

Gloria Filiorum Patres

Each day, discovery.



ELTHAM COLLEGE  
SIXTH FORM



## The Course

### A level Chemistry

The examination board for your chemistry course is AQA. You can find more about what's involved by looking at the specification:

<https://filestore.aqa.org.uk/resources/chemistry/specifications/AQA-7404-7405-SP-2015.PDF>



## The Booklet

There are four **core** areas covered here of which you will need a good working knowledge before starting the A Level course:

Topic 1: Atomic Structure

Topic 2: Formulae and Chemical Equations

Topic 3: Chemical Calculations: The Mole

Topic 4: Chemical Bonding, Structure and Properties

Topic 5 consists of **extension** material some of you may wish to attempt before September.



## Suggested Resources

### Online Activities

There are quite literally thousands of websites available. The ones we suggest have a dual purpose.

- to provide sites directly relevant to the tasks in this booklet
- to provide sites that will, in time, broaden your perspective and put Chemistry in context.

The sites suggested are comprehensive but are not necessarily the best for your particular learning preference. You will need to be selective with what information to use.

### Websites relevant to this booklet

*Knockhardy Publishing:* <http://www.knockhardy.org.uk/sci.htm>

A website providing many useful PowerPoints and detailed summary notes in pdf format



*Chemguide:* <http://chemguide.co.uk>

A website full of clear, detailed explanations of A Level Chemistry topics. An excellent first port of call when you are stuck.



*Kahn Academy:* <https://www.khanacademy.org>

This is fantastic, but can have too much information for our purposes. Skip through the bits that are not relevant, but the short tests are well worth doing as they will guide you to what bits you need to brush up on.



### Book Suggestions

There are a number of books that are worth purchasing and/or reading. Some will help with completing the tasks here and your studies directly. Others will broaden your horizons, something that is most useful if you aspire to attend top universities and/or competitive courses.

- Essential Maths Skills for A level Chemistry (CGP. ISBN: 9781782944720)
- Head Start to A level Chemistry (CGP. ISBN: 9781782942801)
- Calculations in AS/A level Chemistry (Jim Clark. ISBN: 9780582411272)



## CORE TASKS

### Topic 1 - Atomic Structure

#### Objectives

- Deduce the components of an atom from its atomic and mass number (GCSE).
- Recall the subatomic particles and know the mass and charge of each (GCSE).
- Deduce the number of subatomic particles in ions (GCSE).
- Recall definitions for relative atomic mass, relative formula mass, relative isotopic mass (GCSE and A level).
- Deduce the % abundance of a given isotope from data of the other isotopes and  $A_r$ . (A level).
- Calculate the relative atomic mass of an element given the % abundances of its isotopes (GCSE and A level).
- Give the similarities and differences between atoms of the same element (definition of isotopes) (GCSE).

#### Resources:

<https://www.chemguide.co.uk/atommenu.html>



<https://www.khanacademy.org/science/chemistry/atomic-structure-and-properties>



[http://www.knockhardy.org.uk/sci\\_hm\\_files/15atoms.pdf](http://www.knockhardy.org.uk/sci_hm_files/15atoms.pdf)





Task 1A: Atomic Structure and the Periodic Table

1 State what is meant by the term *relative formula mass*.

(2 marks)

2 a State what is meant by the term *relative isotopic mass*.

(2 marks)

b State what is meant by the term *isotopes*.

(2 marks)

c i State what is meant by the term *relative atomic mass*.

(2 marks)

ii A sample of boron contains:

- 19.7% of boron-10
- 80.3% of boron-11.

Use this information to calculate the relative atomic mass of boron.

(3 marks)

3 The relative atomic mass is defined as ...

- A the mass of an atom of an element relative to  $\frac{1}{12}$  the mass of a carbon-12 atom.
- B the mass of an atom of an element relative to the mass of a hydrogen atom.
- C the average mass of an element relative to  $\frac{1}{12}$  the mass of a carbon atom.
- D the average mass of an atom of an element relative to  $\frac{1}{12}$  the mass of a carbon-12 atom.

