# Moles and Stoichiometry

Theory Questions

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## Contents

## MASS and MOLES

**Question 1.**

**(d)** Cement is made by heating calcium carbonate and clay together at a very high temperature.

One of the compounds produced is a form of calcium silicate, $Ca_3SiO_5$.

In the presence of water a chemical reaction takes place that helps in the setting of cement.

$$2Ca_3SiO_5 + 6H_2O \rightarrow Ca_3Si_2O_7.3H_2O + 3Ca(OH)_2$$

Calculate the mass of calcium hydroxide formed from 912 g of $Ca_3SiO_5$.

.....

.....

.....

.....

..... [3]

s/06/qp2

**Question 2.**

**(c)** Potassium sulphate can be prepared by the reaction between dilute sulphuric acid and potassium carbonate.

$$H_2SO_4 + K_2CO_3 \rightarrow K_2SO_4 + CO_2 + H_2O$$

Calculate the mass of potassium sulphate that can be prepared from 3.45 g of potassium carbonate. [3]

s/06/qp2

**Question 3.**

**B9** Hydrogen and iodine react together to form hydrogen iodide in a reversible redox reaction. The forward reaction is endothermic.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H = +53 \text{ kJ mol}^{-1}$$

Hydrogen and hydrogen iodide are colourless gases whereas iodine gas is purple.

**(c)** Calculate the maximum mass of hydrogen iodide that can be made from 45.3 g of hydrogen.

maximum mass of hydrogen iodide = ..... g [3]

s/10/qp22

**Question 4.**

**(b)** Octane burns in air.

$$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$$

A petrol-powered motor car travels at a constant speed of 80 km/h. For every kilometre travelled 108 g of carbon dioxide are formed.

When the motor car travels 100 km calculate

**(i)** the mass of carbon dioxide emitted by the car,

[1]

**(ii)** the mass of petrol burned by the car assuming that petrol is 100% octane.

[4]

s/09/qp2

**Question 5.**

**(iv)** Calculate the mass of uranium that can be made from 1.00 tonne of uranium(IV) oxide.

[One tonne is one million grams.]

mass of uranium = ..... tonnes [3]

s/11/qp21

**Question 6.**

**B7** Nitric oxide, NO, is an atmospheric pollutant formed inside car engines by the reaction between nitrogen and oxygen.

$$N_2(g) + O_2(g) \longrightarrow 2NO(g) \quad \Delta H = +66\,kJ\,mol^{-1}$$

This reaction is endothermic.

**(c)** Calculate the mass of nitric oxide formed when 100 g of nitrogen reacts completely with oxygen.

mass of nitric oxide = ..... g [3]

s/11/qp22

**Question 7.**

**(c)** Fermentation converts glucose into ethanol, a biofuel.

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

**(i)** State **two** essential conditions for fermentation to take place.

1 .....

2 .....[2]

**(ii)** Calculate the maximum mass of ethanol that can be made from 1 tonne of glucose.
[One tonne is one million grams.]

maximum mass of ethanol = ..... tonne [3]

s/11/qp22

**Question 8.**

$2\ NaCl \rightarrow 2\ Na + Cl_2$

**(b)** Chlorine is manufactured by the electrolysis of concentrated sodium chloride.

**(i)** Write equations for both of the electrode reactions.

**(ii)** Calculate the maximum volume of chlorine, at r.t.p., which can be obtained from 175.5 kg sodium chloride.

[5]

w/01/qp2

**Question 9.**

**(b)** Ammonium sulphate can be made by reacting aqueous ammonia with dilute sulphuric acid.

$$2NH_3(aq) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq)$$

Calculate the mass of ammonium sulphate that can be made from 51 g ammonia.

.....

.....

..... [3]

w/04/qp2

**Question 10.**

**(d)** Methylamine is made by reacting methanol with excess ammonia under pressure in the presence of a catalyst.

$$CH_3OH + NH_3 \rightarrow CH_3NH_2 + H_2O$$

**(i)** Define the term *catalyst*.

.....[1]

**(ii)** Calculate the theoretical yield of methylamine that can be obtained from 240 kg of methanol.

[2]

w/08/qp2

**Question 11.**

**(e)** Solid zinc chloride absorbs ammonia to form tetrammine zinc chloride, $Zn(NH_3)_4Cl_2$.

$$ZnCl_2 + 4NH_3 \rightarrow Zn(NH_3)_4Cl_2$$

Calculate the maximum yield, in grams, of tetrammine zinc chloride formed when 3.4 g of zinc chloride reacts with excess ammonia.

