ACADEMIC ASSOCIATES

WACE 3A & 3B
CHEMISTRY

TRIAL EXAMINATION PAPER 2

Student Name: _____

Date: ____/____/____

Time Commenced: _____

Time allowed for this paper

Reading time before commencing work: Ten minutes
Working time for paper: Three hours

Materials required for this paper

- Chemistry Data Sheet – this is located at the end of this book.

Materials to be provided by the candidate

Standard Items: pens, pencils, eraser, correction fluid, ruler, highlighters.

Special Items: non-programmable calculators satisfying the conditions set out by the Curriculum Council for this course.

STRUCTURE OF THIS PAPER

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Multiple choice	25	25	50	25	25
Section Two: Short answer	11	11	60	70	35
Section Three: Extended answer	6	6	70	80	40
					100

Instructions to candidates

- Write answers in the spaces provided.
- Working or reasoning should be clearly shown when doing calculations.
- Final numerical answers should be quoted to three significant figures.

SECTION ONE: MULTIPLE-CHOICE 25% (50 marks)

This section has **25** questions. Answer **all** questions. For each question write your answer in the box opposite. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time for this section is 50 minutes.

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1. Consider an atom Y with the electron configuration 2, 4 and Z with the electron configuration 2, 8, 7. Which of the following is most likely when Y and Z chemically combine?

   (a) The product is ionic with the formula Y_3Z.
   (b) The product is covalent with the formula YZ_4.
   (c) The product is covalent with the formula YZ_3.
   (d) The product is ionic with the formula YZ_4. Answer ☐

2. Which one of the following descriptions about the polarities and shapes of certain molecules is **incorrect?**

   (a) NH_3 is a polar molecule which is pyramidal.
   (b) SO_2 is a polar molecule which is bent.
   (c) SO_3 is a polar molecule which is triangular planar.
   (d) $CC\ell_4$ is a non polar molecule which is tetrahedral. Answer ☐

3. Which one of the following statements is **true** about the elements of the periodic table?

   (a) Ionisation energy increases down a group.
   (b) The number of valence electrons decreases across a period.
   (c) Electronegativity increases up a group.
   (d) The basicity of the oxides of the elements increases across a period. Answer ☐

4. Metallic bonding is described as a strong electrostatic attraction between positive metal ions and a sea of delocalised electrons. This theory explains which of the following properties of metals?

   (a) Can be hammered into sheets.
   (b) Can easily transfer electricity.
   (c) Change from a solid to a liquid at high temperatures.
   (d) All of the above. Answer ☐

5. Which one of the following correctly defines why graphite is a good conductor of electricity?

   (a) Each carbon atom in a layer is only bonded to three other carbon atoms.
   (b) Covalent bonds are formed between neighbouring carbon atoms.
   (c) Weak Van der Waals forces exist throughout the carbon structure.
   (d) The ions of the carbon carry the charge through the lattice. Answer ☐

6. A student reacts excess monoprotic acid with 0.125 moles of metal M. The volume of hydrogen gas collected is 4.201 L at S.T.P. What is the valency of the metal ion produced in solution when the reaction is complete?

(a) +4
(b) +3
(c) +1
(d) +2

Answer ☐

7. A buffer solution consists of weak acid, such as acetic acid and its sodium salt, sodium acetate. One important property of such a buffer solution is

(a) its pH is at a constant value of 7.00.
(b) its pH is greater than the pH of the original acetic acid solution.
(c) its pH is significantly changed by the addition of a small amount of 1mol L^{-1} solution of a strong acid.
(d) its pH is less than the pH of the original acetic acid solution.

Answer ☐

8. Which of the following oxide compounds will give a solution with a strongly basic pH?

(a) sodium oxide.
(b) aluminium oxide.
(c) sulfur dioxide.
(d) diphosphorus pentoxide.

Answer ☐

9. A student is asked to calculate the oxidation number of the bolded element in each of the formulae shown below.

A: $Na_2\mathbf{S}O_3$ B: $Na\mathbf{N}O_2$ C: Na**I** D: $Na\mathbf{Mn}O_4$

In which of the following does the bolded element exist in its lowest possible oxidation state?

(a) A.
(b) B.
(c) C.
(d) D.

Answer ☐

10. Which of the following is **false** concerning the operation of a galvanic cell?

(a) The salt bridge allows ions to move freely between the oxidant and reductant solutions.
(b) The electrons flow from the anode to the cathode via an external wire.
(c) The emf is calculated from the two half reactions and is constant for the duration of the reaction.
(d) Oxidation occurs in the half cell containing the reactant anode.

Answer ☐

11. On reaction between an organic liquid and a warm solution of acidified potassium dichromate, a colour change is observed. The organic compound could be classified as a(n)

(i) primary alcohol (ii) ketone (iii) aldehyde (iv) secondary alcohol.

Which of the above statements is/ are true?
(a) (i) only.
(b) (i), (iii) and (iv) only.
(c) (ii) and (iii) only.
(d) All of (i), (ii), (iii) and (iv).

Answer ☐

12. A student is completing a titration between sodium hydroxide (from the burette) and hydrochloric acid (from the conical flask). Which of the following would most likely lead to an appreciable error in the student's results?

(a) Adding three or four drops of methyl orange indicator to the conical flask before the titration.
(b) Adding distilled water to the conical flask before titrating.
(c) Rinsing the burette with distilled water and then base solution before titrating.
(d) Rinsing the conical flask with the hydrochloric acid solution before titrating.

Answer ☐

Questions 13 refers to the chemical reaction below:

$$Ba(OH)_{2(s)} + 2NH_4SCN_{(s)} + 483kJ \rightarrow Ba^{2+}_{(aq)} + 2SCN^{-}_{(aq)} + 2NH_{3(aq)} + 2H_2O_{(l)}$$

13. Which of the following statements describes the sign of ΔH and the energy of products for the above equation?

(a) The sign of ΔH is positive and the products have more enthalpy than the reactants.
(b) The sign of ΔH is positive and the products have less enthalpy than the reactants.
(c) The sign of ΔH is negative and the products have more enthalpy than the reactants.
(d) The sign of ΔH is negative and the products have less enthalpy than the reactants.

Answer ☐

Questions 14 and 15 refer to the equilibrium equation below.

$$FeO_{(s)} + CO_{(g)} \rightleftharpoons Fe_{(s)} + CO_{2(g)} \quad \Delta H = -283kJ\ mol^{-1}$$

14. Which of the following changes on the equilibrium conditions will favour the formation of solid iron?

(a) Increase the temperature of the system.
(b) Decrease the pressure of the system.
(c) Add more finely powdered iron (II) oxide.
(d) Remove some carbon dioxide gas from the system.

