

# MOLES & STOICHIOMETRY WS 2

1 When an excess of chlorine was reacted with 0.72 g of titanium, 2.85 g of a chloride **A** was formed.

(i) Calculate the amount, in moles, of titanium used.

(ii) Calculate the amount, in moles, of chlorine atoms that reacted.

iii) Hence, determine the empirical formula of **A**.

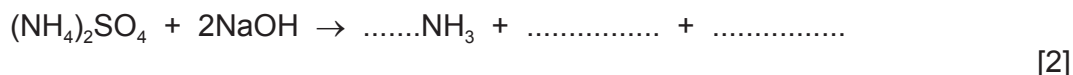
iv) Construct a balanced equation for the reaction between titanium and chlorine.

.....  
[4]

2 Ammonium sulfate,  $(\text{NH}_4)_2\text{SO}_4$ , is widely used as a fertiliser.

In order to determine its percentage purity, a sample of ammonium sulfate fertiliser was analysed by reacting a known amount with an excess of  $\text{NaOH}(\text{aq})$  and then titrating the unreacted  $\text{NaOH}$  with dilute  $\text{HCl}$ .

- (a) Ammonium sulfate reacts with  $\text{NaOH}$  in a 1 : 2 ratio.  
Complete and balance the equation for this reaction.



- (b) A 5.00g sample of a fertiliser containing  $(\text{NH}_4)_2\text{SO}_4$  was warmed with  $50.0\text{cm}^3$  (an excess) of  $2.00\text{mol dm}^{-3}$   $\text{NaOH}$ .

When all of the ammonia had been driven off, the solution was cooled.

The remaining  $\text{NaOH}$  was then titrated with  $1.00\text{mol dm}^{-3}$   $\text{HCl}$  and  $31.2\text{cm}^3$  were required for neutralisation.

- (i) Write a balanced equation for the reaction between  $\text{NaOH}$  and  $\text{HCl}$ .  
.....

- (ii) Calculate the amount, in moles, of  $\text{HCl}$  in  $31.2\text{cm}^3$  of  $1.00\text{mol dm}^{-3}$   $\text{HCl}$ .

- (iii) Calculate the amount, in moles, of  $\text{NaOH}$  in  $50.0\text{cm}^3$  of  $2.00\text{mol dm}^{-3}$   $\text{NaOH}$ .

- (iv) Use your answers to (i), (ii) and (iii) to calculate the amount, in moles, of  $\text{NaOH}$  used up in the reaction with  $(\text{NH}_4)_2\text{SO}_4$ .

- (v) Use your answer to (iv) and the equation in (a) to calculate the amount, in moles, of  $(\text{NH}_4)_2\text{SO}_4$  that reacted with NaOH.
- (vi) Use your answer to (v) to calculate the mass of  $(\text{NH}_4)_2\text{SO}_4$  that reacted with NaOH.
- (vii) Hence, calculate the percentage purity of the ammonium sulfate fertiliser.

[7]

3 Washing soda is hydrated sodium carbonate,  $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ .

A student wished to determine the value of  $x$  by carrying out a titration, with the following results.

5.13 g of washing soda crystals were dissolved in water and the solution was made up to  $250 \text{ cm}^3$  in a standard volumetric flask.

$25.0 \text{ cm}^3$  of this solution reacted exactly with  $35.8 \text{ cm}^3$  of  $0.100 \text{ mol dm}^{-3}$  hydrochloric acid and carbon dioxide was produced.

(a) (i) Write a balanced equation for the reaction between  $\text{Na}_2\text{CO}_3$  and  $\text{HCl}$ .

.....

(ii) Calculate the amount, in moles, of  $\text{HCl}$  in the  $35.8 \text{ cm}^3$  of solution used in the titration.

(iii) Use your answers to (i) and (ii) to calculate the amount, in moles, of  $\text{Na}_2\text{CO}_3$  in the  $25.0 \text{ cm}^3$  of solution used in the titration.