(1 mark)



4 The isotopes of magnesium  $^{25}\text{Mg}$  and  $^{24}\text{Mg}$  both form ions with charge  $\text{Mg}^{2+}$ . Which of the following statements about these ions is true?

- A Both ions have electronic configuration  $1s^2 2s^2 2p^6 3s^2$ .
- B  $^{25}_{12}\text{Mg}^{2+}$  has more protons than  $^{24}_{12}\text{Mg}^{2+}$ .
- C The ions have the same number of electrons but different numbers of neutrons.
- D The ions have the same number of neutrons but different numbers of protons.

(1 mark)

5 Chlorine has two isotopes with relative isotopic mass 35 and 37. Four  $m/z$  values are given below. Which will occur in a mass spectrum of chlorine gas,  $\text{Cl}_2$ , from an ion with a single positive charge?

- A 35.5
- B 36
- C 71
- D 72

(1 mark)

6 The following data were obtained from the mass spectrum of a sample of platinum.

Peak at $m/z$	%
194	32.8
195	30.6
196	25.4
198	11.2

- a Calculate the relative atomic mass of platinum in this sample. Give your answer to one decimal place.

(2 marks)



- 7 The radioactive isotope iodine-131,  ${}_{53}^{131}\text{I}$ , is formed in nuclear reactors providing nuclear power. Naturally occurring iodine contains only the isotope  ${}_{53}^{127}\text{I}$ .

a Complete the table to show the number of protons and neutrons in these two isotopes.

Isotope	${}_{53}^{131}\text{I}$	${}_{53}^{127}\text{I}$
Number of protons		
Number of neutrons		

(2 marks)

b When iodine-131 decays, one of its neutrons emits an electron and forms a proton. Identify the new element formed.

(1 mark)



## CORE TASKS

### Topic 2 – Formulae and Chemical Equations

#### Objectives

- Deduce the formulae for compounds with more complex anions (compound ions) (GCSE).
- Deduce the formulae for simple ionic compounds with just two types of elements (GCSE).
- Work out the charge on an ion from its position in the Periodic Table (GCSE).
- Given a reaction in words, write a balanced symbol equation (GCSE and A level).
- Write down ionic equations and know which ions can be omitted. (A level)
- Write equations with state symbols for chemical reactions from observations recorded (GCSE and A level).
- Know how to balance equations (GCSE).

#### Resources

<https://www.khanacademy.org/science/chemistry/chemical-reactions-stoichiome>



[http://www.knockhardy.org.uk/sci\\_htm\\_files/15equat.pdf](http://www.knockhardy.org.uk/sci_htm_files/15equat.pdf)



<http://www.chemicalformula.org>







### Task 2A: Chemical Formulae

Write the formulae of the following compounds.

Copper(II) sulfate	
Nitric acid	
Copper(II) nitrate	
Sulfuric acid	
Sodium carbonate	
Aluminium sulfate	
Ammonium nitrate	
Nitrogen dioxide	
Sulfur dioxide	
Ammonia	
Ammonium sulfate	
Potassium hydroxide	
Calcium hydroxide	



### Task 2B: Cations and Anions

Complete the table below to show the substance, its formula and its individual ions. Remember to include the charge on the individual ions.

Substance	Formula	Cation	Anion
Sodium bromide		Na <sup>+</sup>	Br <sup>-</sup>
	KI		
Silver nitrate			NO <sub>3</sub> <sup>-</sup>
Copper(II) sulfate			
	NaHCO <sub>3</sub>		
Magnesium carbonate			
Lithium carbonate			
	Ca(HSO <sub>4</sub> ) <sub>2</sub>		
Aluminium nitrate			
Calcium phosphate			
Potassium hydride			H <sup>-</sup>
Sodium ethanoate			
	KMnO <sub>4</sub>		
Potassium dichromate(VI)			
Zinc chloride			
Strontium nitrate			
Sodium chromate(VI)			
Calcium fluoride			
Potassium sulphide			
Magnesium nitride			
Lithium hydrogensulfate			
	(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>		



### Task 2C: Writing Equations

Write: (a) the chemical equation and (b) the ionic equation for each of the following reactions.  
Remember to include state symbols in both forms of equation.