Answer ☐

15. Which of the statements below is correct concerning K (the equilibrium constant) for the above equation?

(a) K relates to the speed at which solid iron and gaseous carbon dioxide are formed, and not to how much of each is formed.
(b) Increasing pressure on the reactant system will increase the value of K for this equation.
(c) K is independent of the concentration of iron (II) oxide in this equation, as the concentration of iron (II) oxide does not vary.
(d) A small value for K indicates the formation of products for the equation above, thus the concentrations of products will be favoured at equilibrium.

Answer ☐

16. Which of the following is classified as a redox reaction?

(a) $BaO + SO_2 \rightarrow BaSO_3$
(b) $2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$
(c) $CaCO_3 \rightarrow CaO + CO_2$
(d) $2KClO_3 \rightarrow 2KCl + 3O_2$

Answer ☐

Questions 17, 18 and 19 refer to the information below.

Pure water is considered to be a weak electrolyte because of its ability to ionise. The equation for ionisation is shown below.

$$H_2O_{(l)} \rightleftharpoons H^+_{(aq)} + OH^-_{(aq)} \qquad \Delta H = 56.0 \text{ kJ mol}^{-1}$$

K_w (water equilibrium constant) is measured at a temperature of 283 K and found to be 2.92×10^{-15}. The sample of water is then heated to 298 K and the K_w increases to 1.00×10^{-14}.

17. Which of the following reasons best explains why the K_w is different when the temperature is changed?

(a) As the temperature of the system is increased, the water molecules have more kinetic energy, thus will react at a faster rate, favour the formation of the ions and increase K_w
(b) As the forward reaction is endothermic, increasing the temperature will favour a shift in equilibrium towards the products, thus increasing K_w
(c) At the higher temperature, there is a greater concentration of water molecules, thus increasing K_w at higher temperatures.
(d) Increasing the temperature provides a lower energy pathway for the reactant water molecules, thus favouring a shift in equilibrium toward the products and increasing K_w

Answer ☐

18. What is the concentration of hydrogen ions in the pure water at 283 K?

(a) 1.85×10^{-7} mol L^{-1}.
(b) 1.00×10^{-7} mol L^{-1}.
(c) 5.40×10^{-8} mol L^{-1}.
(d) There is insufficient information to calculate the concentration of hydrogen ions at 283 K.

Answer ☐

19. From the table below, choose the correct alternative that describes the pH and acidity for pure water at 283 K.

	pH	Acidity
(a)	7.27	Neutral
(b)	> 7.00	Basic
(c)	= 7.00	Neutral
(d)	< 7.00	Acidic

Answer ☐

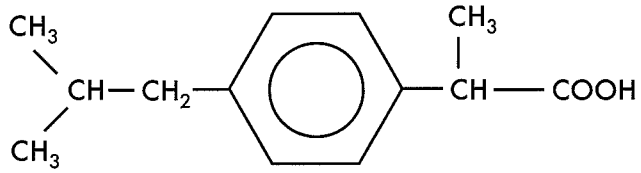
20. A solution contains 45.2 ppm concentration of K^+ ions. Assuming the density of the solution is 1.01g mL^{-1}, what is the concentration in mol L^{-1} of potassium chloride present?

(a) 1.15×10^{-4} mol L^{-1}.
(b) 6.12×10^{-4} mol L^{-1}.
(c) 4.52×10^{-3} mol L^{-1}.
(d) 1.17×10^{-3} mol L^{-1}. Answer ☐

21. What is the molecular formula for a compound that contains 46.2% carbon, 5.2% hydrogen and 48.6% fluorine, if the molecular mass of the compound is 156.1 g mol^{-1}?

(a) $C_3H_4F_2$
(b) $C_6H_6F_3$
(c) $C_5H_{10}F_5$
(d) $C_6H_8F_4$ Answer ☐

22. Ibuprofen has the chemical structure shown below.



To which two classes of organic compounds does Ibuprofen belong?

(a) Aromatic and carboxylic acid.
(b) Primary alcohol and ketone.
(c) Aromatic and alcohol.
(d) Cycloalkene and alcohol Answer ☐

23. How many isomers (structural and geometric) are there with the molecular formula C_3H_5Br ?

(a) 5.
(b) 4.
(c) 3.
(d) 2. Answer ☐

24. A sample of $CH_3CH_2CH_2OH$ is oxidised. Which of the following **cannot** be a product?

(a) CO_2
(b) CH_3CH_2COOH
(c) CH_3CH_2CHO
(d) CH_3COCH_3 Answer ☐

25. A chemist in a laboratory reacts some ethanol, propanoic acid and sulfuric acid together. The correct formula of the organic compound produced is

(a) $CH_3COOCH_2CH_2CH_3$
(b) $CH_3COCH_2CH_2CH_3$
(c) $CH_3CH_2COOCH_2CH_3$
(d) $CH_3CH_2CH_2CH_2CHO$ Answer ☐

END OF SECTION ONE

SECTION TWO: SHORT ANSWER 35% (70 marks)

This section has **11** questions. Answer **all** questions. Write your answers in the space provided.

Spare pages are included at the end of this trial paper if required.

Suggested working time for this section is 60 minutes.

Question 26 (4 marks)

(a) The electron configuration of a lithium atom is 2, 1. Using the same notation, give the electron configuration of

(i) a phosphide ion _____

(ii) a calcium atom _____

(2 marks)

(b) Noble gases are said to have a stable valence electron configuration. List two other species which have the same electron valence electron configuration as a neon atom.

_____

(2 marks)

Question 27 (8 marks)

In a chemistry laboratory, the labels have fallen off three bottles containing colourless organic liquids. The labels are propanal, propan-1-ol and propanoic acid. The chemist measures the boiling points of the liquids and writes the following observations.

Tests on liquid A show a boiling point of 97°C.
Tests on liquid B show a boiling point of 47°C.
Liquid C boiled at 140°C.

(a) Identify the name of each liquid and place in the spaces below.

Liquid A	Liquid B	Liquid C

(3 marks)

(b) Explain, in terms of intermolecular forces, why the three liquids have vastly different boiling points.

(3 marks)

(c) Describe one chemical test that could be used to distinguish between propan-1-ol and propanoic acid.