(iv) Use your answer to (iii) to calculate the amount, in moles, of  $\text{Na}_2\text{CO}_3$  in the  $250 \text{ cm}^3$  of solution in the standard volumetric flask.

(v) Hence calculate the mass of  $\text{Na}_2\text{CO}_3$  present in 5.13 g of washing soda crystals.

[6]

(b) Use your calculations in (a) to determine the value of x in  $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ .

[2]

4 Compounds of phosphorus have many uses in everyday life, e.g. fertilisers, matches and in water softeners.

(a) State the full electronic configuration of phosphorus.

.....[1]

(b) Phosphoric acid,  $\text{H}_3\text{PO}_4$ , is used in the manufacture of phosphate fertilisers.

Deduce the oxidation number of phosphorus in  $\text{H}_3\text{PO}_4$ .

.....[1]

(c) The salt sodium phosphate,  $\text{Na}_3\text{PO}_4$ , is a water-softening agent.

(i) Write the equation for the complete neutralisation of phosphoric acid with aqueous sodium hydroxide.

.....

Sodium phosphate was prepared from  $50.0\text{ cm}^3$  of  $0.500\text{ mol dm}^{-3}$   $\text{H}_3\text{PO}_4$  and an excess of aqueous sodium hydroxide.

(ii) How many moles of  $\text{H}_3\text{PO}_4$  were used?

(iii) Use your equation in (c)(i) to calculate how many moles of sodium hydroxide are required.

[3]

(d) Phosphorus sulphide,  $\text{P}_4\text{S}_3$ , is used in small amounts in the tip of a match. On striking a match, this compound burns.

(i) Construct an equation for this reaction.

.....

(ii) Both oxides formed in (i) dissolve in water to give acidic solutions. Construct an equation for the reaction of each oxide with water.

.....

.....[4]

- 5 Methanoic acid,  $\text{HCO}_2\text{H}$ , was formerly known as formic acid because it is present in the sting of ants and the Latin name for ant is *formica*. It was first isolated in 1671 by John Ray who collected a large number of dead ants and extracted the acid from them by distillation.

**In this question, you should give all numerical answers to two significant figures.**

At room temperature, pure methanoic acid is a liquid which is completely soluble in water.

When we are stung by a 'typical' ant a solution of methanoic acid, **A**, is injected into our skin.

Solution **A** contains 50% by volume of pure methanoic acid.

A 'typical' ant contains  $7.5 \times 10^{-6} \text{ dm}^3$  of solution **A**.

- (a) (i) Calculate the volume, in  $\text{cm}^3$ , of solution **A** in one ant.

volume = .....  $\text{cm}^3$

- (ii) Use your answer to (i) to calculate the volume, in  $\text{cm}^3$ , of pure methanoic acid in one ant.

volume = .....  $\text{cm}^3$

- (iii) Use your answer to (ii) to calculate how many ants would have to be distilled to produce  $1 \text{ dm}^3$  of pure methanoic acid.

number = .....  
[3]

When we are stung by an ant, the amount of solution **A** injected is 80% of the total amount of solution **A** present in one ant.

The density of pure methanoic acid is  $1.2 \text{ g cm}^{-3}$ .

**(b) (i)** Calculate the volume, in  $\text{cm}^3$ , of **pure** methanoic acid injected in one ant sting.

volume = .....  $\text{cm}^3$

**(ii)** Use your answer to **(i)** to calculate the mass of methanoic acid present in one ant sting.

mass = ..... g  
[3]

Bees also sting us by using methanoic acid. One simple treatment for ant or bee stings is to use sodium hydrogencarbonate,  $\text{NaHCO}_3$ .

**(c) (i)** Construct a balanced equation for the reaction between methanoic acid and sodium hydrogencarbonate.

.....