- 1 Magnesium with sulfuric acid
- 2 Calcium carbonate with nitric acid
- 3 Hydrochloric acid with sodium hydroxide
- 4 Aqueous barium chloride with aqueous sodium sulfate
- 5 Aqueous sodium hydroxide with sulfuric acid
- 6 Aqueous silver nitrate with aqueous magnesium chloride
- 7 Solid magnesium oxide with nitric acid
- 8 Aqueous copper(II) sulfate with aqueous sodium hydroxide
- 9 Aqueous lead(II) nitrate with aqueous potassium iodide
- 10 Aqueous iron(III) nitrate with aqueous sodium hydroxide



## CORE TASKS

### Topic 3 - Chemical Calculations: The Mole

#### Objectives

This section covers one of the most important areas of the chemistry specification. A good understanding of the concepts covered here, will have a huge impact on your studies of later topics.

Perhaps the biggest barrier to understanding is what is being asked when a practical scenario is given. Formulae and equations are not provided in Chemistry exams so it is important that you know these very well and, more importantly, are able to manipulate them as necessary to solve a given problem.

- Know what is meant by the term empirical formula and molecular formula (GCSE and A level).
- Be able to calculate empirical and molecular formulae from experimental data (calculations may involve composition by mass or percentage) (GCSE and A level).
- Be able to calculate amounts of substance in reactions involving mass, volumes of solution and concentration (stoichiometry) (GCSE and A level).

#### Resources

<https://www.khanacademy.org/science/chemistry/chemical-reactions-stoichiome/stoichiometry-ideal/a/stoichiometry>



<https://www.khanacademy.org/science/chemistry/chemical-reactions-stoichiome/empirical-molecular-formula/v/empirical-molecular-and-structural-formulas>



<https://www.khanacademy.org/science/chemistry/acid-base-equilibrium/titrations/v/titration-introduction>  
(and subsequent videos)



[http://www.knockhardy.org.uk/sci\\_htm\\_files/15moles.pdf](http://www.knockhardy.org.uk/sci_htm_files/15moles.pdf)





### Task 3A: Mole Calculations

1. Which of the following statements is true? The Avogadro constant is the number of

- A grams of any element which contains  $6.02 \times 10^{23}$  atoms of that element.
- B atoms contained in one mole of any element.
- C atoms contained in one mole of any monatomic element.
- D particles (atoms, molecules or ions) required to make one gram of a substance.

**Working**

(1 mark)

2. 1.12 g of iron reacts with oxygen to form 1.60 g of an oxide of iron. Use relative atomic masses:

Fe = 56, O = 16.

What is the formula of this oxide of iron?

- A FeO<sub>5</sub>
- B Fe<sub>2</sub>O<sub>10</sub>
- C Fe<sub>3</sub>O<sub>2</sub>
- D Fe<sub>2</sub>O<sub>3</sub>

(1 mark)



3. A compound has the composition 62.1% C, 10.3% H and 27.6% O. What is its empirical formula?

- A CH<sub>2</sub>O
- B C<sub>6</sub>H<sub>2</sub>O
- C C<sub>6</sub>H<sub>3</sub>O
- D C<sub>3</sub>H<sub>6</sub>O

(1 mark)

4. Calculate the mass of calcium hydroxide, Ca(OH)<sub>2</sub>, present in 100 cm<sup>3</sup> of a 0.100 mol dm<sup>-3</sup> solution. [Assume the molar mass of Ca(OH)<sub>2</sub> is 74.0 g mol<sup>-1</sup>.]

- A 0.570 g
- B 0.740 g
- C 1.85 g
- D 3.70 g

(1 mark)

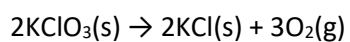


5. A sample of gas was prepared for use in helium-neon lasers. It contained 4 g of helium and 4 g of neon. What is the ratio of helium atoms to neon atoms in the sample?