[2]

w/10/qp22

**Question 12.**

**(e)** Molybdenum, atomic number 42, is manufactured by the displacement reaction between molybdenum(VI) oxide and aluminium.

$$MoO_3 + 2Al \longrightarrow Mo + Al_2O_3$$

Calculate the mass of aluminium needed to make 1 tonne of molybdenum.
[1 tonne is one million grams.]

mass of aluminium = ..... [2]

s/12/qp21

## Moles and Heat Energy

**Question 13.**

**B9** Hydrogen has many industrial uses. One possible way to manufacture hydrogen involves the reversible reaction between methane and steam.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \quad \Delta H = +210\,kJ/mol$$

The reaction is carried out in the presence of a nickel catalyst. The conditions used are 30 atmospheres pressure and a temperature of 750 °C.

**(d)** In the reaction, 210 kJ of heat energy is used to form 3.0 moles of hydrogen.

Calculate how much heat energy is needed to make 1000 kg of hydrogen.

heat energy = ..... kJ [2]

s/12/qp21

**Question 14.**

**B9** Methanol, $CH_3OH$, is manufactured from carbon dioxide and hydrogen.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g) \quad \Delta H = -49\,kJ/mol$$

**(c)** In the reaction when 3.0 moles of hydrogen react, 49 kJ of heat energy is released.

Calculate how much heat energy is released when 500 kg of hydrogen react.

heat energy = ..... kJ [2]

w/12/qp22

## CONCENTRATION and MOLES

**Question 15.**

**(d)** The mass of iron(II) ions in a sample of fertiliser can be determined by the reaction between iron(II) ions and acidified potassium manganate(VII), $KMnO_4$.

A student analysed a sample of the fertiliser. He dissolved the sample in 25.0 $cm^3$ of dilute sulphuric acid and titrated the solution formed with 0.0200 $mol/dm^3$ potassium manganate(VII).

The student used 22.5 $cm^3$ of potassium manganate(VII) to reach the end-point.

**(i)** Calculate the number of moles of potassium manganate(VII) used in the titration.

..... moles [1]

**(ii)** One mole of potassium manganate(VII) reacts with five moles of iron(II) ions. Calculate the mass, in grams, of iron(II) ions in the sample analysed.

..... g [2]

[Total: 9]

s/07/qp2

**(e)** An impure sample of iron(II) sulphate was analysed by titration.

The sample was dissolved in 25.0 $cm^3$ of dilute sulphuric acid and then titrated against 0.0400 $mol/dm^3$ potassium dichromate(VI) solution.

19.0 $cm^3$ of potassium dichromate(VI) solution was required to reach the end-point.

**(i)** Calculate the number of moles of potassium dichromate(VI) used in the titration.

..... moles [1]

**(ii)** One mole of potassium dichromate(VI) reacts with six moles of iron(II) ions. Calculate the mass, in grams, of iron(II) ions in the sample analysed.

mass of iron(II) ions..... g [2]

[Total: 11]

s/08/qp2

**Question 16.**

Sulfamic Acid = $SO_3NH_3$

**(c)** A 0.105 g sample of sulfamic acid is dissolved in 25.0 $cm^3$ of water. The sulfamic acid solution requires 10.8 $cm^3$ of 0.100 $mol\,dm^{-3}$ potassium hydroxide for complete neutralisation.

Calculate the number of moles of sulfamic acid that react with one mole of potassium hydroxide.

number of moles of sulfamic acid = ..... [3]

s/11/qp21

**Question 17.**

$Na_2O + H_2O \rightarrow 2\ NaOH$

Sodium oxide reacts with water to form sodium hydroxide.

**(b)** Write an equation for this reaction.

.....[1]

**(c)** 62 g of sodium oxide are used to make 2 $dm^3$ of aqueous sodium hydroxide.
What is the concentration of the sodium hydroxide solution?

Answer ..... $mol/dm^3$ [2]

w/03/qp2

**Question 18.**

**(d)** 12.0 $cm^3$ of an aqueous solution of sulphuric acid exactly neutralised 20.0 $cm^3$ of a solution of sodium hydroxide of concentration 0.150 $mol/dm^3$.

$$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$$

Calculate the concentration, in $mol/dm^3$ of the aqueous sulphuric acid. [3]

w/06/qp2

**Question 19.**

**(iii)** 25.0 $cm^3$ of an aqueous solution of calcium hydroxide is exactly neutralised by 18.0 $cm^3$ of 0.040 $mol/dm^3$ hydrochloric acid.

$$Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$$

Calculate the concentration, in $mol/dm^3$, of the aqueous calcium hydroxide.

concentration = .....$mol/dm^3$ [3]

w/08/qp2

**Question 20.**

**(b)** A solution of fumaric acid was titrated against aqueous sodium hydroxide.

$$HO_2CCH{=}CHCO_2H + 2NaOH \rightarrow NaO_2CCH{=}CHCO_2Na + 2H_2O$$

18.0 $cm^3$ of 0.200 $mol/dm^3$ sodium hydroxide were required to neutralise 60.0 $cm^3$ of fumaric acid solution.
Calculate the concentration, in $mol/dm^3$, of the fumaric acid solution.