**(ii)** In a typical bee sting, the mass of methanoic acid injected is  $5.4 \times 10^{-3} \text{ g}$ . Calculate the mass of  $\text{NaHCO}_3$  needed to neutralise one bee sting.

mass = ..... g  
[3]



6 Zinc is an essential trace element which is necessary for the healthy growth of animals and plants. Zinc deficiency in humans can be easily treated by using zinc salts as dietary supplements.

(a) One salt which is used as a dietary supplement is a hydrated zinc sulfate,  $\text{ZnSO}_4 \cdot x\text{H}_2\text{O}$ , which is a colourless crystalline solid.

Crystals of zinc sulfate may be prepared in a school or college laboratory by reacting dilute sulfuric acid with a suitable compound of zinc.

Give the formulae of **two** simple compounds of zinc that could **each** react with dilute sulfuric acid to produce zinc sulfate.

..... and ..... [2]

(b) A simple experiment to determine the value of  $x$  in the formula  $\text{ZnSO}_4 \cdot x\text{H}_2\text{O}$  is to heat it carefully to drive off the water.



A student placed a sample of the hydrated zinc sulfate in a weighed boiling tube and reweighed it. He then heated the tube for a short time, cooled it and reweighed it when cool. This process was repeated four times. The final results are shown below.

mass of empty tube /g	mass of tube + hydrated salt /g	mass of tube + salt after fourth heating /g
74.25	77.97	76.34

(i) Why was the boiling tube heated, cooled and reweighed four times?

.....  
.....

(ii) Calculate the amount, **in moles**, of the anhydrous salt produced.

(iii) Calculate the amount, **in moles**, of water driven off by heating.

(iv) Use your results to (ii) and (iii) to calculate the value of  $x$  in  $\text{ZnSO}_4 \cdot x\text{H}_2\text{O}$ .

[7]

(c) For many people, an intake of approximately 15 mg per day of zinc will be sufficient to prevent deficiencies.

Zinc ethanoate crystals,  $(\text{CH}_3\text{CO}_2)_2\text{Zn} \cdot 2\text{H}_2\text{O}$ , may be used in this way.

(i) What mass of pure crystalline zinc ethanoate ( $M_r = 219.4$ ) will need to be taken to obtain a dose of 15 mg of zinc?

(ii) If this dose is taken in solution as  $5 \text{ cm}^3$  of aqueous zinc ethanoate, what would be the concentration of the solution used?  
Give your answer in  $\text{mol dm}^{-3}$ .

[4]

7 A sample of a fertiliser was known to contain ammonium sulfate,  $(\text{NH}_4)_2\text{SO}_4$ , and sand only.

A 2.96 g sample of the solid fertiliser was heated with  $40.0 \text{ cm}^3$  of  $\text{NaOH}(\text{aq})$ , an excess, and all of the ammonia produced was boiled away.

After cooling, the remaining  $\text{NaOH}(\text{aq})$  was exactly neutralised by  $29.5 \text{ cm}^3$  of  $2.00 \text{ mol dm}^{-3}$   $\text{HCl}$ .

In a separate experiment,  $40.0 \text{ cm}^3$  of the original  $\text{NaOH}(\text{aq})$  was exactly neutralised by  $39.2 \text{ cm}^3$  of the  $2.00 \text{ mol dm}^{-3}$   $\text{HCl}$ .

(a) (i) Write balanced equations for the following reactions.

$\text{NaOH}$  with  $\text{HCl}$

.....

$(\text{NH}_4)_2\text{SO}_4$  with  $\text{NaOH}$

.....

(ii) Calculate the amount, in moles, of  $\text{NaOH}$  present in the  $40.0 \text{ cm}^3$  of the original  $\text{NaOH}(\text{aq})$  that was neutralised by  $39.2 \text{ cm}^3$  of  $2.00 \text{ mol dm}^{-3}$   $\text{HCl}$ .

(iii) Calculate the amount, in moles, of  $\text{NaOH}$  present in the  $40.0 \text{ cm}^3$  of  $\text{NaOH}(\text{aq})$  that remained after boiling the  $(\text{NH}_4)_2\text{SO}_4$ .