- A 1 : 1
- B 2.5 : 1
- C 1 : 5
- D 5 : 1

(1 mark)

6. In an experiment, 1.226 g of potassium chlorate(V),  $\text{KClO}_3$ , was heated. A mass of 0.320 g of oxygen gas,  $\text{O}_2$ , was collected.



Use the molar mass of  $\text{KClO}_3 = 122.6 \text{ g mol}^{-1}$  and relative atomic mass  $\text{O} = 16$ .

The percentage yield of oxygen in this experiment is

- A 17.4%
- B 26.1%
- C 66.7%
- D 100%

(1 mark)



7. A compound was found to contain 2.8 g of nitrogen and 8.0 g of oxygen.  
What is the empirical formula of the compound?  
Use the Periodic Table as a source of data.

- A NO  
 B NO<sub>2</sub>  
 C N<sub>2</sub>O<sub>3</sub>  
 D N<sub>2</sub>O<sub>5</sub>

(1 mark)

8. How many moles of **atoms** are present in 240 cm<sup>3</sup> of carbon dioxide at room temperature and pressure?

[1 mol of any gas occupies 24 dm<sup>3</sup> at room temperature and pressure.]

- A 0.010  
 B 0.020  
 C 0.024  
 D 0.030

(1 mark)





9. A compound was analysed and found to contain

1.45g Carbon

0.482g Hydrogen

1.69g Nitrogen

[Relative atomic masses: C = 12; H = 1; N = 14]

The empirical formula of the compound is

- A CH<sub>3</sub>N
- B CH<sub>4</sub>N
- C CH<sub>5</sub>N
- D C<sub>2</sub>H<sub>4</sub>N

(1 mark)

10. What is the percentage by mass of nitrogen in ammonium nitrate, NH<sub>4</sub>NO<sub>3</sub>?

[Molar masses/g mol<sup>-1</sup>: N = 14.0; H = 1.0; O = 16.0]

- A 14.0%
- B 17.5%
- C 28.0%
- D 35.0%

(1 mark)



11. How many moles of **ions** are present in 20 cm<sup>3</sup> of 0.050 mol dm<sup>-3</sup> calcium chloride solution, CaCl<sub>2</sub>(aq)?

A 0.0050

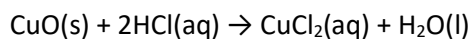
B 0.0030

C 0.0020

D 0.0010

(1 mark)

12. An excess of copper(II) oxide is mixed with 40.0 cm<sup>3</sup> of 2.50 mol dm<sup>-3</sup> hydrochloric acid.



(a) If the mass of copper(II) chloride produced is 5.50 g, what is the percentage yield of copper(II) chloride?

[Molar mass of copper(II) chloride = 134.4 g mol<sup>-1</sup>]

A 81.8%

B 67.2%

C 40.9%

D 20.4%

(1 mark)



(b) The ionic equation for the reaction is

- A  $\text{Cu}^{2+}(\text{s}) + 2\text{Cl}^{-}(\text{aq}) \rightarrow \text{CuCl}_2(\text{aq})$
- B  $\text{CuO}(\text{s}) + 2\text{H}^{+}(\text{aq}) \rightarrow \text{Cu}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$
- C  $\text{CuO}(\text{s}) + 2\text{H}^{+}(\text{aq}) + 2\text{Cl}^{-}(\text{aq}) \rightarrow \text{Cu}^{2+}(\text{Cl}^{-})_2(\text{aq}) + \text{H}_2\text{O}(\text{l})$
- D  $\text{CuO}(\text{s}) + 2\text{Cl}^{-}(\text{aq}) \rightarrow \text{CuCl}_2(\text{aq}) + \text{O}^{2-}(\text{l})$

(1 mark)

13. 0.400 g of magnesium ribbon reacted with exactly 22.2 cm<sup>3</sup> of hydrochloric acid of concentration 1.50 mol dm<sup>-3</sup>. 400 cm<sup>3</sup> of hydrogen gas was formed, the volume being measured at room temperature and pressure.