.....

.....

.....

.....

.....

..... [3]

w/09/qp2

**Question 21.**

**(e)** An aqueous solution of calcium hydroxide was titrated with 0.0150 $mol/dm^3$ hydrochloric acid.

$$Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$$

It required 6.00 $cm^3$ of this aqueous hydrochloric acid to neutralise 20.0 $cm^3$ of the calcium hydroxide solution.
Calculate the concentration, in $mol/dm^3$, of the calcium hydroxide solution.

[3]

w/10/qp22

**Question 22.**

**B6** Seawater contains many dissolved ions. The table shows the concentration of some of these ions in a typical sample of seawater.

| ion | formula | concentration / $g/dm^3$ |
|---|---|---|
| chloride | $Cl^-$ | 19.00 |
| sodium | $Na^+$ | 10.56 |
| sulfate | $SO_4^{2-}$ | 2.65 |
| magnesium | $Mg^{2+}$ | 1.26 |
| calcium | $Ca^{2+}$ | 0.40 |
| potassium | $K^+$ | 0.38 |
| hydrogencarbonate | $HCO_3^-$ | 0.14 |

**(a)** Suggest the formula of one salt dissolved in seawater.

..... [1]

**(b)** Calculate the concentration, in $mol/dm^3$, of sulfate ions in seawater.

.....

.....

..... [1]

s/12/qp21

**Question 23.**

**(b)** The student uses 25.0 $cm^3$ of 1.60 $mol/dm^3$ sodium hydroxide to prepare the crystals.

$$2NaOH(aq) + H_2SO_4(aq) + 8H_2O(l) \longrightarrow Na_2SO_4.10H_2O(s)$$

Calculate the maximum mass of hydrated sodium sulfate crystals that can be formed.

[4]

**(c)** When hydrated sodium sulfate crystals are heated gently, water is given off.

Describe a chemical test for water.

test .....

observation ..... [2]

w/11/qp21

**Question 24.**

$Mg + H_2SO_4 \rightarrow MgSO_4 + H_2$

**(ii)** A student reacts 3.0 g of magnesium with 2.5 $mol/dm^3$ sulfuric acid.
Calculate the minimum volume of sulfuric acid that reacts with all the magnesium.

[2]

w/11/qp22

**Question 25.**

**(c)** Chlorine reacts with cold dilute sodium hydroxide to form sodium chlorate(I), NaC*l*O, sodium chloride and water.
Construct an equation for this reaction.

[1]

**(d)** The concentration of sodium chlorate(I) in a solution can be found by reacting sodium chlorate(I) with excess acidified potassium iodide and then titrating the iodine liberated with aqueous sodium thiosulfate, $Na_2S_2O_3$.

$$I_2 + 2Na_2S_2O_3 \rightarrow 2NaI + Na_2S_4O_6$$

A solution of sodium thiosulfate contains 12.4 g of sodium thiosulfate, $Na_2S_2O_3.5H_2O$, in 1.00 $dm^3$ of solution.

**(i)** Calculate the concentration of the sodium thiosulfate solution in mol/$dm^3$.

concentration = ..... mol/$dm^3$ [1]

**(ii)** 23.6 $cm^3$ of this sodium thiosulfate solution reacts with exactly 12.5 $cm^3$ of aqueous iodine.
Calculate the concentration, in mol/$dm^3$, of the aqueous iodine.

[3]

**(b)** Nickel carbonyl has the formula $Ni(CO)_x$.
The relative molecular mass of nickel carbonyl is 171.
Calculate the value of x.

value of x = .....[1]

w/12/qp22

**Question 26.**

**(c)** Sulfuric acid is formed from sulfur trioxide in two stages.
Firstly, the sulfur trioxide, $SO_3$, is absorbed in concentrated sulfuric acid to form oleum, $H_2S_2O_7$.

$$SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$$

The oleum is then mixed with water to form sulfuric acid.
Construct an equation for this reaction.

[1]

**(d)** Aqueous sulfuric acid is titrated with aqueous sodium hydroxide.

$$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$$

It requires 28.0 $cm^3$ of 0.100 $mol/dm^3$ aqueous sodium hydroxide to neutralise 9.50 $cm^3$ of sulfuric acid.
Calculate the concentration, in $mol/dm^3$, of the aqueous sulfuric acid.
Give your answer to 3 significant figures.

concentration of the aqueous sulfuric acid ..... $mol/dm^3$ [3]

w/12/qp21

## VOLUME OF GAS

**Question 27.**

**B7** Hydrazine, $N_2H_4$, is a liquid that has been used as a rocket fuel. It reacts with oxygen as shown in the equation.

$$N_2H_4 + O_2 \rightarrow N_2 + 2H_2O$$

**(c) (i)** Calculate the volume of oxygen, measured at room temperature and pressure, needed to completely combust 1.00 tonne of hydrazine.
[One tonne is $10^6$ grams. One mole of any gas at room temperature and pressure occupies a volume of 24 $dm^3$.]

volume of oxygen = ..... $dm^3$ [3]

**(ii)** A rocket burns hydrazine in an atmosphere of oxygen. Both hydrazine and oxygen are stored in the rocket as liquids. Suggest why oxygen is stored as a liquid rather than as a gas.