(iv) Use your answers to (ii) and (iii) to calculate the amount, in moles, of  $\text{NaOH}$  that reacted with the  $(\text{NH}_4)_2\text{SO}_4$ .

(v) Use your answers to (i) and (iv) to calculate the amount, in moles, of  $(\text{NH}_4)_2\text{SO}_4$  that reacted with the NaOH.

(vi) Hence calculate the mass of  $(\text{NH}_4)_2\text{SO}_4$  that reacted.

(vii) Use your answer to (vi) to calculate the percentage, by mass, of  $(\text{NH}_4)_2\text{SO}_4$  present in the fertiliser.

Write your answer to a suitable number of significant figures.

[9]

(b) The uncontrolled use of nitrogenous fertilisers can cause environmental damage to lakes and streams. This is known as *eutrophication*.

What are the processes that occur when excessive amounts of nitrogenous fertilisers get into lakes and streams?

.....  
.....  
..... [2]

(c) Large quantities of ammonia are manufactured by the Haber process.

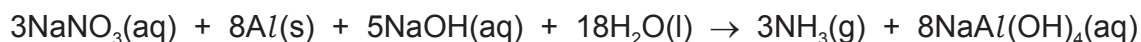
Not all of this ammonia is used to make fertilisers.

State **one** large-scale use for ammonia, **other than** in the production of nitrogenous fertilisers.

..... [1]

- 8 Chile saltpetre is a mineral found in Chile and Peru, and which mainly consists of sodium nitrate,  $\text{NaNO}_3$ . The mineral is purified to concentrate the  $\text{NaNO}_3$  which is used as a fertiliser and in some fireworks.

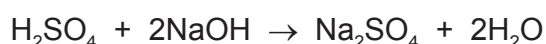
In order to find the purity of a sample of sodium nitrate, the compound is heated in  $\text{NaOH}(\text{aq})$  with Devarda's alloy which contains aluminium. This reduces the sodium nitrate to ammonia which is boiled off and then dissolved in acid.



The ammonia gas produced is dissolved in an excess of  $\text{H}_2\text{SO}_4$  of known concentration.



The amount of unreacted  $\text{H}_2\text{SO}_4$  is then determined by back-titration with  $\text{NaOH}$  of known concentration.



- (a) A 1.64 g sample of impure  $\text{NaNO}_3$  was reacted with an excess of Devarda's alloy. The  $\text{NH}_3$  produced was dissolved in  $25.0 \text{ cm}^3$  of  $1.00 \text{ mol dm}^{-3} \text{ H}_2\text{SO}_4$ . When all of the  $\text{NH}_3$  had dissolved, the resulting solution was titrated with  $\text{NaOH}(\text{aq})$ . For neutralisation,  $16.2 \text{ cm}^3$  of  $2.00 \text{ mol dm}^{-3} \text{ NaOH}$  were required.
- (i) Calculate the amount, in moles, of  $\text{H}_2\text{SO}_4$  present in the  $25.0 \text{ cm}^3$  of  $1.00 \text{ mol dm}^{-3} \text{ H}_2\text{SO}_4$ .
- (ii) Calculate the amount, in moles, of  $\text{NaOH}$  present in  $16.2 \text{ cm}^3$  of  $2.00 \text{ mol dm}^{-3} \text{ NaOH}$ .
- (iii) Use your answer to (ii) to calculate the amount, in moles, of  $\text{H}_2\text{SO}_4$  that reacted with  $16.2 \text{ cm}^3$  of  $2.00 \text{ mol dm}^{-3} \text{ NaOH}$ .
- (iv) Use your answers to (i) and (iii) to calculate the amount, in moles, of  $\text{H}_2\text{SO}_4$  that reacted with the  $\text{NH}_3$ .