(2 marks)

Question 28 **(7 marks)**

Lime (calcium oxide) can be prepared industrially by the decomposition of limestone. The limestone is placed into a well ventilated kiln at atmospheric pressure and the system is heated to 1000°C. The reaction is shown below.

$$CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)} \qquad \Delta H = +178 \text{ kJ mol}^{-1}$$

(a) Explain why the reaction is carried out at a very high temperature and low pressure.

(4 marks)

(b) Explain why the kiln is well ventilated. (2 marks)

(c) Why will equilibrium never be established in this reaction vessel? (1 mark)

Question 29 **(12 marks)**

A new type of galvanic cell utilises methanol and oxygen in its reaction. Oxidation of the methanol occurs at the anode to produce carbon dioxide, while reduction of the oxygen occurs at the cathode to produce water.

(a) Write the oxidation and reduction half equations and the overall equation for the fuel cell. (3 marks)

(i) Oxidation

(ii) Reduction

(iii) Overall

(b) Prove, using oxidation numbers, that the methanol is oxidised in the above equation. (2 marks)

(c) As the reaction takes place at relatively low temperatures, the fuel cells contain a platinum catalyst. Explain, using the collision theory, how the use of a platinum catalyst affects the reaction rate in the above system. (3 marks)

(d) The methanol is dissolved in water to make a 1.25 mol L^{-1} solution. If 100 mL cartridges of the methanol solution are reacted and a total of 1.15 L of carbon dioxide gas was collected at a temperature of 298 K and 106 kPa over the life of the cell, calculate the percentage efficiency of the cell.

(4 marks)

Question 30 **(4 marks)**

Write the equation for the reaction that occurs in each of the following procedures. If no reaction occurs, write 'no reaction'. For full marks, chemical equations should refer only to those species consumed in the reaction and the new species produced. These species may be **ions** [for example $Ag^{+}_{(aq)}$], **molecules** [for example $NH_{3(g)}$, $NH_{3(aq)}$, $CH_3COOH_{(aq)}$] or **solids** [for example $BaSO_{4\,(s)}$, $Cu_{(s)}$, $Na_2CO_{3(s)}$].

(a) Solid potassium sulfate is added slowly to a lead (II) nitrate solution. (2 marks)

Equation:

(b) Some hydrogen peroxide solution is added to solid manganese dioxide. (2 marks)

Equation:

Question 31 **(4 marks)**

Write observations for any reactions that occur in the following procedures. In each case, describe in full what you would observe. Include any

- colours
- odours
- precipitates (give the colour)
- gases evolved (give the colour or describe as colourless).

If no change is observed, you should state this.

(a) Concentrated nitric acid is added to copper metal. (2 marks)

Observation:

(b) Propene is bubbled into a dilute aqueous bromine solution. (2 marks)

Observation:

Question 32 (5 marks)

Redox titrations involve a reaction between two solutions, one of which is a primary standard of known concentration and a solution of unknown concentration.

(a) List one example of a compound used as a primary standard in redox titrations. (1 mark)

(b) Describe two characteristics a primary standard must have to be a suitable reagent in redox titrations. (2 marks)

i)

ii)

(c) Why are indicators not necessary in some redox titrations? (2 marks)

Question 33 (7 marks)

Carbon dioxide can be produced by the reaction of solid lithium carbonate with dilute hydrochloric acid.

(a) Write a balanced ionic equation for the reaction. (2 marks)

(b) If 8.34 g of lithium carbonate is fully reacted, what volume of 0.498 mol L^{-1} HCl would be needed? (3 marks)

(c) A student investigating the reaction makes the following hypothesis.

"Doubling the volume of 0.498 mol L^{-1} HCl will increase the rate at which the carbon dioxide gas is produced."

The student tested the hypothesis. What would the student observe about the reaction rate?

(2 marks)

Question 34 **(5 marks)**

(a) The following compounds are soluble in water and have varying pH levels. Classify the compounds according to their pH when dissolved in water and place in the table below.

(3 marks)

K_2CO_3 $LiNO_3$ NH_4Cl $Mg(NO_3)_2$ $NaHSO_4$ NH_3

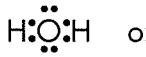
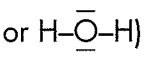
pH > 7	pH = 7	pH < 7

(b) Potassium sulfide solution has a pH greater than 7.00. Explain with the aid of an equation why this is so.

(2 marks)

Question 35 **(8 marks)**

For each species listed in the table below, draw the electron dot structure, representing all valence shell electron pairs either as : or as – **and** state or draw the shape of the molecule or ion.

For example, water  or  or )

Species	Electron Dot Structure (showing all valence shell electrons)	Shape (sketch or name)
NO_2^-		
CHI_3		
SO_4^{2-}		
Sodium hydroxide		(name only)

Question 36 **(6 marks)**

A frequently used example of an alkaline buffer solution prepared in the laboratory is a 1.00 litre of buffer solution containing 0.1 mol L^{-1} $NH_4C\ell$ and 0.1 mol L^{-1} NH_3.

The ammonia is firstly added to the water to create an equilibrium in the solution according to the equation below.

$$NH_{3(aq)} + H_2O_{(l)} \rightleftharpoons NH_4^{+}{}_{(aq)} + OH^{-}{}_{(aq)}$$

(a) Explain, using Le Chatelier's Principle, the effect on the reaction when the ammonium chloride is added to the ammonia solution to complete the buffer.

(3 marks)

(b) A student adds a little potassium hydroxide solution to the buffer solution. Explain, using an equation, why the pH of the solution does not change significantly.

(3 marks)

END OF SECTION TWO

SECTION THREE: EXTENDED ANSWER 40% (80 Marks)

This section contains **six (6)** questions. You must answer **all** questions. Write your answers in the space provided.

Spare pages are included at the end of this trial paper if required.

Suggested working time for this section is 70 minutes.

Question 37 (18 marks)

Chemists and laboratory technicians are often relied upon to analyse the constituents of food products. Vinegar is one such flavouring product used throughout the world. Vinegar is handy around the house as it is a very useful general multipurpose cleaner. Vinegar's key ingredient is ethanoic acid, a weak acid obtained from fermenting ethanol. Vinegar can also contain small amounts of tartaric and citric acids.

(a) Explain, using an equation, why ethanoic acid is classified as a weak acid.

(2 marks)

A 0.830 g sample of the primary standard tartaric acid dihydrate ($C_4H_6O_6.2H_2O$) was dissolved in some distilled water and made up to 250 mL in a volumetric flask. It was then titrated against the sodium hydroxide (to standardise it), with a 20 mL aliquot of the acid solution reacting exactly with 10.6 mL of the base.