.....

..... [1]

s/10/qp22

**Question 28.**

**Stage 2:** the nitrogen dioxide is converted to nitric acid.

$$4NO(g) + 2H_2O(g) + 3O_2(g) \rightarrow 4HNO_3(aq)$$

**(c)** Calculate the maximum mass of nitric acid which can be made from 720 $dm^3$ of nitrogen(II) oxide, NO, at room temperature and pressure. [3]

w/02/qp2

**Question 29.**

1 mol $MgCO_3$ or $ZnCO_3$ produces 1 mol $CO_2$

**(b)** Calculate the maximum volume of carbon dioxide, at room temperature and pressure, that can be formed from 10.5 g of magnesium carbonate. [3]

**(c)** The experiment was repeated under the same conditions using zinc carbonate instead of magnesium carbonate.

**(i)** Describe how the rates of the reactions would be different. Explain your answer.

**(ii)** The same mass (10.5 g) of zinc carbonate was used. Would the total volume of carbon dioxide formed be the same? Explain your answer. [4]

w/04/qp2

**Question 30.**

**5** An experiment was carried out to measure the rate of reaction between excess powdered calcium carbonate and dilute acids.

**(a)** In **Experiment 1**, 25 $cm^3$ of 1.5 $mol/dm^3$ hydrochloric acid was used.

Complete the equation for the reaction by filling in the missing state symbols.

**(i)** $2HCl(.....) + CaCO_3(.....) \rightarrow CaCl_2(aq) + H_2O(.....) + CO_2(.....)$

**(ii)** Calculate the total volume of carbon dioxide that is made from this reaction at r.t.p.

[4]

w/05/qp2

**Question 31.**

**B9** Phosphine, $PH_3$, is a gas which has a smell of garlic. It is formed when white phosphorus is warmed with aqueous sodium hydroxide.

$$4P + 3NaOH + 3H_2O \rightarrow PH_3 + 3NaH_2PO_2$$

**(a)** Draw a 'dot-and-cross' diagram for phosphine.

Show only the outer electrons.

[1]

**(b)** **(i)** Calculate the maximum mass of phosphine formed when 1.86 g of phosphorus reacts with excess aqueous sodium hydroxide.

[2]

**(ii)** Calculate the volume of phosphine formed from 1.86 g of phosphorus at r.t.p.

[1]

**(c)** Phosphine decomposes into its elements on warming. Write an equation for this reaction.

.....[2]

w/10/qp21

**Question 32.**

**(d)** The overall reaction for the electrolysis of aqueous sodium hydroxide is shown below.

$$2H_2O(l) \longrightarrow 2H_2(g) + O_2(g)$$

This reaction is endothermic.

**(i)** Explain, in terms of the energy changes associated with bond breaking and bond forming, why the reaction is endothermic.

.....

.....

.....

..... [2]

**(ii)** Some submarines use this reaction to provide oxygen for the occupants to breathe.

Calculate the mass of water which must be electrolysed to make 2500 $dm^3$ of oxygen at room temperature and pressure.
[One mole of any gas at room temperature and pressure occupies a volume of 24 $dm^3$.]

mass of water = ..... g [3]

s/12/qp21

**Question 33.**

$2\ H_2 + O_2 \rightarrow 2\ H_2O$

**(c)** A hydrogen-oxygen fuel cell uses 2000 $dm^3$ of hydrogen measured at room temperature and pressure.
Calculate the volume of oxygen, measured at room temperature and pressure, used by the fuel cell.
[One mole of any gas at room temperature and pressure occupies a volume of 24 $dm^3$.]

.....

.....

.....

volume of oxygen = ..... $dm^3$ [2]

w/12/qp22

**Question 34.**

**B9** Hydrogen fluoride, hydrogen chloride and hydrogen iodide are all acidic gases.

**(a)** A student makes hydrogen chloride by reacting sodium chloride with excess concentrated sulfuric acid at room temperature and pressure.

$$NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl$$

**(i)** Calculate the maximum volume of hydrogen chloride that can be made from 0.2 moles of sodium chloride at room temperature and pressure.

[1]

**(ii)** Draw a 'dot-and-cross' diagram for hydrogen chloride.
Show only the outer electrons.

[1]

w/11/qp21

**Question 35.**

**(d)** A student ignites a mixture of 15 $cm^3$ of propane and 100 $cm^3$ of oxygen. The oxygen is in excess. All measurements of volume are taken at room temperature and pressure.

