Chemical Calculations-Tutorial 7

1.

Vinegar is a solution of ethanoic acid. A 10.0 cm^3 portion of a certain brand of vinegar needed 55.0 cm^3 of 0.200 mol dm^{-3} sodium hydroxide solution to neutralise the ethanoic acid in it.

$$\text{Ethanoic acid} + \text{Sodium hydroxide} \longrightarrow \text{Sodium ethanoate} + \text{Water}$$

$$CH_3CO_2H(aq) + NaOH(aq) \longrightarrow CH_3CO_2Na(aq) + H_2O(l)$$

Calculate the concentration of ethanoic acid in the vinegar in mol dm^{-3}.

2.

A mixture of gases coming from a coke-producing plant contains ammonia. The mixture is bubbled through dilute sulphuric acid to remove the ammonia.

a Write a balanced equation for the reaction which occurs.

b What volume of ammonia (at r.t.p.) could be removed by 50 dm^3 of 1.50 mol dm^{-3} sulphuric acid?

c What use could be made of the product?

(r.t.p.= room temperature and presure and V_m = 24 L mol^{-1})

3.

0.500 g of impure ammonium chloride is warmed with an excess of sodium hydroxide solution. The ammonia liberated neutralised 22.20 cm^3 of 0.200 mol dm^{-3} sulphuric acid. Calculate the percentage of ammonium chloride in the sample.

a Write the equation for the reaction between ammonia and sulphuric acid.

b Calculate **(i)** the amount of sulphuric acid neutralised **(ii)** the amount of ammonia liberated.

c Calculate the mass of ammonium chloride that will give this amount of ammonia.

d Find the percentage of ammonium chloride in the sample.

4.

The problem is to find the percentage of ammonia in a household cleaner. A 23.80 g sample of the cleaner is dissolved in water and made up to 250 cm^3. A 25.0 cm^3 sample of this solution needs 35.0 cm^3 of 0.360 mol dm^{-3} sulphuric acid for neutralisation.

a Write the equation for the reaction between ammonia and sulphuric acid to form $(NH_4)_2SO_4$.

b Find the amount of sulphuric acid used in the titration.

c Find **(i)** the amount **(ii)** the mass of ammonia in 25.0 cm^3 of solution.

d Find the mass of ammonia in the sample of cleaner and from this the percentage.

Answers

(1) 1.1 M (2) 3 L (3) 4.44×10^{-3} mol, 8.88×10^{-3} mol, 0.475 g, 95% (4) 0.0126 mol, 0.0252 mol, 0.4284 mol, 18%

5.

An impure sample of barium hydroxide $Ba(OH)_2$ of mass 1.6524 g was added to 100 cm^3 of 0.200 mol dm^{-3} hydrochloric acid. All the barium hydroxide reacted. The excess of acid needed 10.9 cm^3 of 0.200 mol dm^{-3} sodium hydroxide solution for neutralisation.

Calculate the percentage purity of the sample of barium hydroxide.

a Complete and balance the equation

$$Ba(OH)_2(s) + HCl(aq) \longrightarrow$$

b You want to find the amount of acid used. To do this, find the amount of acid left over. You can do this by finding the amount of sodium hydroxide used to neutralise it.

c What amount of acid was left unused after the reaction with barium hydroxide?

d What amount of acid was added originally?

e What amount of acid reacted with barium hydroxide?

f Now you can find **(i)** the amount **(ii)** the mass **(iii)** the percentage of barium hydroxide in the sample.

6.

A fertiliser contains ammonium sulphate and potassium sulphate. A sample of 0.225 g of fertiliser was warmed with sodium hydroxide solution.

$$(NH_4)_2SO_4(s) + 2NaOH(aq) \longrightarrow 2NH_3(g) + Na_2SO_4(aq)$$

The ammonia evolved was neutralised by 15.7 cm^3 of 0.100 mol dm^{-3} hydrochloric acid. Calculate the percentage of ammonium sulphate in the sample.

a Find the amount of hydrochloric acid used in the titration.

b Find the amount of ammonia neutralised.

c This will give you **(i)** the amount and **(ii)** the mass of ammonium sulphate in the sample.

d Now work out the percentage.

7.