(b) Calculate the concentration of the tartaric acid solution.

(3 marks)

(c) Calculate the concentration of the sodium hydroxide solution.
N.B. Tartaric acid has two ionisable hydrogen atoms per molecule of acid.

(3 marks)

(d) A chemist is asked to test a commercial brand of vinegar. The chemist obtains a 25.0 mL sample of the vinegar. The chemist takes 10.00 mL of the vinegar and dilutes it to 250 mL in a volumetric flask. 20.00 mL aliquots of the diluted vinegar solution were then titrated against the standard sodium hydroxide solution. The average titre value of sodium hydroxide was 13.6 mL. Calculate the % composition of the original vinegar solution. (Assume density of commercial vinegar is 1.00 g mL^{-1}).

(5 marks)

(e) Describe a suitable indicator for the second titration and indicate why it is a suitable indicator.

(2 marks)

Choice of Indicator:

(f) When performing titrations, it is important not to add the solution from the burette too quickly. Explain why doing this would give inaccurate results.

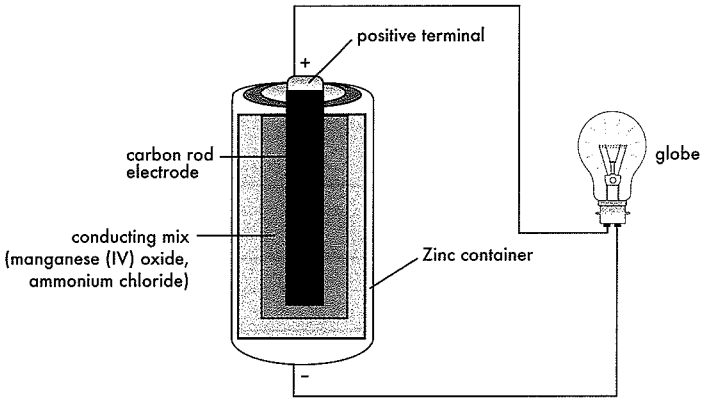
(1 mark)

(g) Name **two** variables that must be kept constant during the above experiment.

(2 marks)

Question 38 (9 marks)

The ordinary dry cell or Leclanche cell, is a primary cell and is one of the cheapest and simplest type of galvanic cells. Dry cells are designed to produce a maximum terminal voltage of 1.50 volts which decreases over time. A dry cell is composed of an outer zinc casing surrounding a graphite (C) rod immersed in a paste containing manganese (IV) oxide (MnO_2) and ammonium chloride (NH_4Cl). Between the casing, there is a porous fibre which allows ion flow between the electrode whilst isolating the zinc and manganese dioxide. The cross sectional structure of the ordinary dry cell in shown below. It is connected in series with a light globe.



The overall cell discharge reactions for a dry cell are:

Oxidation: $Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2e^-$

Reduction: $2MnO_{2(s)} + 2NH_4^+{}_{(aq)} + 2e^- \rightarrow Mn_2O_{3(s)} + 2NH_{3(aq)} + H_2O_{(l)}$

(a) Write the overall redox equation for a dry cell. (1 mark)

Overall: _____

(b) Label the anode and cathode in the above diagram. (2 marks)

(c) Show, using an arrow, the direction of electron flow in the external wire. (1 mark)

(d) Why does the terminal voltage of the dry cell decrease over time? (2 marks)

_____

_____

(e) Some dry cells are used in a torch but a person leaves their torch switched on. The dry cells in the battery go flat and the person takes the "dead" batteries out. Use the equations above to explain why it is more likely for a dead battery to leak its contents out over time compared to a "fresh" unused battery. (3 marks)

_____

_____

_____

Question 39

(13 marks)

Gunpowder consists of a carefully ground together mixture of potassium nitrate, charcoal and sulfur. Potassium nitrate is the major ingredient in gunpowder and comprises 75.0% of gunpowder. The sulfur in gunpowder acts as a fuel and increases the rate of combustion. Gunpowder is typically 10.0% sulfur. The third ingredient in gunpowder is carbon in the form of charcoal and makes up the remaining composition of gunpowder. The role of the charcoal is to provide energy for the reaction.

Combustion of the gunpowder converts some of the gunpowder to a gas, while the remainder ends up as a solid residue inside the gun barrel. The equation for combustion is

$$10\ KNO_{3(s)} + 3\ S_{(s)} + 8\ C_{(s)} \rightarrow 2\ K_2CO_{3(s)} + 3\ K_2SO_{4(s)} + 6\ CO_{2(g)} + 5\ N_{2(g)}$$

Gunpowder is set off by flame, sparks, friction or impact. One gram of solid gunpowder will expand to a size of 0.25 L and release over 2900 kJ of energy upon ignition.

(a) Why is the gunpowder ground together before being fired? (2 marks)

(b) How does the charcoal act as a fuel during the ignition of gunpowder? (2 marks)

(c) The reaction is trialled on a small scale in a controlled laboratory. A chemist ignites 1.67 g of potassium nitrate with 0.230 g of sulfur and excess charcoal. If the reaction process is 91.0% efficient, calculate the total mass of soot (potassium carbonate and potassium sulfate) produced. (Ignore the mass of excess reagent).

(7 marks)

(d) Calculate the theoretical mass of nitrogen gas that could be produced.

(2 marks)

Question 40 (16 marks)

Glutamine is one of twenty amino acids found in the body and it is important as a fuel source for immune cells and cell functions. Glutamine contains the elements carbon, hydrogen, nitrogen and oxygen.

A 3.24 g sample of the glutamine was burnt in a current of dry oxygen, 4.88 g of carbon dioxide and 2.00 g of water were produced. A separate 1.60 g sample was combusted, the nitrogen dioxide gas isolated, collected and found to have a mass of 1.01 g.

(a) Calculate the empirical formula of glutamine. (8 marks)

(b) 0.0170 mol of glutamine is weighed and has a mass of 2.484 g. Calculate the relative molecular mass and hence determine the molecular formula of the glutamine.

(3 marks)

(c) What two functional groups are present in amino acid structures?

(2 marks)

(d) Glutamine is an alpha (α) amino acid. By looking at the chemical structure of the substance, how can a chemist recognise if a substance is an alpha (α) amino acid?