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$$

Calculate

the volume of carbon dioxide formed,

..... $cm^3$ [1]

the volume of unreacted oxygen remaining.

..... $cm^3$ [1]

**(e)** Explain why the **incomplete** combustion of an alkane in an enclosed space is hazardous.

.....

..... [2]

w/11/qp22

## LIMITING and EXCESS REACTANTS

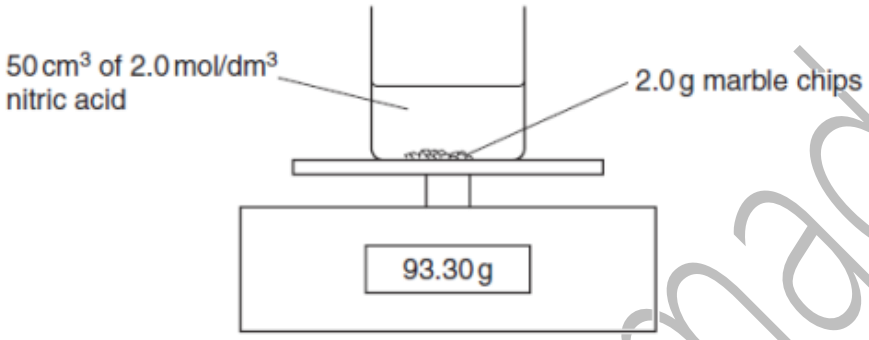
**Question 36.**

**A5** Marble statues are being damaged by acid rain. The chemical name for marble is calcium carbonate.

A student investigated the reaction between marble chips and nitric acid.

$$CaCO_3(s) + 2HNO_3(aq) \rightarrow Ca(NO_3)_2(aq) + H_2O(l) + CO_2(g)$$

The diagram shows the apparatus the student used.




The student recorded the balance reading every minute.

The table shows the results.

| time / minutes | balance reading / g |
|---|---|
| 0 | 93.30 |
| 1 | 93.28 |
| 2 | 93.26 |
| 3 | 93.24 |
| 4 | 93.22 |
| 5 | 93.21 |
| 6 | 93.20 |
| 7 | 93.19 |
| 8 | 93.18 |
| 9 | 93.17 |
| 10 | 93.16 |
| 11 | 93.15 |
| 12 | 93.15 |
| 13 | 93.14 |
| 14 | 93.14 |

**(a)** Explain why the balance reading decreases during the experiment.

.....

.....[1]

**(b)** How can the student tell when the reaction has finished?

.....

.....[1]

**(c)** **(i)** Calculate the number of moles of nitric acid in 50 $cm^3$ of 2.0 mol / $dm^3$ solution.

**(ii)** Calculate the number of moles of calcium carbonate in 2.0 g.

**(iii)** Which reagent, calcium carbonate or nitric acid, is in excess?
Explain your answer.

[5]

**(d)** The student repeats the experiment using the same quantities of calcium carbonate and nitric acid. This time the acid is at a higher temperature. Describe and explain, in terms of collisions between reacting particles, the effect of increasing the temperature on the rate of reaction.

.....

.....

.....[2]

s/03/qp2

**Question 37.**

**B9** Dilute ethanoic acid and dilute hydrochloric acid both react with magnesium ribbon to form hydrogen.

**(a)** Give the formula of one ion found in both of these dilute acids. [1]

**(b)** Magnesium ribbon reacts with hydrochloric acid as shown in the equation.

$$Mg + 2HCl \longrightarrow MgCl_2 + H_2$$

A 0.24 g sample of magnesium ribbon is added to 5.0 $cm^3$ of 2.0 $mol/dm^3$ hydrochloric acid.

**(i)** Which reactant, magnesium or hydrochloric acid, is in excess? Use calculations to explain your answer. [2]

**(ii)** Calculate the maximum mass of magnesium chloride that can be formed in this reaction. [2]

**(iii)** A 0.24 g sample of magnesium ribbon is added to 5.0 $cm^3$ of 2.0 $mol/dm^3$ ethanoic acid.
Explain why this reaction forms the same volume of hydrogen but takes place much more slowly than the reaction of the same mass of magnesium with 5.0 $cm^3$ of 2.0 $mol/dm^3$ hydrochloric acid. [3]

**(c)** **(i)** Write an equation for the reaction between dilute ethanoic acid and sodium carbonate. [1]

**(ii)** What observations would be made during this reaction? [1]

[Total: 10]

s/08/qp2

**Question 38.**

**A3** Analysis of a compound **Z** obtained from the planet Mars showed **Z** has the following composition.

| element | percentage by mass |
|---|---|
| potassium | 39.4 |
| iron | 28.3 |
| oxygen | 32.3 |

**(a)** Show that the empirical formula of **Z** is $K_2FeO_4$.

.....