Calculate the number of carboxyl groups per molecule in the compound $C_6H_8O_6$, given that 0.440 g of it neutralised 37.5 cm^3 of 0.200 mol dm^{-3} sodium hydroxide.

$$RCO_2H(aq) + NaOH(aq) \longrightarrow RCO_2Na(aq) + H_2O(l)$$

a Where do you start? You have data on sodium hydroxide so first find the amount of sodium hydroxide used.

b How many moles of $-CO_2H$ groups did it react with?

c How many moles of $C_6H_8O_6$ are present in 0.440 g?

d From **b** and **c** you now know how many $-CO_2H$ groups per molecule.

Answers: 5 2.18×10^{-3} mol, 2.18×10^{-3} mol, 2×10^{-2} mol, 8.91×10^{-3} mol, 91.88%
6. 1.57×10^{-3} mol, 1.57×10^{-3} mol, 0.10362 g, 46.05 % 7. 7.5 $\times10^{-3}$ mol, 7.5 $\times10^{-3}$ mol, 2.5×10^{-3} mol, 3

8.

Sodium carbonate crystals have the formula $Na_2CO_3 . nH_2O$. A 27.8230 g sample of crystals was dissolved in water and made up to 1.00 dm^3. 25.0 cm^3 of the solution were neutralised by 48.8 cm^3 of 0.1000 mol dm^{-3} hydrochloric acid. Find n in the formula for the crystals.

a Complete and balance the equation

$$Na_2CO_3(aq) + HCl(aq) \longrightarrow$$

b Find the amount of hydrochloric acid used.

c What amount of sodium carbonate did it neutralise?

d Find **(i)** the amount **(ii)** the mass of sodium carbonate present in 1.00 dm^3 of solution.

e You now know the mass of Na_2CO_3 in the sample and by subtraction, the mass of H_2O. From the masses and the molar masses you can find the formula of the crystals.

9.

A solution of potassium dichromate is standardised by titration with sodium ethanedioate solution. If 47.0 cm^3 of the dichromate solution were needed to oxidise 25.0 cm^3 of ethanedioate solution of concentration 0.0925 mol dm^{-3}, what is the concentration of the potassium dichromate solution?

10.

An excess of sodium hydroxide, 30.0 cm^3 of 1.00 mol dm^{-3} solution, reacted with 2.38 g of an impure sample of ethyl ethanoate.

$$CH_3CO_2C_2H_5(l) + NaOH(aq) \longrightarrow CH_3CO_2Na(aq) + C_2H_5OH(aq)$$

The remaining sodium hydroxide required 25.0 cm^3 of 0.100 mol dm^{-3} sulphuric acid for neutralisation. Calculate the percentage purity of ethyl ethanoate.

11.

a What volume of acidified potassium manganate(VII) of concentration 0.0200 mol dm^{-3} is decolourised by 100 cm^3 of hydrogen peroxide of concentration 0.0100 mol dm^{-3}? The equation is

$$MnO_4^-(aq) + H_2O_2(aq) + H^+(aq) \longrightarrow Mn^{2+}(aq) + O_2(g) + H_2O(l)$$

b What volume of oxygen is evolved at s.t.p.? (GMV = 22.4 dm^3 mol^{-1} at s.t.p.)

12.

A 25.0 cm^3 portion of a solution containing Fe^{2+} ions and Fe^{3+} ions was acidified and titrated against potassium manganate(VII) solution. 15.0 cm^3 of a 0.0200 mol dm^{-3} solution of potassium manganate(VII) were required. A second 25.0 cm^3 portion was reduced with zinc and titrated against the same manganate(VII) solution. 19.0 cm^3 of the oxidant solution were required. Calculate the concentrations of **a** Fe^{2+} and **b** Fe^{3+} in the solution.

Answers

(8) 4.88×10^{-3} mol, 2.44×10^{-3} mol, 0.976 g, 10.3456 g, x=10

(9) 0.016 mol dm^{-3}

(10) 92.4%

(11) 20 mL, 22.4 mL; (12) [Fe^{2+}] = 0.06 mol dm^{-3}; [Fe^{3+}] = 0.016 mol dm^{-3}

13.