(1 mark)

(e) (i) Alpha amino acid molecules such as glutamine can join together to form large polypeptide chains known as proteins. A polypeptide is a condensation polymer. Describe the process that happens when glutamine undergoes condensation polymerisation.

(1 mark)

(ii) Draw a polymer sequence of three monomers of glutamine, given that it has the general formula H_2N - R - COOH. (N.B. The key functional groups are -NH_2, -COOH and R, where "R" is the middle part of the molecule).

(1 mark)

Question 41 (9 marks)

Chromium is a grey, lustrous and hard metal and is a member of the transition metal block. Chromium is used in stainless steel to increase its resistance to corrosion and discolouration. It is also used to electroplate other metals and increase surface hardness.

For the production of pure chromium, the iron has to be separated from the chromium in a multi step process. The reactions are:

i) $4\ FeCr_2O_{4(s)} + 8\ Na_2CO_{3(s)} + 7\ O_{2(g)} \rightarrow 8\ Na_2CrO_{4(s)} + 2\ Fe_2O_{3(s)} + 8\ CO_{2(g)}$

ii) $2\ Na_2CrO_{4(aq)} + H_2SO_{4(aq)} \rightarrow Na_2Cr_2O_{7(aq)} + Na_2SO_{4(aq)} + H_2O_{(l)}$

iii) $Na_2Cr_2O_{7(aq)} + 2\ C_{(s)} \rightarrow Cr_2O_{3(s)} + Na_2CO_{3(aq)} + CO_{(g)}$

iv) $Cr_2O_{3(s)} + 2\ A\ell_{(s)} \rightarrow 2\ Cr_{(s)} + A\ell_2O_{3(s)}$

(a) If the ore is 48.0% $FeCr_2O_4$, calculate the mass of chromium produced if 2.50 tonnes of ore is reacted.

(6 marks)

(b) Calculate the volume of carbon monoxide produced in step (iii), if the reaction is carried out at 420°C and a pressure of 130 kPa. (3 marks)

Question 42 **(15 marks)**

An acid-base titration is an volumetric analysis laboratory process. Describe a titration procedure a student could use to determine the concentration of an unknown hydrochloric acid solution. You are permitted to use any classroom laboratory equipment. Discuss the following ideas within your extended answer:

- Standardising solutions
- Correct use of equipment
- Rinsing procedures
- Indicators
- Equivalence point and end point
- Sources of error and minimising errors
- Handling of chemicals (safety).

To obtain maximum marks, include diagrams, equations and appropriate illustrations. Do **not** do any calculations in your response, but indicate the **method used** for the calculation. Write your response in 1–2 pages.

Additional working space

Additional working space

END OF PAPER

SOLUTIONS TO TRIAL PAPER

Section One: Multiple Choice

1. (b) Y is in group 14 and Z group 17. A stable structure will be covalent with the formula YZ_4.

2. (c) Sulfur trioxide is a non polar molecule (but still triangular planar).

3. (c) This is the only trend of the alternatives given that is true of the elements of the periodic table.

4. (d) Metals are malleable because of non directional bonding between ions and sea of electrons. Metals have a high melting point because of the strong forces between metal ions and electrons. Metals conduct heat energy as kinetic energy via mobile delocalised electrons.

5. (a) Each carbon in the graphite structure has one delocalised valence electron. As these electrons are mobile and free to move within a layer, they can carry an electrical charge.

6. (b) $n(H_2) = \frac{V}{22.41}$ Ratio $\frac{(H_2)}{M} = \frac{0.1875}{0.125}$

$= \frac{4.201}{22.41}$ ≈ 1.5

$= 0.1875$ mol

$2M + 6H^+ \rightarrow 2M^{3+} + 3H_2$

$\therefore$ M is 3+

7. (b) Buffers must consist of an acid and its conjugate base. By adding the sodium acetate to the acetic acid, the pH of the solution increases.

8. (a) Metal oxides and hydroxides are basic, but aluminium oxide is insoluble in water. Thus sodium oxide will dissolve to give a strongly basic pH solution.

9. (c) Iodine's lowest oxidation state is -1 (as shown).

10. (c) The emf of a galvanic cell decreases as the concentration of reactants decreases. Thus emf is not constant for the duration of a reaction.

11. (b) Ketones do not react with acidified dichromte, but all of the others do.

12. (d) Rinsing the conical flask with HCl solution will alter the number of moles of acid reacting in the titration.

13. (a) ΔH = (products – reactants) = 483 kJ mol^{-1}. This reaction is endothermic as shown, therefore ΔH must have a positive sign. Therefore the energy of products is greater than energy of reactants.

14. (d) Removing carbon dioxide gas from system will shift equilibrium to the right and favour the formation of solid iron. Adding more finely powdered iron (II) oxide will have no effect as it is a solid.

15. (c) $K = [CO_2]/[CO]$. Iron, a (II) oxide, is a solid and does not have a concentration.

16. (d) Chlorine changes oxidation state from +5 to -1 ie chlorine is reduced. Oxygen changes oxidation state from -2 to 0 i.e. oxygen is oxidised. Other equations: there are no changes in oxidation numbers.

17. (b) The forward reaction is endothermic, therefore according to Le Chatelier's Principle, increasing temperature will favour the endothermic reaction. Thus a greater concentration of hydrogen and hydroxide ions, and a greater K value.

18. (c) $K_w = [H^+]\,[OH^-]$ but in pure water $[H^+] = [OH^-]$
thus $[H^+] = \sqrt{2.92 \times 10^{-15}}$
$= 5.40 \times 10^{-8}$ mol L^{-1}

19. (a) $pH = -\log [H^+] = -\log 5.40 \times 10^{-8} = 7.27$
In pure water $[H^+] = [OH^-]$. Thus the solution must be neutral.

20. (d) 45.2 ppm = 45.2×10^{-3} g solute per kg of solution
Density = 1.01 g mL^{-1} thus 1 litre of solution has a mass of 1010 g.
Therefore amount of solute in 1010 g of solution
$= 45.2 \times 10^{-3} \times 1.01 = 4.5955 \times 10^{-2}$g potassium ions
$n(KCl) = n(K^+) = 4.5955 \times 10^{-2}/39.1$
$= 1.17 \times 10^{-3}$ mol L^{-1}.

21. (d)

	C	H	F
	46.2%	5.2%	48.6%
n=	46.2/12.01	5.2/1.008	48.6/19
=	3.85	5.15	2.56
Ratio	1.5	2	1
EF	3	4	2

Thus M(EF) = 3 x 12.01 + 4 x 1.008 + 2 x 19 $\approx$ 78
M(MF) = 2 x M(EF) thus MF is $C_6H_8F_4$

22. (a) The two functional groups present are the

aromatic (benzene ring) and the carboxylic acid (R-COOH) groups.

