Dot points that may be covered in the examination.

Measuring solubility and concentration

- solution concentration as a measure of the quantity of solute dissolved in a given mass or volume of solution (mol L^{-}, g L^{-}, %(m/v), %(v/v), ppm), including unit conversions
- the use of solubility tables and solubility graphs to predict experimental determination of ionic compound solubility; the effect of temperature on the solubility of a given solid, liquid or gas in water
- the use of precipitation reactions to remove impurities from water

Analysis for acids and bases

- volume-volume stoichiometry (solutions only) and application of volumetric analysis, including the use of indicators, calculations related to the preparation of standard solutions, dilution of solutions, and use of acid-base titrations (excluding back titrations) to determine the concentration of an acid or a base in a water sample

Measuring gases

- CO_2, CH_4 and H_2O as three of the major gases that contribute to the natural and enhanced greenhouse effects due to their ability to absorb infrared radiation
- the definitions of gas pressure and standard laboratory conditions (SLC) at 25 °C and 100 kPa
- calculations using the ideal gas equation ($pV = nRT$), limited to the units kPa, Pa, atm, mL, L ,°C, and K (including unit conversions)
- the use of stoichiometry to solve calculations related to chemical reactions involving gases (including moles, mass and volume of gases
- calculations of the molar volume or molar mass of a gas produced by a chemical reaction

Acid-base (proton transfer) reactions in water:

- the Brønsted-Lowry theory of acids and bases, including polyprotic acids and amphiprotic species, and the writing of balanced ionic and full equations, with states, for their reactions in water
- the ionic product of water, the pH scale and the use of pH in the measurement and calculations of strengths of acids and bases and dilutions of solutions (calculations involving acidity constants are not required)
- the distinction between strong and weak acids and strong and weak bases, and between concentrated and dilute acids and bases, including common examples
- the reactions of acids with metals, carbonates and hydroxides including balanced full and ionic equations, with states

Neutralisation reactions to produce salts:

- reactions of acids with metal carbonates and hydroxides, including balanced full and ionic equations, with states
- types of antacids and their use in the neutralisation of stomach acid
- accuracy and precision in measurement as illustrated by the comparison of natural indicators, commercial indicators, and pH meters to determine the relative strengths of acidic and basic solutions
- applications of acid-base reactions in society: for example, natural acidity of rain due to dissolved CO_2 and the distinction between the natural acidity of rain and acid rain, or the action of CO_2 forming a weak acid in oceans and the consequences for shell growth in marine invertebrates

Water as a unique chemical:

- the existence of water in all three states at Earth's surface, including the distribution and proportion of available drinking water
- the relatively high latent heat of vaporisation of water and its impact on the regulation of the temperature of the oceans and aquatic life
- explanation of the anomalous properties of H_2O (ice and water), with reference to hydrogen bonding:
  - trends in the boiling points of Group 16 hydrides
  - the density of solid ice compared with liquid water at low temperatures
  - specific heat capacity of water including units and symbols

Redox (electron transfer) reactions:

- oxidising and reducing agents, and redox reactions, including writing of balanced half and overall redox equations (including in acidic conditions), with states
- the reactivity series of metals and metal displacement reactions, including balanced redox equations, with states
- applications of redox reactions in society: for example, corrosion or the use of simple primary cells in the production of electrical energy from chemical energy

Analysis for salts:

- sources of salts found in water or soil (which may include minerals, heavy metals, organo-metallic substances) and the use of electrical conductivity to assess the salinity and quality of water or soil samples
- quantitative analysis of salts:
  - molar ratio of water of hydration for an ionic compound
  - the application of mass-mass stoichiometry to determine the mass present of an ionic compound
  - the application of colorimetry and/or UV-visible spectroscopy, including the use of a calibration curve to determine the concentration of ions or complexes in a water or soil sample

Revision for the 2026 end-of-year examination of (90 minutes)

1. Which volume of gas at 25°C and 1 atm contains 2 moles of gas?
   a. 49.6 L
   b. 22.4 L
   c. 11.2 L
   d. 0.0821 L

2. What is the molarity of a solution made by dissolving 0.5 mol of solute in 250 mL of solution?
   a. 0.5 M
   b. 2.0 M
   c. 0.125 M
   d. 0.25 M

3. Which metal will react fastest with dilute hydrochloric acid?
   a. Copper
   b. Zinc
   c. Gold
   d. Silver

4. A compound X has empirical formula CH_2O and molar mass about 180 g/mol. Its molecular formula is:
   a. CH_2O
   b. $C_3H_6O_3$
   c. $C_6H_{12}O_6$
   d. $C_2H_4O_2$

