 Pa.

(4 marks)

(c) A different group of students decided to measure the rate of reaction by collecting the volume of sulfur dioxide produced over a period of time.

The students attempted to collect the gas in a measuring cylinder over water, but were unsuccessful. Suggest why they were unsuccessful.

(1 mark)

(d) Determine the pH of the acid used and suggest how pH could be used to measure the rate of reaction.

(2 marks)

(e) Determine the reagent in excess in this reaction and state the amount, in moles, that will be in excess.

(3 marks)

3 (a) A student carried out an experiment involving a solution of potassium dichromate(VI), $K_2Cr_2O_7$, with iron(II) sulfate, to find the mass of $FeSO_4.7H_2O$ in an impure sample, **A**.

The student recorded the mass of **A**, dissolved the sample in water and then made the solution up to 500 cm^3. After an excess was added, the student found that 25.00 cm^3 of this solution reacted with 22.10 cm^3 of a 0.020 mol dm^{-3} solution of $K_2Cr_2O_7$.

Deduce the full equation for the reaction between acidic $Cr_2O_7^{2-}$ (aq) and Fe^{2+} (aq) to form Cr^{3+} (aq) and Fe^{3+} (aq).

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(2 marks)

(b) Use section 7 of the Data booklet to determine the mass, in grams, of $FeSO_4.7H_2O$ in sample, **A.** Give your answer to three significant figures.

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(4 marks)

(c) A student performs a titration to determine the molar mass and structure of a dicarboxylic acid, **X**, which only contains carbon, hydrogen and oxygen.

The student prepares a 250.0 cm^3 solution from 1.513 g of X.

The solution of X is added to the burette and titrated with 25.00 cm^3 aliquot of 0.112 mol dm^{-3} NaOH (aq).

The student recorded their results in the table below:

	Titration 1	Titration 2	Titration 3
Final burette reading / cm^3	28.60	27.95	29.45
Initial burette reading / cm^3	1.10	0.70	2.10
Volume added / cm^3	27.50	27.25	27.35

i) Determine the mean volume, in dm^3, of the titre.

[1]

ii) Determine the amount, in moles, of **X** in the original sample.

[3]

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(4 marks)

(d) Using section 7 in the Data booklet, suggest a structure for **X.**

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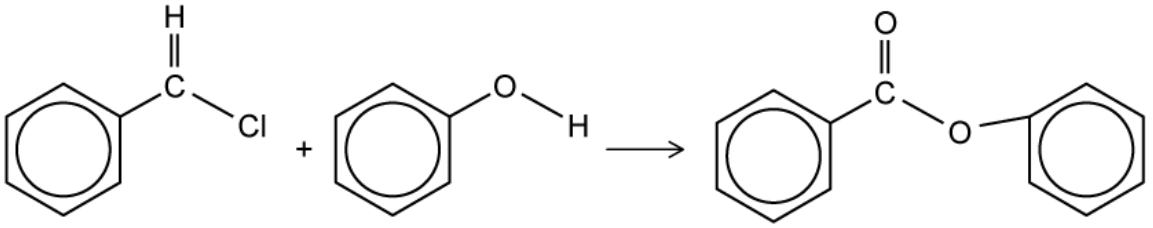
(2 marks)

4 (a) A student prepared some phenyl benzoate by reacting phenol with benzoyl chloride in alkaline conditions. The equation for the reaction is:



Benzoyl chloride **Phenol** **Phenyl benzoate + Hcl**

The table shows the data recorded by the student:

Mass of phenol used	4.85 $\pm$ 0.02 g
Mass of phenyl benzoate obtained	6.34 $\pm$ 0.02 g

State the names of two functional groups found in the product

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(2 marks)

(b) Determine the following quantities from the data in part a):

i) The amount, in mol, of phenol used

[2]

ii) The theoretical yield, in g, of phenyl benzoate

[2]

iii) The percentage yield of phenyl benzoate

[1]

(5 marks)

(c) State the number of significant figures associated with the mass of phenyl benzoate obtained and calculate the percentage uncertainty associated with this mass.

(2 marks)

(d) Another student repeated the experiment and obtained an experimental yield of 145%.

The teacher checked the student's calculations and found no errors. Suggest an explanation for this result.

(1 mark)