23. (a)
2-bromo prop-1-ene
3-bromo prop-1-ene
trans-1-bromo prop-1-ene
cis-1-bromo prop-1-ene
bromocyclopropane

24. (d) Alternative d is a ketone, not a product of any oxidation of primary alcohols. Carbon dioxide is the product of the combustion of any organic compound in excess oxygen.

25. (c) Product name is the ester ethyl propanoate. Alternative c is the correct structure for ethyl propanoate.

Section Two: Short Answer

26. (i) a) phosphide ion 2, 8 ,8
b) calcium atom 2, 8, 8, 2
(ii) Any 2 of fluoride, oxide, nitride, sodium, magnesium or aluminium ions.

27. (a) Liquid A is propan-1-ol, liquid B is propanal, liquid C is propanoic acid.
(b) Propanal has dipole – dipole interactions, propan-1-ol and propanoic acid have hydrogen bonding which is a stronger intermolecular force. Propanoic acid has the opportunity for more hydrogen bonding because it has an extra carbon to oxygen double bond, i.e. propanal has the lowest boiling point, propan-2-ol moderate boiling point and propanoic acid the highest.
(c) React a little of both with acidified permanganate or acidified dichromate solutions. Look for colour change with propan-1-ol.

28. (a) A very high temperature increases the reaction rate and according to Le Chatelier's Principle, favours the endothermic reaction, therefore equilibrium will shift to the right. At a low pressure, the system will move to increase the pressure, i.e. favour the reaction with the most moles of gas, i.e. shift equilibrium to the right.
(b) The carbon dioxide gas can escape, decrease the pressure and shift the equilibrium to the right, increasing yield of lime.
(c) The reaction is not a closed system, thus true equilibrium can never be established.

29. (a)
(i) $(CH_3OH + H_2O \rightarrow CO_2 + 6H^+ + 6e^-) \times 2$
(ii) $\{ O_2 + 4H^+ + 4e^- \rightarrow 2H_2O \} \times 3$
(iii) Overall $2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$

(b) Oxidation number of carbon in methanol is -2 and in carbon dioxide is +4, i.e. oxidation number increases and methanol is oxidised.
(c) A catalyst increases the reaction rate. It provides a lower energy reaction pathway. Therefore, more reactant particles have enough energy greater than the activation energy. Therefore, more collisions will occur and a faster reaction rate will occur.
(d)
$n(CH_3OH) = cV$
$= 1.25 \times 0.100 = 0.125$ mol

Assuming 100% efficiency

$n(CO_2) = n(CH_3OH)$
$= 0.125$ mol
$V(CO_2) = nRT/P$

$$= \frac{0.125 \times 8.315 \times 298}{106}$$

$= 2.922$ L

Therefore % efficiency

$$= \frac{1.15}{2.922} \times 100$$

$= 39.4\%$

30. (a) $Pb^{2+}_{(aq)} + K_2SO_{4(s)} \rightarrow PbSO_{4(s)} + 2K^+_{(aq)}$
(b) $2H_2O_{2(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)}$ (MnO_2 catalyst)

31. (a) A salmon pink solid is added to a colourless solution. A brown pungent gas is evolved and the solution turns deep green/blue. Salmon pink solid appears to turn black in colour and dissolves.
(b) A colourless gas is added to a red/brown solution. The solution decolourises.

32. (a) Ammonium iron (II) sulfate, oxalic acid or sodium oxalate.
(b) i) and ii)
- Obtain in pure form (purity preferably > 99.5%)
- Be sufficiently stable.
- Have high molecular mass.
- Does not react with air
- Water soluble (any two)

(c) The aqueous redox solutions change colour naturally during a redox titration. i.e. reagents are coloured. (E.g. MnO_4^{-1} is purple and Mn^{2+} colourless to faint pink.

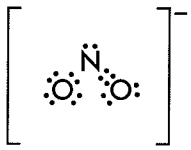
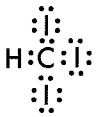
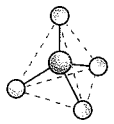
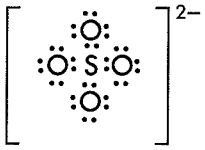
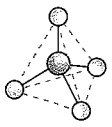
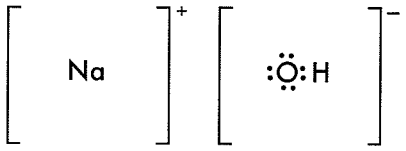
33.
(a) $Li_2CO_{3(s)} + 2H^+_{(aq)} \rightarrow 2Li^+_{(aq)} + CO_{2(g)} + H_2O_{(l)}$
(b) $n(Li_2CO_3) = m/M$
$= 8.34/73.892$
$= 0.1129$ mol
$Mr\ (Li_2CO_3) = 73.892$

$n(H^+) = 2 \times n(Li_2CO_3) = 0.2257$ mol
$V(H^+) = n/c = 0.226/ 0.498 = 0.453$ L (453mL)

(c) The reaction would proceed at the same rate as before since [HCl] remains constant.

34. (a) pH > 7, NH_3 and K_2CO_3
pH = 7, $LiNO_3$ and $Mg(NO_3)_2$
pH < 7, NH_4Cl and $NaHSO_4$
(b) The sulfide ion partially hydrolyses in water to form a weakly basic solution of hydrogen sulfide and hydroxide ions, thus the pH is greater than 7.00. $S^{2-}(aq) + H_2O(l) \rightleftharpoons HS^-(aq) + OH^-(aq)$

35.

Species	Structural formula (showing all valence shell electrons)	Shape (sketch or name)
NO_2^-		V shaped or bent 
CHI_3		Tetrahedral 
SO_4^{2-}		Tetrahedral 
Sodium hydroxide		3-D Lattice

36. (a) The addition of NH_4^+ increases the concentration of NH_4^+ ions. According to Le Chatelier's Principle, the system will move to decrease the concentration of NH_4^+ ions. The equilibrium will shift to the left and favour the reactants.
(b) The addition of hydroxide ions will shift the equilibrium to the left and the the reaction $NH_4^+ + OH^- \rightarrow NH_3 + H_2O$ will be favoured. Any excess ammonia produced will react with the H_3O^+ ions to form more NH_4^+ ions, thus keeping a balanced pH i.e.
$NH_3 + H_3O^+ \rightleftharpoons NH_4^+ + H_2O$

OR

Two reactions occur to ensure the concentration of H_3O^+ and OH^- are kept fairly constant even when a small amount of strong base is added (with equations above).