In the calculations that follow, use the following molar masses:

$$\text{Mg} = 24.0 \text{ g mol}^{-1}$$

$$\text{Cl} = 35.5 \text{ g mol}^{-1}$$

- (a) Calculate the amount (in moles) of magnesium used.

(1 mark)

- (b) Calculate the amount (in moles) of hydrochloric acid used.

(1 mark)

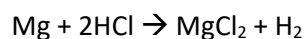


(c) Calculate the amount (in moles) of hydrogen produced.

[Molar volume of any gas at room temperature and pressure =  $24\,000\text{ cm}^3\text{ mol}^{-1}$ ]

(1 mark)

(d) Show that the calculated amounts of magnesium, hydrochloric acid and hydrogen are consistent with the following equation for the reaction



(1 mark)

(e) Calculate the maximum mass of magnesium chloride that would be formed in this reaction. Give your answer to **three** significant figures.

(3 marks)

14. Which of the following solutions would react exactly with a solution containing 0.0500 mol sulfuric acid?

A 50.0 cm<sup>3</sup> of 1.00 mol dm<sup>-3</sup> KOH

B 100.0 cm<sup>3</sup> of 2.00 mol dm<sup>-3</sup> KOH

C 100.0 cm<sup>3</sup> of 2.00 mol dm<sup>-3</sup> Ba(OH)<sub>2</sub>

D 50.0 cm<sup>3</sup> of 1.00 mol dm<sup>-3</sup> Ba(OH)<sub>2</sub>

(1 mark)



15. Which of the following contains the most chloride ions?

- A  $10 \text{ cm}^3$  of  $3.30 \times 10^{-2} \text{ mol dm}^{-3}$  aluminium chloride solution
- B  $20 \text{ cm}^3$  of  $5.00 \times 10^{-2} \text{ mol dm}^{-3}$  calcium chloride solution
- C  $30 \text{ cm}^3$  of  $3.30 \times 10^{-2} \text{ mol dm}^{-3}$  hydrochloric acid
- D  $40 \text{ cm}^3$  of  $2.50 \times 10^{-2} \text{ mol dm}^{-3}$  sodium chloride solution

(1 mark)

16. A student is provided with a  $5.00 \text{ cm}^3$  sample of  $1.00 \times 10^{-2} \text{ mol dm}^{-3}$  hydrochloric acid. The student is asked to devise a method to prepare a hydrochloric acid solution with a concentration of  $5.00 \times 10^{-4} \text{ mol dm}^{-3}$  by diluting the sample with water.

Which of these is the correct volume of water that should be added?

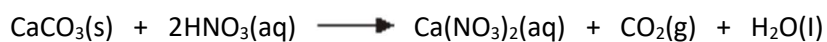
- A  $45.0 \text{ cm}^3$
- B  $95.0 \text{ cm}^3$
- C  $100 \text{ cm}^3$
- D  $995 \text{ cm}^3$

(1 mark)



17. Norgessalpeter was the first nitrogen fertiliser to be manufactured in Norway. It has the formula  $\text{Ca}(\text{NO}_3)_2$

- (a) Norgessalpeter can be made by the reaction of calcium carbonate with dilute nitric acid as shown by the following equation.



In an experiment, an excess of powdered calcium carbonate was added to  $36.2 \text{ cm}^3$  of  $0.586 \text{ mol dm}^{-3}$  nitric acid.

- (i) Calculate the amount, in moles, of  $\text{HNO}_3$  in  $36.2 \text{ cm}^3$  of  $0.586 \text{ mol dm}^{-3}$  nitric acid.

Give your answer to 3 significant figures.

(1 mark)

- (ii) Calculate the amount, in moles, of  $\text{CaCO}_3$  that reacted with the nitric acid. Give your answer to 3 significant figures.

(1 mark)

- (iii) Calculate the minimum mass of powdered  $\text{CaCO}_3$  that should be added to react with all of the nitric acid. Give your answer to 3 significant figures.