Brass is an alloy of copper and zinc. It reacts with nitric acid to give a solution containing Cu^{2+} and Zn^{2+} ions. The concentration of Cu^{2+} can be found by reaction with an excess of potassium iodide

$$2Cu^{2+}(aq) + 4I^{-}(aq) \longrightarrow 2CuI(s) + I_2(aq)$$

followed by titration of iodine against thiosulphate

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

The iodine liberated by a 0.2055 g piece of brass required 13.7 cm^3 of 0.150 mol dm^{-3} thiosulphate solution.

Calculate the percentage of copper in brass.

14.

A piece of steel of mass 0.200 g reacts with dilute sulphuric acid. The resulting solution requires 34.0 cm^3 of 0.0200 mol dm^{-3} potassium manganate(VII) in acidic solution in a titration.

Calculate the percentage of iron in the steel.

15.

A piece of impure copper was allowed to react with dilute nitric acid. The copper(II) nitrate solution formed liberated iodine from an excess of potassium iodide solution. The iodine was estimated by titration with a solution of sodium thiosulphate. If a 0.877 g sample of copper was used, and the volume required was 23.7 cm^3 of 0.480 mol dm^{-3} thiosulphate solution, what is the percentage of copper in the sample?

16.

A 0.6125 g sample of potassium iodate(V), KIO_3, is dissolved in water and made up to 250 cm^3. A 25.0 cm^3 portion of the solution is added to an excess of potassium iodide in acid solution. The iodine formed requires 22.5 cm^3 of sodium thiosulphate solution for titration. What is the concentration of the thiosulphate solution?

$$IO_3^{-}(aq) + 5I^{-}(aq) + 6H^{+}(aq) \longrightarrow 3I_2(aq) + 3H_2O(l)$$

17.

The ammonium ion content of fertilisers can be found by heating the fertiliser with sodium hydroxide and passing the ammonia produced into an excess of hydrochloric acid.

(i) Write an equation for the reaction between ammonium sulphate and sodium hydroxide.

(ii) 3.00 g of a fertiliser mixture containing ammonium sulphate was made up to 250 cm^3 of solution. 25.0 cm^3 portions of this were added to an excess of sodium hydroxide solution, and the ammonia produced passed into 50.0 cm^3 of 0.100 mol dm^{-3} hydrochloric acid solution. The residual acid was then titrated with 0.100 mol dm^{-3} sodium hydroxide solution, 25.4 cm^3 being required. Find the percentage by mass of ammonium sulphate in the fertiliser mixture.

Answers 13. 63.26%, 14. 95.2%, 15. 81.76% 16. 0.0686 mol dm^{-3} 17. 54.12 %

18.

A household bleach contains sodium chlorate(I), NaOCl. The chlorate(I) ion will react with potassium iodide to give iodine, which can be estimated with a standard thiosulphate solution.

a Write the equations for the reaction of ClO^- and I^- to give I_2 and for the reaction of iodine and thiosulphate ions.

b A 25.0 cm^3 sample of household bleach is diluted to 250 cm^3. A 25.0 cm^3 portion of the solution is added to an excess of potassium iodide solution and titrated against 0.200 mol dm^{-3} sodium thiosulphate solution. The volume required is 18.5 cm^3. What is the concentration of sodium chlorate(I) in the bleach?

$$ClO^-(aq) + I^-(aq) + H^+(aq) \longrightarrow I_2(aq) + Cl^-(aq) + H_2O(l)$$
$$I_2(aq) + S_2O_3^{2-}(aq) \longrightarrow I^-(aq) + S_4O_6^{2-}(aq)$$

Not balanced

19.

The sulphur dioxide content of a wine can be found by titration. An analyst found that the sulphur dioxide in 50.0 cm^3 of a sample of white wine reacted with exactly 16.4 cm^3 of 0.0100 mol dm^{-3} aqueous iodine.

(i) How many moles of iodine, I_2, did the analyst use in the titration?

(ii) How many moles of sulphur dioxide were in the 50.0 cm^3 of wine?

(iii) What was the concentration, in mol dm^{-3}, of sulphur dioxide in the wine?

(iv) What was the concentration, in g dm^{-3}, of sulphur dioxide in the wine?

20.

(i) Potassium manganate(VII), $KMnO_4$, can be used in the quantitative estimation of ethanedioate ions, $C_2O_4^{2-}$, in an acidified aqueous solution. In this reaction, ethanedioate ions are converted into carbon dioxide. Deduce half equations for the redox processes involved and hence derive an equation for the overall reaction.