Section Three: Extended answer

37. (a) Ethanoic acid only partially ionises in solution to produce some hydrogen ions, thus it is classified as a weak acid i.e.

$$CH_3COOH_{(aq)} + H_2O_{(l)} \rightleftharpoons CH_3COO^-_{(aq)} + H_3O^+_{(aq)}$$

(b) $n(\text{acid}) = \dfrac{0.830}{186.12}$

$= 4.459 \times 10^{-3}$ mol

$M(\text{acid}) = 4 \times C + 10 \times H + 8 \times O$

$= 4 \times 12.01 + 10 \times 1.008 + 8 \times 16.00$

$= 186.12$

$c(\text{tartaric acid}) = n/V$
$= 4.459 \times 10^{-3} / 0.250$
$= 0.0178 \text{ mol L}^{-1}$

(c) $n(\text{acid}) = cV$
$= 0.01783 \times 0.0200$
$= 3.568 \times 10^{-4}$ mol

$n(\text{base}) = 2n(\text{acid})$
$= 2 \times 3.57 \times 10^{-4}$
$= 7.135 \times 10^{-4}$ mol

$c(\text{base}) = n/V$
$= 7.13 \times 10^{-4} / 0.0106$
$= 0.0673 \text{ mol L}^{-1}$

(d) $n(\text{base}) = cV$
$= 0.06731 \times 0.0136$
$= 9.155 \times 10^{-4}$ mol

$n(\text{acid}_{\text{in 20mL}}) = 9.155 \times 10^{-4}$ mol

$n(\text{acid}_{\text{in 250mL}}) = \dfrac{250 \times 9.155 \times 10^{-4}}{20.00}$

$= 0.0114$ mol

Density = 1g mL^{-1} i.e. 10 mL ≡ 10 g of solution

$m(\text{acid}) = nM$
$= 0.0114 \times 60.052$
$= 0.687\text{g}$

$M(\text{acid}) = 2 \times C + 4 \times H + 2 \times O$

$= 2 \times 12.01 + 4 \times 1.008 + 2 \times 16.00$

$= 60.052$

$\%(\text{acid}) = \dfrac{0.687 \times 100}{10}$

$= 6.87\%$

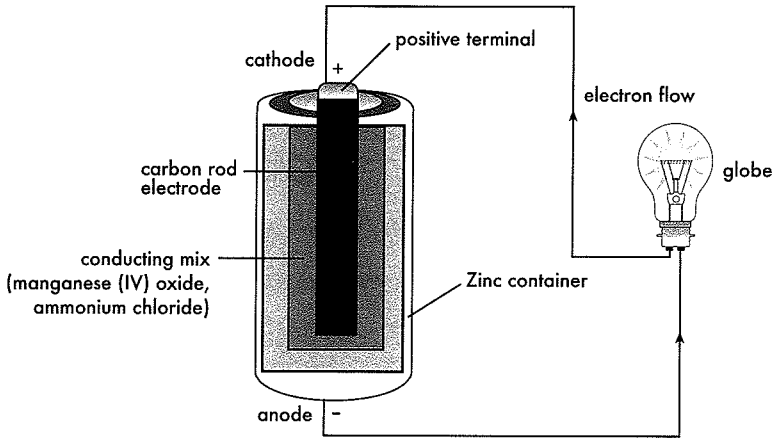
(e) Phenolphthalein – The end point in a weak acid/strong base titration lies between pH 8–10, thus making this indicator suitable. (Indicator range 8.3–10).

(f) The solutions will not have reacted fully and the colour change/end point would be difficult to detect. The solution requires thorough mixing otherwise the endpoint will be missed.

(g) Using the same glassware, using the same standardised solution, using the same indicators (or other suitable responses; any two).

38. (a) $Zn_{(s)} + 2MnO_{2(s)} + 2NH_4^+{}_{(aq)} \rightarrow Zn^{2+}{}_{(aq)} + Mn_2O_{3(s)} + 2NH_{3(aq)} + H_2O_{(l)}$

(b) and (c)



(d) The emf supplied to the cell is a result of the concentration of reactants. Over the duration of the life of the battery, the concentration of reactants decreases, thus decreasing the emf of the reaction.

(e) $Zn_{(s)} \rightarrow Zn^{2+}{}_{(aq)} + 2e^-$
The zinc casing reacts and dissolves away. Therefore in an old battery, the contents may leak through the dissolved container. OR The zinc reacts with the acidic ammonium chloride and the casing therefore dissolves.

39. (a) To increase the surface area of the reactant surfaces, therefore a faster reaction rate occurs.
(b) Combustion of the charcoal is exothermic, therefore releasing energy when burnt.
(c) $n(KNO_3)$ $= m/M$ $M_r(KNO_3) = 101.11$ $n(S) = m/M$ $M_r(S) = 32.06$
$= 1.67/101.11$ $= 0.230/32.06$
$= 0.0165$ mol $= 7.174 \times 10^{-3}$ mol

Compare actual ratio moles to stoichiometric ratio moles KNO_3/ S

Stoich $= 10/3 = 3.33$ Actual $= 0.0165/ 7.174 \times 10^{-3} = 2.304$

Actual < Stoich, therefore the KNO_3 is the limiting reagent.

$n(K_2SO_{4\ produced}) = 0.910 \times 3/10 \times n(KNO_3)$
$= 4.509 \times 10^{-3}$ mol

$n(K_2CO_{3\ produced}) = 0.910 \times 2/10 \times n(KNO_3)$
$= 3.006 \times 10^{-3}$ mol

$m(K_2SO_4) = nM \quad M(K_2SO_4) = 174.26$
$= 4.509 \times 10^{-3} \times 174.26$
$= 0.7857$ g

$m(K_2CO_3) = nM \quad M(K_2CO_3) = 138.21$
$= 3.006 \times 10^{-3} \times 138.21$
$= 0.4155$ g

Therefore m(soot) = 0.7857 + 0.4155 = 1.20 g

(d) $n(N_2) = 0.910 \times 5/10 \times n(KNO_3)$
$= 0.910 \times 0.5 \times 1.65 \times 10^{-2}$
$= 7.515 \times 10^{-3}$ mol