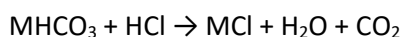
(2 marks)

- (iv) State the type of reaction that occurs when calcium carbonate reacts with nitric acid.

(1 mark)



18. This question is about a white solid,  $\text{MHCO}_3$ , that dissolves in water and reacts with hydrochloric acid to give a salt.



A student was asked to design an experiment to determine a value for the  $M_r$  of  $\text{MHCO}_3$ . The student dissolved 1464 mg of  $\text{MHCO}_3$  in water and made the solution up to  $250 \text{ cm}^3$ .

$25.0 \text{ cm}^3$  samples of the solution were titrated with  $0.102 \text{ mol dm}^{-3}$  hydrochloric acid. The results are shown in the table.

	<b>Rough</b>	<b>1</b>	<b>2</b>	<b>3</b>
<b>Initial burette reading / <math>\text{cm}^3</math></b>	0.00	10.00	19.50	29.25
<b>Final burette reading / <math>\text{cm}^3</math></b>	10.00	19.50	29.25	38.90
<b>Titre / <math>\text{cm}^3</math></b>	10.00	9.50	9.75	9.65

- (a) Calculate the mean titre and use this to determine the amount, in moles, of HCl that reacted with  $25.0 \text{ cm}^3$  of the  $\text{MHCO}_3$  solution.

(3 marks)

- (b) Calculate the amount, in moles, of  $\text{MHCO}_3$  in  $250 \text{ cm}^3$  of the solution.

Then calculate the experimental value for the  $M_r$  of  $\text{MHCO}_3$ .

Give your answer to the appropriate number of significant figures.

.....

(3 marks)



## CORE TASKS

### Topic 4 - Chemical Bonding, Structure and Properties

#### Objectives

- Use dot-and-cross diagrams to show ionic and covalent bonding (GCSE).
- Describe the lattice structure of covalent substances (GCSE).
- Describe the lattice structure of metallic substances (GCSE).
- Describe the lattice structure of ionic substances (GCSE).
- Deduce the type of structure of a substance from solubility and electrical conductivity data (GCSE).
- Relate the physical properties of covalent compounds to their bonding and structure (GCSE).
- Relate the physical properties of ionic compounds to their bonding and structure (GCSE).
- Relate the physical properties of metallic substances to their bonding and structure (GCSE).

#### Resources

<https://www.chemguide.co.uk/atoms/bondingmenu.html>



<https://www.khanacademy.org/science/chemistry/chemical-bonds>



[http://www.knockhardy.org.uk/sci\\_htm\\_files/15sandb.pdf](http://www.knockhardy.org.uk/sci_htm_files/15sandb.pdf)







### Task 4A Bonding and Structure

1 Chlorine forms compounds with magnesium and with carbon.

- a Draw a dot-and-cross diagram to show the electronic structure of the compound magnesium chloride (only the outer electrons need be shown). Include the charges present.

(2 marks)

- b Draw a dot-and-cross diagram to show the electronic structure of the compound tetrachloromethane (only the outer electrons need be shown).

(2 marks)

- c Draw a dot-and-cross diagram of a molecule of carbon dioxide. Show outer electrons only.

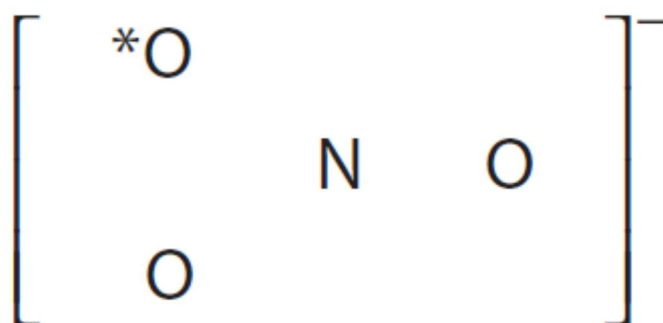
(2 marks)



- 2 The nitrate ion,  $\text{NO}_3^-$ , contains both covalent and dative covalent bonds. Complete the dot-and-cross diagram to show the bonding in the nitrate ion.