- (v) Use your answer to (iv) to calculate the amount, in moles, of  $\text{NH}_3$  that reacted with the  $\text{H}_2\text{SO}_4$ .
- (vi) Use your answer to (v) to calculate the amount, in moles, of  $\text{NaNO}_3$  that reacted with the Devarda's alloy.
- (vii) Hence calculate the mass of  $\text{NaNO}_3$  that reacted.
- (viii) Use your answer to (vii) to calculate the percentage by mass of  $\text{NaNO}_3$  present in the impure sample.  
Write your answer to a suitable number of significant figures.

[9]

- (b) The above reaction is an example of a redox reaction.  
What are the oxidation numbers of nitrogen in  $\text{NaNO}_3$  and in  $\text{NH}_3$ ?

$\text{NaNO}_3$  .....

$\text{NH}_3$  .....

[1]

- 9 A sample of a hydrated double salt,  $\text{Cu}(\text{NH}_4)_x(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$ , was boiled with an excess of sodium hydroxide. Ammonia was given off.

The ammonia produced was absorbed in  $40.0 \text{ cm}^3$  of  $0.400 \text{ mol dm}^{-3}$  hydrochloric acid. The resulting solution required  $25 \text{ cm}^3$  of  $0.12 \text{ mol dm}^{-3}$  sodium hydroxide to neutralise the excess acid.

- (a) Write the ionic equation for the reaction between ammonium ions and hydroxide ions.

..... [1]

- (b) (i) Calculate the amount, in moles, of hydrochloric acid in  $40.0 \text{ cm}^3$  of  $0.400 \text{ mol dm}^{-3}$  solution.

[1]

- (ii) Calculate the amount, in moles, of sodium hydroxide needed to neutralise the excess acid. This will be equal to the amount of hydrochloric acid left in excess.

[1]

- (iii) Calculate the amount, in moles, of hydrochloric acid that reacted with ammonia.

[1]

- (iv) Calculate the amount, in moles, of ammonium ions in the sample of the double salt.

[1]

- (v) The sample contained 0.413 g of copper. Use this information and your answer to (iv) to calculate the value of  $x$  in  $\text{Cu}(\text{NH}_4)_x(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$ .

[2]

- (vi) Calculate the  $M_r$  of  $\text{Cu}(\text{NH}_4)_x(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$ .

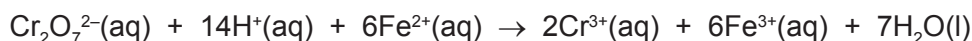
[1]

[Total: 8]



- 10 Spathose is an iron ore that contains iron(II) carbonate,  $\text{FeCO}_3$ . The percentage of iron(II) carbonate in spathose can be determined by titration with acidified potassium dichromate(VI) solution using a suitable indicator.

The ionic equation is shown below.



- (a) A 5.00 g sample of spathose was reacted with excess concentrated hydrochloric acid and then filtered.

The filtrate was made up to  $250\text{ cm}^3$  in a volumetric flask with distilled water.

A  $25.0\text{ cm}^3$  sample of the standard solution required  $27.30\text{ cm}^3$  of  $0.0200\text{ mol dm}^{-3}$  dichromate(VI) solution for complete reaction.

- (i) Calculate the amount, in moles, of dichromate(VI) ions used in the titration.

amount = ..... mol [1]

- (ii) Use your answer to (i) to calculate the amount, in moles, of  $\text{Fe}^{2+}$  present in the  $25.0\text{ cm}^3$  sample.

amount = ..... mol [1]

- (iii) Use your answer to (ii) to calculate the amount, in moles, of  $\text{Fe}^{2+}$  present in the  $250\text{ cm}^3$  volumetric flask.

amount = ..... mol [1]

- (iv) Use your answer to (iii) to calculate the mass of iron(II) carbonate present in the sample of spathose.

mass = ..... g [2]

- (v) Calculate the percentage of iron(II) carbonate in the sample of spathose.

percentage of iron(II) carbonate = ..... % [1]



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