.....

.....

.....

..... [2]

**(b)** $K_2FeO_4$ can be prepared in the laboratory by the reaction between iron(III) oxide, $Fe_2O_3$, chlorine, $Cl_2$, and potassium hydroxide, KOH.

$$Fe_2O_3 + 3Cl_2 + 10KOH \longrightarrow 2K_2FeO_4 + 6KCl + 5H_2O$$

A 2.00 g sample of $Fe_2O_3$ is added to 20.0 $cm^3$ of 4.00 mol $dm^{-3}$ KOH.

**(i)** Calculate the amount, in moles, of $Fe_2O_3$ used.

.....

..... [2]

**(ii)** Calculate the amount, in moles, of KOH used.

.....

..... [1]

**(iii)** Which reagent, $Fe_2O_3$ or KOH, is in excess in this reaction?

.....

Explain your answer.

.....

..... [1]

s/10/qp21

**Question 39.**

**(c)** Magnesium reacts with propanoic acid to form magnesium propanoate and hydrogen.

$$Mg + 2C_2H_5CO_2H \rightarrow (C_2H_5CO_2)_2Mg + H_2$$

A student added 4.80 g of magnesium to 30.0 g of propanoic acid.

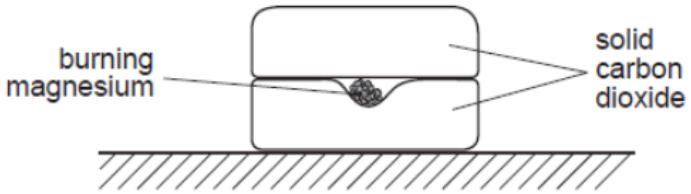
**(i)** Which one of these reactants, magnesium or propanoic acid, is in excess? Explain your answer. [2]

**(ii)** Calculate both the number of moles of hydrogen and the volume of hydrogen formed at r.t.p. [2]

w/07/qp2

**Question 40.**

**A2** Several small pieces of magnesium are placed on a block of solid carbon dioxide. The solid carbon dioxide is at a temperature of -60 °C. The magnesium is ignited and another block of solid carbon dioxide is immediately placed on top.




A vigorous reaction is observed.

$$2Mg + CO_2 \rightarrow 2MgO + C$$

**(a)** Suggest what could be seen as the reaction proceeds to completion.

.....

..... [2]

**(b)** Why is another block of solid carbon dioxide placed above the burning magnesium?

..... [1]

**(c)** State **one** factor in the experiment which slows down the reaction.

..... [1]

**(d)** When 2 moles of magnesium react with one mole of carbon dioxide, 810 kJ of energy are released.
Calculate the energy released when 2.0 g of magnesium reacts completely with carbon dioxide.

[2]

**(e)** In a second experiment 6.0 g of magnesium and 4.4 g of carbon dioxide are used. Which solid, magnesium or carbon dioxide is in excess?
Show your working.

[2]

w/08/qp2

## PERCENTAGE YIELD

**Question 41.**

**(d)** Ethanol can also be manufactured from glucose, $C_6H_{12}O_6$.

$$C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH.$$

A solution containing 18 kg of glucose makes only 0.92 kg of ethanol.
Calculate the percentage yield of ethanol.

[3]

s/09/qp2

**Question 42.**

**B8** One of the reactions in the manufacture of nitric acid involves the oxidation of ammonia. This reaction is exothermic.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \quad \Delta H = -909\,kJ\,mol^{-1}$$

**(b)** A factory uses 100 tonnes of ammonia each day to produce 160 tonnes of nitrogen monoxide, NO.
Calculate the percentage yield of nitrogen monoxide.

percentage yield = ..... % [3]

s/10/qp21

**Question 43.**

**B8** Ethanoic acid is manufactured by a reaction between methanol, $CH_3OH$, and carbon monoxide.

$$CH_3OH + CO \rightleftharpoons CH_3COOH \quad \Delta H = -137\,kJ\,mol^{-1}$$

This reaction is exothermic.

**(d)** In an investigation 10.0 moles of methanol are mixed with 20.0 moles of carbon monoxide.
At the end of the reaction 9.8 moles of ethanoic acid are formed.
Calculate the percentage yield of ethanoic acid.

percentage yield = ..... % [2]

s/11/qp21

**Question 44.**

**B9** **(a)** Define the term *relative atomic mass*.

.....

..... [1]

**(b)** The relative atomic mass of magnesium can be determined in the laboratory by finding the volume of hydrogen given off when magnesium reacts with hydrochloric acid.

$$Mg + 2HCl \longrightarrow MgCl_2 + H_2$$

0.036 g of magnesium reacts at room temperature and pressure with excess hydrochloric acid to produce 36 $cm^3$ of hydrogen.
1 mole of any gas at room temperature and pressure occupies 24 $dm^3$.
Show by calculation that the relative atomic mass of magnesium is 24.