Only the outer electron shells for each atom need to be shown.

Represent the nitrogen electrons with crosses (×), and oxygen electrons with dots (•). The symbol \* on the diagram represents the extra electron giving the ion its charge.



(3 marks)

- 3 A molecule is ...

- A a group of atoms joined by ionic bonding.
- B a group of atoms joined by covalent bonding.
- C a group of ions joined by covalent bonding.
- D a group of atoms joined by metallic bonding.

(1 mark)

- 4 Suggest why the melting temperature of magnesium oxide is higher than that of magnesium chloride, even though both are almost 100% ionic.

(3 marks)



5 Silicon exists as a giant covalent lattice.

a The electrical conductivity of pure silicon is very low. Explain why this is so in terms of the bonding.

(2 marks)

b Explain the high melting temperature of silicon in terms of the bonding.

(2 marks)

6 The melting temperatures of the elements of Period 3 are given in the table below. Use these values to answer the questions that follow.

Element	Na	Mg	Al	Si	P (white)	S (monoclinic)	Cl	Ar
Melting temperature / K	371	922	933	1683	317	392	172	84

a Explain why the melting temperature of sodium is very much less than that of magnesium.

(3 marks)

b Explain why the melting temperature of silicon is very much greater than that of white phosphorus.

(3 marks)



c Explain why the melting temperature of argon is the lowest of all the elements of Period 3.

(1 mark)

d Explain why magnesium is a good conductor of electricity whereas sulfur is a non-conductor.

(2 marks)



## Topic 5: Extension Activities

If you have managed to complete all of these and feel that you have a good understanding of these topics, have a go at the next couple of questions. They are considerably more challenging, so good luck!

1. This question is about calcium carbide.



Calcium carbide,  $\text{CaC}_2$ , also known as calcium acetylide, is produced in large quantities around the world, mostly in the Far East. Calcium carbide has been used in a variety of ways, including as a component in self-igniting maritime distress flares.

Use the following information about calcium carbide to help you answer questions (a)-(g) below

- Calcium carbide is formed from the reaction between lime (calcium oxide) and coke (carbon) at about  $2000\text{ }^\circ\text{C}$ . The side-product of this reaction is a toxic gas, **A**, that is a reducing agent.
- The lime used in the production process commonly contains a small amount of calcium phosphate(v) as an impurity. In the reaction with coke, this impurity reacts to form compound **B** (a simple ionic compound of calcium and phosphorus) as well as gas **A**.
- Calcium carbide reacts with excess water to form a colourless, flammable gas, **C**. A white solid is also formed which is slightly soluble in water to give a colourless alkaline solution. Gas **C** is a hydrocarbon containing 92.3% carbon by mass. The relative molecular mass of **C** is shown to be 26.
- The addition of calcium carbide to water generates an unpleasant smell. It is now known that it is actually the reaction of water with compound **B** that produces this smell.

(a) Draw a 'dot cross' diagram of the carbide ion  $\text{C}_2^{2-}$

(b) Which two well-known diatomic gases are *iso-electronic* (same number of electrons) with the carbide ion?



- (c) Write a balanced equation for the formation of calcium carbide and gas **A** from lime and coke.
- (d) Calculate the (i) empirical and (ii) molecular formula of the hydrocarbon **C**
- (e) Write a balanced equation for the reaction of calcium carbide and water.
- (f) Write a balanced equation for the reaction between calcium phosphate(v) and coke to form gas **A** and compound **B**.
- (g) Suggest the identity of the molecule responsible for the unpleasant odour that is produced when compound **B** reacts with water.



2. This question is about the combining proportions of the elements.

Understanding the proportions in which the elements combine was a crucial step in developing the atomic theory of matter. The picture above shows an experiment performed in the 1660s in which antimony was heated using the sun's rays to form and oxide

In the experiment 'ye Artist' reported that '12 *grains* of antimony increased to 15 *grains* of calx', (a *grain* is an old measure of mass). Given the crudeness of the experiment, this value is remarkably close to the theoretical yield of 14.4. *grains*.