(ii) A 1.93 g sample of a crystalline ethanedioate salt was dissolved in water and made up to 250 cm^3. 25.0 cm^3 of this solution, after acidification, was found to react with 30.4 cm^3 of 0.0200 M $KMnO_4$. Calculate the percentage by mass of ethanedioate ions in the original salt.

21. Ammonium iron (II) sulfate have the following formula: $(NH_4)_2SO_4.FeSO_4.nH_2O$. In an experiment to determine *n*, 8.492 g of the salt was dissolved and was made into a 250 mL of the solution with dilute sulfuric acid and distilled water. A 25.00 mL solution was further acidified and titrated against $KMnO_4$ solution of concentration 0.015 mol dm^{-3}. A volume of 22.5 mL was required. Calculate the value of *n*.

Answers
18. 0.74 mol dm^{-3} 19. 1.64×10^{-4} mol, 1.64×10^{-4} mol, 3.28×10^{-4} mol, 0.21 g dm^{-3} 20. 69.3%
21. 12

22.

The sulphite of a Group I metal was oxidised by aqueous potassium dichromate(VI), $K_2Cr_2O_7$, under acidic conditions. 1.90 g of anhydrous metal sulphite was made up to 250 cm^3 of solution with acid and water. 20.0 cm^3 portions of this solution were titrated with 0.0200 mol dm^{-3} potassium dichromate(VI) from the burette.

The following burette readings were obtained;

	Trial	1	2	3
Final reading/cm^3	26.0	42.0	17.6	33.6
Start reading/cm^3	8.6	26.0	1.0	17.6

(i) What colour change would be observed during the titration reaction?

(ii) During the reaction, the sulphite ion is oxidised, and the dichromate(VI) ion is reduced to the chromium(III) ion. Give the ionic half-equations for *both* reactions. Hence show that 1 mole of dichromate(VI) ion oxidises 3 moles of sulphite ion.

(iii) What titre value would you use for the calculation?

(iv) Use the data to calculate the relative molecular mass of the metal sulphite. Identify the metal.

23.

Potassium manganate(VII) is an effective oxidizing agent when mixed with dilute sulphuric acid. It is able to oxidize iron(II) ions to iron(III) ions. Solutions containing $Fe^{2+}(aq)$ can be titrated against potassium manganate(VII) solution. This titration forms the basis of an analytical technique for the estimation of iron in substances such as flour.

1.00 g of a flour was vigorously shaken with dilute sulphuric acid and the volume of the solution was made up to 100 cm^3 in a volumetric flask. 10 cm^3 portions of the solution were titrated with 5.00×10^{-6} M potassium manganate(VII). An average titre of 11.0 cm^3 was recorded.

(i) Copy and complete the balancing of the equation for the titration reaction.

$$MnO_4^-(aq) + Fe^{2+}(aq) + H^+(aq) \longrightarrow Mn^{2+}(aq) + Fe^{3+}(aq) + H_2O(l)$$

(ii) Calculate the number of moles of manganate(VII) ion used in each titration.

(iii) Calculate the number of moles of iron(II) ions in 1.00 g of flour.

(iv) Flour must contain 1.65 mg of iron per 100 g of flour, by law. By carrying out an appropriate further calculation, decide if this flour contains sufficient iron to fulfil this legal requirement.

Answers

22. colorless to pink, 16 mL, 38.185 g mol^{-1}, K, 23. 1.54 mg

24.

In a textbook, the instructions for an experiment to find the value of x in the formula $Na_2CO_3 . xH_2O$ in a sample of hydrated sodium carbonate crystals were as follows:

> Weigh out accurately about 5 grams of soda crystals, being careful to select well-defined translucent crystals rather than those covered in powder. Dissolve these in a beaker of water, transfer to a 250 cm^3 flask, shake well and make up to the mark. Pipette 25.0 cm^3 of this solution into a conical flask, add a few drops of methyl orange and titrate with standard 0.2 M hydrochloric acid until the first permanent colour change is observed. Repeat to obtain two results within 0.1 cm^3 of each other.