[3]

**(c)** Magnesium reacts with oxygen in the air to form magnesium oxide.

$$2Mg + O_2 \longrightarrow 2MgO$$

**(i)** If the yield of the reaction is 75% calculate the mass of magnesium oxide formed when 12 kg of magnesium burns in excess air.

[2]

**(ii)** Magnesium nitride is also formed when magnesium burns in air.
Magnesium nitride is an ionic compound.
Deduce the formula for magnesium nitride.

..... [1]

w/12/qp21

## PERCENTAGE COMPOSITION

**Question 45.**

**A2** Iron(II) sulphate, $FeSO_4$, is easily oxidised to iron(III) sulphate.

**(a)** Calculate the percentage by mass of iron in iron(II) sulphate.

..... % [2]

s/08/qp2

**Question 46.**

**B10** The table below shows some of the ores of iron.

| ore | formula |
|---|---|
| haematite | $Fe_2O_3$ |
| magnetite | $Fe_3O_4$ |
| siderite | $FeCO_3$ |

**(a)** Which ore in the table contains the greatest percentage by mass of iron? Explain your answer. [2]

s/04/qp2

**Question 47.**

**A2** A fertiliser contains three compounds:

- ammonium sulphate, $(NH_4)_2SO_4$,
- iron(II) sulphate, $FeSO_4$,
- sand, $SiO_2$.

**(a)** Calculate the percentage by mass of nitrogen in ammonium sulphate.

..... % [2]

s/07/qp2

**Question 48.**

**(c)** Verdigris has the formula $[Cu(CH_3CO_2)_2]_2.Cu(OH)_2.xH_2O$.
It has a relative formula mass of 552.
Calculate the value of **x** in the formula.

**x** is ..... [2]

[Total: 5]

s/07/qp2

**Question 49.**

**(ii)** Calculate the percentage by mass of nitrogen in ammonium phosphate.

% by mass = ..... [2]

s/10/qp22

**Question 50.**

**B10** Fertilisers supply the essential elements, nitrogen, phosphorus and potassium for plant growth.
A bag of fertiliser contains 500 g of ammonium sulfate, $(NH_4)_2SO_4$, and 500 g of potassium nitrate, $KNO_3$.

**(a)** Calculate the percentage by mass of nitrogen in the bag of fertiliser.

[4]

s/09/qp2

**Question 51.**

**(d)** Farmers that grow vegetable oil crops often use large quantities of ammonium nitrate fertiliser, $NH_4NO_3$.
Calculate the percentage by mass of nitrogen in ammonium nitrate.

percentage = ..... % [2]

s/11/qp22

**Question 52.**

**(iii)** Calculate the percentage of copper by mass in $Cu_2O$.

[5]

w/05/qp2

**Question 53.**

**(d)** Fertilisers are added to the soil to improve crop yields.
A farmer has the choice of two fertilisers, ammonium nitrate, $NH_4NO_3$, or diammonium hydrogen phosphate, $(NH_4)_2HPO_4$.

Show by calculation which of these fertilisers contains the greater percentage of nitrogen by mass.
You must show your working. [3]

w/06/qp2

**Question 54.**

**(ii)** Another compound of bromine and fluorine is bromine(V) fluoride, $BrF_5$.
Calculate the percentage of bromine by mass in bromine(V) fluoride.

[2]

w/11/qp22

**Question 55.**

**(c)** Ammonium nitrate, $NH_4NO_3$, and ammonium sulfate, $(NH_4)_2SO_4$, are commonly used in fertilisers.

**(i)** Calculate the percentage of nitrogen by mass in ammonium nitrate.

[3]

w/12/qp22

## EMPIRICAL FORMULA

**Question 56.**

**(c)** Analysis of an organic acid isolated from red ants shows that it contains 0.060 g of carbon, 0.010 g of hydrogen and 0.16 g of oxygen.
Calculate the empirical formula for this acid. [2]

s/03/qp2

**Question 57.**

**(c)** Ethene can also be converted into a compound that contains carbon, hydrogen and oxygen. A sample of the compound was analysed and found to contain 0.72 g of carbon, 0.18 g of hydrogen and 0.96 g of oxygen.
Show that the empirical formula of the compound is $CH_3O$. [3]

s/04/qp2

**Question 58.**

**(e)** A sample of a compound of iron is analysed. The sample contains 0.547 g of potassium, 0.195 g of iron, 0.252 g of carbon and 0.294 g of nitrogen.
Calculate the empirical formula of this compound.