$m(N_2) = nM$
$= 7.515 \times 10^{-3} \times 28.02$
$= 0.211$ g

40.(a) $n(C) = n(CO_2) = 4.88/44.01 = 0.1109$ mol
$m(C) = nM = 0.1109 \times 12.01 = 1.331$g

$n(H) = 2n(H_2O) = 2 \times 2.00/18.016 = 0.222$ mol
$m(H) = nM = 0.222 \times 1.008 = 0.224$ g

$n(N) = n(NO_2) = 1.01/46.01 = 2.195 \times 10^{-2}$ mol

$m(N_{in\ 3.24g}) = \frac{3.24}{1.6} \times 2.195 \times 10^{-2} \times 14.01$

$= 0.622$ g

$n(N_{in\ 3.24g}) = \frac{3.24}{1.6} \times 2.195 \times 10^{-2}$

$= 0.0444$ mol

$m(O) = 3.24 - [1.33 + 0.224 + 0.622] = 1.0622$ g

$n(O) = 1.0622/16 = 0.0664$ mol

	C	H	N	O
n	0.1109	0.222	0.0444	0.0664
Ratio	2.5	5	1	1.5
EF	5	10	2	3

Therefore the EF is $C_5H_{10}N_2O_3$.

(b) $M = m/n = 2.484/ 0.0170 = 146.117$

$M(EF) = (5 \times 12.01) + (10 \times 1.008) + (2 \times 14.01) + (3 \times 16) = 146.15$

Therefore MF = EF, therefore MF is $C_5H_{10}N_2O_3$

(c) Amine and carboxylic acid groups.

(d) The amine functional group is attached to the carbon attached to the carboxylic acid group.

(e) (i) Monomer glutamine units join together to form a long chain and molecules of water are eliminated from the structure.
(ii) -[-HN-R-CO-HN-R-CO-HN-R-CO-]n-

41. (a) $n(FeCr_2O_4) = m/M = \frac{2.50 \times 10^6 \times 0.480}{223.85}$

$M(FeCr_2O_4) = 1 \times 55.85 + 2 \times 52 + 4 \times 16 = 223.85$

$= 5.361 \times 10^3$ mol

From equations $n(Cr) = 2 \times n(FeCr_2O_4)$

$= 2 \times 5.361 \times 10^3$

$= 1.072 \times 10^4$ mol

$m(Cr) = nM$

$= 1.072 \times 10^4 \times 52.00$

$= 5.58 \times 10^5$ g (0.558 tonnes)

(b) From equations $n(CO) = n(FeCr_2O_4)$

$= 5.361 \times 10^3$

$PV = nRT$

$V = nRT/P$

$= \frac{5.361 \times 10^3 \times 8.315 \times (420 + 273.1)}{130}$

$= 2.38 \times 10^5$ L

42.

- Weigh an appropriate amount of anhydrous sodium carbonate into a clean 250 mL beaker. The sodium carbonate must be dry, pure and unreactive.
- Dissolve the sodium carbonate in a small amount of deionised water.
- Transfer the solution to a 250 mL volumetric flask. Calculate the concentration of the standardised sodium carbonate solution.
- Rinse the beaker with deionised water and transfer all rinses to the volumetric flask.
- Fill up the volumetric flask so the bottom of the meniscus is on the calibration line.
- Seal the flask and invert the flask a number of times.
- Label the flask as standard sodium carbonate solution (include its concentration on the label).
- Clean four 250 mL conical flasks with detergent/water and rinse with deionised water.
- Clean a 50 mL burette with detergent/water and rinse with a small amount of unknown hydrochloric acid solution.
- Clean a 20 mL pipette with detergent/water and then rinse with a little of the standardised sodium carbonate solution.
- Carefully pour hydrochloric acid solution into the burette and close the tap. Ensure there are no air bubbles in the burette. Remove filter funnel from top of burette.
- Accurately pipette 20 mL samples of the standardised sodium carbonate solution into the conical flasks. Ensure all of the 20 mL has droppered into the conical flasks (do not "blow out" the remaining drop in the bottom of the pipette).
- The titration involves a weak acid and a strong base, so the pH change will be in the region of pH 4- 6. Methyl orange indicator changes colour in the range of pH 3.1 – 4.4, and is a suitable indicator for this titration. In this titration it will change from yellow to orange in the titrant solution. Other indicators which may be suitable are bromophenol blue or cresol red.
- The equivalence point is when the reaction between the combined acid and base are in stoichiometric proportions. The end point of the titration is when the indicator initially changes colour, signalling equivalence has occurred.
- Add three or four drops of indicator to the conical flasks and swirl.
- Record initial volume of acid from the burette and begin to titrate by opening the burette tap.
- Slowly add the acid solution to the base solution, while swirling the conical flask.
- From time to time, rinse the inside of the conical flask with deionised water, to ensure all of the base is in the bottom of the flask.
- Slow the pouring of the acid from the burette once the colour begins to show signs of changing.
- Rinse the inside of the conical flask with deionised water once again.
- At first sign of permanent colour change from yellow to orange, stop titration and note final volume. Care should be taken to read the burette with the bottom of the meniscus at eye level. Read to 2 decimal places.
- Calculate the final titre volume by subtracting the initial volume from the final volume. The first titre is a rough titration to show approximately the volume of acid needed to titrate against the standardised base.
- Repeat the titration above again a number of times, ensuring that the titration is stopped at the first sign of a permanent colour change (yellow to orange).
- Keep repeating the process until three titre volumes are within 0.1 mL to 0.2mL of each other.
- Calculate the average titre volume of the acid used and use the standard concentration/ volume of base to calculate the concentration of acid.
- The reaction for the above equation is

$$2H^{+}_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow CO_{2(g)} + H_2O_{(l)}$$

- The concentration of the acid is equal to two times the concentration of the base used times the volume of the base used (20 mL), divided by the average titre volume of the acid used from the burette.
- This will give you the concentration of hydrochloric acid.
- Sources of error include (but are not limited to) incorrect rinsing of glassware, using incorrect indicator, not measuring volumes accurately, not effectively transferring solutions, adding titrant acid too quickly, having air bubbles in the burette, not calculating the concentrations correctly.
- Minimising errors can be achieved by following the above procedures carefully and consistently.
- Students can include diagrams of various glassware, e.g. pipette, burette, conical flask.
- Students should be safe at all times, wearing safety glasses while titrating. Students should also carry solutions around safely. If there is a solution spill, rinse appropriately and notify your teacher.