A student who follows these instructions weighs out 4.90 g of the crystals and finds that an accurate titre of 17.7 cm^3 is required for neutralisation.

a What is meant by **standard** 0.2 M hydrochloric acid?

b **(i)** What colour change will be observed with the methyl orange?

(ii) Why did the instructions suggest the use of translucent crystals rather than those covered in powder?

c **(i)** How many moles of hydrochloric acid were used?

(ii) Write an equation for the reaction between the hydrochloric acid and the sodium carbonate solution.

(iii) Calculate the concentration of the sodium carbonate solution.

(iv) Calculate the value of x.

25.

Potassium iodate(V), KIO_3, is used in the standardisation of aqueous sodium thiosulphate.

Iodine is liberated from excess acidified aqueous potassium iodide according to

$$IO_3^-(aq) + 6H^+(aq) + 5I^-(aq) \longrightarrow 3I_2(aq) + 3H_2O(l)$$

and the liberated iodine is titrated against sodium thiosulphate.

a Write down the balanced equation for the reaction between iodine and sodium thiosulphate.

b A mass of 0.1500 g of potassium iodate(V), KIO_3, was dissolved in water and made up to 250.0 cm^3 of solution. 25.00 cm^3 of this solution was added to excess aqueous potassium iodide and aqueous acid and the liberated iodine just reacted with 22.60 cm^3 of aqueous sodium thiosulphate. Calculate the concentration of the potassium iodate(V) solution and hence the concentration of the aqueous sodium thiosulphate, in mol dm^{-3}.

Answers

24. A solution with accurate concentration, Orange to pink, because powder has lost the water of crystallization, 3.54×10^{-3} mol, 0.0708 mol dm^{-3}, X=10

25. 0.0185 mol dm^{-3}

26.

In order to analyse an impure sample of vanadium(V) oxide, a 0.200 g sample was treated with dilute sulphuric acid and an excess of sodium sulphite. A blue solution was formed containing vanadium(IV) as VO^{2+}. This solution required 20.0 cm^3 of 0.0200 M potassium manganate(VII) to convert all the vanadium back into the vanadium(V) state as VO_2^+. The equations for the reactions which occurred were

$$V_2O_5 + 2H^+ \longrightarrow 2VO_2^+ + H_2O$$
$$2VO_2^+ + SO_3^{2-} + 2H^+ \longrightarrow 2VO^{2+} + SO_4^{2-} + H_2O$$
$$5VO^{2+} + MnO_4^- + H_2O \longrightarrow Mn^{2+} + 5VO_2^+ + 2H^+$$

Use these data to calculate the percentage by mass of vanadium in the sample of vanadium(V) oxide.

V= 51

27.

A 1.00 g sample of sodium hydride was added to water and the resulting solution was diluted to a volume of exactly 250 cm^3.

(i) Calculate the concentration, in mol dm^{-3}, of the sodium hydroxide solution formed.

(ii) Calculate the volume of hydrogen gas evolved, measured at 293 K and 100 kPa.

(iii) Calculate the volume of 0.112 M hydrochloric acid which would react exactly with a 25.0 cm^3 sample of the sodium hydroxide solution.

28.

1.50 g of an impure sample of silicon tetrachloride was weighed out on an accurate balance. It was cautiously added to water and when the reaction was complete, the mixture was made up to 250 cm^3 with pure water.

A 25.0 cm^3 portion was titrated, using a suitable indicator, with 0.100 M sodium hydroxide solution. 30.0 cm^3 was needed for neutralization.

(i) What piece of apparatus would you use for

A making up the solution to exactly 250 cm^3?

B removing a 25.0 cm^3 portion for the titration?

(ii) Suggest a suitable indicator for this titration and give the colour change.

(iii) The procedure described is incomplete. Suggest TWO important steps that the student should have taken to ensure an accurate result.

(iv) Use the information given and the equation

$$SiCl_4(l) + 2H_2O(l) \longrightarrow SiO_2(s) + 4HCl(aq)$$

to calculate the percentage purity of the sample of silicon tetrachloride.

Answers: 26. 51%; 27. 0.167 mol dm^{-3}, 1012 mL, 37.27 mL; 28. Volumetric flask, Pipette, Phenolphthalein, Repeat the titration, use another sample, and repeat the procedure, 85 %