Answer .....[3]

s/05/qp2

**Question 59.**

**B8** An ester is made from a carboxylic acid and an alcohol.

The carboxylic acid has the molecular formula $C_4H_8O_2$. Analysis of the alcohol shows it has the following percentage composition by mass:
52.2% carbon; 13.0% hydrogen; 34.8% oxygen.

**(iii)** What is the empirical formula for the carboxylic acid?

..... [1]

**(b)** Calculate the empirical formula for the alcohol.

.....

.....

.....

.....

..... [2]

s/10/qp2

**Question 60.**

**A2** Small pieces of copper were added to excess concentrated sulfuric acid and the mixture heated for 30 minutes. A colourless gas **Z** was formed. When **Z** was tested with filter paper dipped into acidified potassium dichromate(VI), there was a colour change from orange to green.

The reaction mixture was cooled and then diluted with water. A blue solution, **Y**, was formed. Aqueous sodium hydroxide was added drop by drop to the blue solution. Eventually a blue precipitate, **X**, was formed. On heating the blue precipitate turned black to form compound **V**. Analysis of **V** showed that it contained 79.9 % copper and 20.1 % oxygen by mass.

**(e)** Calculate the empirical formula of the black solid **V**.

empirical formula of **V** is ..... [2]

s/11/qp21

**Question 61.**

**(c)** Butanoic acid can be converted into an ester by heating it with an alcohol and a few drops of concentrated sulphuric acid.

A sample of an ester contains 0.18 g of carbon, 0.03 g of hydrogen and 0.08 g of oxygen. The relative molecular mass of the ester is 116.
Calculate both the empirical and molecular formulae of this ester. [3]

w/06/qp2

**Question 62.**

**(c)** Carbon monoxide reacts with nickel to form a compound containing nickel, carbon and oxygen only. Analysis of 5.70 g of this compound showed that it contained 1.97 g nickel, 1.60 g carbon and 2.13 g oxygen.
Determine the empirical formula of this compound. [3]

w/07/qp2

**Question 63.**

**(c)** Analysis of 10.0 g of carboxylic acid **X** shows that it contains 2.67 g carbon, 0.220 g hydrogen and 7.11 g oxygen.

**(i)** Deduce the empirical formula of **X**. [3]

**(ii)** The relative molecular mass of **X** is 90. Deduce the molecular formula of **X**. [1]

w/08/qp2

**Question 64.**

**(d)** A small amount of xenon is present in the air. Several compounds of xenon have been made in recent years.
A compound of xenon contained 9.825 g of xenon, 1.200 g of oxygen and 5.700 g of fluorine.
Determine the empirical formula of this compound.

[3]

w/08/qp2

**Question 65.**

**(b)** Analysis of 21.25 g of gallic acid showed that it contained 10.50 g of carbon, 0.75 g of hydrogen and 10.00 g of oxygen.

Show that the empirical formula of gallic acid is $C_7H_6O_5$.

[3]

w/10/qp21

**Question 66.**

**(c)** Carboxylic acid **X** contains 55.8% carbon, 7.0% hydrogen and 37.2% oxygen.

**(i)** Calculate the empirical formula of **X**.

[2]

**(ii)** A molecule of carboxylic acid **X** contains four carbon atoms. What is its molecular formula?

..... [1]

**(iii)** Carboxylic acid **X** is an unsaturated compound.
Give a test for an unsaturated compound.

test .....

observation ..... [2]

[Total: 10]

w/11/qp22

**Question 67.**

**(iii)** The composition by mass of ethanal is C 54.5%, H 9.1%, O 36.4%.
Calculate the empirical formula of ethanal.

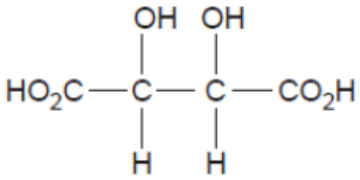
[2]

w/12/qp22

## PERCENTAGE PURITY

**Question 68.**

**(b)** Tartaric acid can also be extracted from grape juice.
The structure of tartaric acid is shown below.



**(i)** Deduce the empirical formula of tartaric acid.

.....[1]

**(ii)** A solution of tartaric acid was titrated with 0.100 mol/dm$^3$ potassium hydroxide.

$$C_2H_2(OH)_2(CO_2H)_2 + 2KOH \rightarrow C_2H_2(OH)_2(CO_2K)_2 + 2H_2O$$

tartaric acid

It required 6.00 cm$^3$ of the potassium hydroxide solution to neutralise 20.0 cm$^3$ of tartaric acid. Calculate the concentration, in mol/dm$^3$, of the tartaric acid solution.

.....mol/dm$^3$ [3]

**(iii)** Tartaric acid is purified by recrystallisation.
On analysis, 8.00 g of impure tartaric acid was found to contain 7.40 g of pure tartaric acid. Calculate the percentage purity of the impure tartaric acid.

.....% [1]

w/07/qp2