(a) Calculate the formula of the oxide formed

In another experiment published in 1673, Robert Boyle measured the increase in mass when zinc metals is heated in air. He describes the experiment thus:

*We took a Drachm of filings of Zink and kept it in a Cupelling-fire about 3 Hours. The it look'd as if the filings had been calcin'd. This being weigh'd in the same scales gain'd full six grains.*

(b) Given that there are 60 grains in a Drachm, calculate the mass of product (in grains) that would have been produced assuming a yield of 100%

Assuming that Boyle's measurements are accurate, only a fraction,  $\alpha$ , of the zinc must have been converted to the oxide. ( $\alpha$  is a fraction between 0 and 1; 0 meaning none of the zinc reacted and 1 meaning all reacted).

(c) Calculate the value of  $\alpha$  and hence the masses of zinc oxide and unreacted zinc metal at the end of the experiment.



3. This question is about homeopathic solutions.

The pseudo-science of homeopathy began over 200 years ago, long before modern medicine. The main idea is that, against all scientific principles, medicines become increasingly potent the more they are diluted. Over the years, just about every well-known poison has been used in certain homeopathic remedies, including arsenic, barium, mercury and even plutonium.

The arsenic compound usually used is an oxide,  $\text{As}_2\text{O}_3$ . In the remedies it is called by its Latin name Arsenicum album (white arsenic). The oxide is prepared industrially by roasting arsenic-containing ores such as arsenopyrite,  $\text{FeAsS}$  in air. The other products formed are iron(III) oxide and sulfur dioxide.



- (a) (i) What is the oxidation state of the arsenic in  $\text{As}_2\text{O}_3$
- (ii) Give an equation for the industrial production of  $\text{As}_2\text{O}_3$  from  $\text{FeAsS}$

$\text{As}_2\text{O}_3$  is moderately soluble in water; one  $\text{dm}^3$  ( $1000 \text{ cm}^3$ ) of a saturated solution at  $25^\circ\text{C}$  contains 20.6 g. When dissolved in water, the oxide reacts to form arsenous acid,  $\text{H}_3\text{AsO}_3$ .

- (b) (i) Given that the hydrogen atoms are in the same chemical environment, suggest a structure for the acid.
- (ii) Give an equation for the formation of arsenous acid from  $\text{As}_2\text{O}_3$





- (iii) Calculate the concentration of arsenous acid in  $\text{mol dm}^{-3}$  in the saturated solution

In homeopathy, a 'decimal-scale' is often used to specify the dilution of a given sample: 1X means the sample has been diluted 1 part in 10. 2X means the sample has been diluted 1 in 10, then 1 part of that solution has been further diluted 1 in 10 again to give a 1 in 100 dilution. A 6X solution has repeated this process six times to give a final dilution of 1 in  $10^6$ .

Arsenicum album is often sold as a 30X preparation. Let us assume that the initial stock solution before dilution was the saturated solution containing  $20.6 \text{ g dm}^{-3}$  of  $\text{As}_2\text{O}_3$ .

- (c) (i) Calculate the mass (in g) of  $\text{As}_2\text{O}_3$  present in  $100 \text{ cm}^3$  glass of the 30X Arsenicum album remedy.
- (ii) Given that 0.1g of  $\text{As}_2\text{O}_3$  is usually fatal, calculate the volume (in  $\text{m}^3$ , where  $1 \text{ m}^3 = 1,000,000 \text{ cm}^3$ ) of the 30X solution that would be needed for a fatal dose of  $\text{As}_2\text{O}_3$ . Also express your answer as a fraction of the volume of the Earth (approximately  $1.08 \times 10^{12} \text{ km}^3$ ).
- (iii) The preparations are usually sold in one ounce bottles ( $1 \text{ ounce} = 28 \text{ cm}^3$ ). Calculate how many bottles of the 30X solution need to be bought in order, on average, to include 1 atom of arsenic.