5. Which one of the following options is an amphoteric substance?
   a. H_2SO_4
   b. NaOH
   c. HCl
   d. H_2O

6. In an acid-base titration, between NaOH and an unknown sample of H_2SO_4, the equivalence point is reached when:
   a. pH = 7
   b. 1 mol of acid = 2 mol of base
   c. the indicator undergoes a colour change
   d. the acid is in excess

7. The density of ice is less than the density of water due to the:
   a. weak dispersion forces present in the liquid state.
   b. weak dipole-dipole bonding present in the liquid state.
   c. strong dispersion forces holding water molecules tightly together in the liquid state.
   d. strong hydrogen bonding holding the water molecules into a rigid 3-dimensional lattice structure in ice.

Use the information below to answer questions 8 and 9

Iron reacts with oxygen to form an ionic compound according to the equation below.

$$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3$$

8. What volume of oxygen gas, at SLC, is needed to fully react with 5.58 g of iron.

   a. $56.0\ X\ \frac{3}{4}\ X\ 24.8$ L
   b. $\frac{5.58}{56}\ X\ 1000\ X\ 24.8$ mL
   c. $\frac{56}{5.58}\ X\ \frac{3}{4}\ X\ 24.8$ L
   d. $\frac{5.58}{56}\ X\ \frac{3}{4}\ X\ 24.8$ L

9. Which of the following is amphoteric?
   a. HCl
   b. H_2O
   c. NaOH
   d. CO_2

10. Phenolphthalein is used as an indicator in titration experiments. When an unknown solution of NaOH is titrated against a standardised HCl solution the phenolphthalein changes colour from :
   a. pink to clear
   b. clear to pink
   c. clear to green
   d. green to clear

11. Which element has the highest electronegativity?
   a. Sodium
   b. Oxygen
   c. Chlorine
   d. Fluorine

12. Which factor increases the rate of a reaction?
    a. Lower temperature
    b. Lower concentration
    c. Adding a catalyst
    d. Reducing surface area

13. Consider the two half cells Zn^{2+}/Zn and Mn^{2+}/Mn. Which comment is true when these two cells are connected with a salt bridge and an external circuit.
    a. Electrons flow through the salt bridge to the Zn electrode
    b. Cations flow to the Zn electrode
    c. A voltage of 0.42 V is produced
    d. No spontaneous reaction will occur.

14. Electrolysis of water takes place according to the equation below. What is the mole ratio of H_2 to O_2 needed in water formation?

$$2H_2O_{(l)} \rightarrow 2H_2(l) + O_2(g)$$

    a. 1:1
    b. 2:1
    c. 2:3
    d. 3:2

15. The pH scale measures:
    a. concentration of OH^- ions
    b. concentration of H_3O^+ ions
    c. concentration of Na^+ ions at pH of 7
    d. temperature of water at a pH of 7

16. Which solution has the highest pH?
    a. 0.01 M NaOH
    b. 0.1 M HCl
    c. 0.001 M HNO_3
    d. 0.05 M CH_3COOH

17. 36.0 grams of an unknown gas is placed in 20.0 L sealed vessel at a pressure of 303 kPa and temperature of 333 °C. The gas is most likely:
    a. O_2
    b. H_2
    c. CO_2
    d. NO

18. A 20.0 mL aliquot of a 0.141 M Na_2CO_3 (106.0 g/mol) is added to a 250 mL volumetric flask and made to the mark with distilled water.
    What is the concentration of Na_2CO_3 in the flask?
    a. 1.13 % (m/v)
    b. 1.13 ppm
    c. 0.00113 M
    d. 1.13×10^{-2} M

19. The total amount, in mol, of ions present in 45.0 g of NaCl (M = 58.44 g/mol) is:
    a. 0.77 mol
    b. 1.54 mol
    c. 2.69 mol
    d. 3.75 mol

20. Which one of the following acids has the highest ion concentration in solution?
    a. 1.00 M HCl
    b. 1.00 M H_2CO_3
    c. 0.5 M CH_3COOH
    d. 1.00 M HF

21. A sealed container has 2 mol of gas at 300 K and 100 kPa. If the volume of the container is doubled at constant temperature, the pressure will:
    a. halve
    b. double
    c. stay the same
    d. reduce to 25% of the original volume

22. A solution of 0.1 M HCl has a pH of:
    a. 1
    b. 7
    c. 3
    d. 0

23. The molar mass of an unknown gas is found by measuring pressure, volume and temperature. The gas is:
    a. Ideal gas
    b. Real gas
    c. Heavier than air
    d. Lighter than air

24. Which ions contribute most to electrical conductivity in a HCl solution?
    a. H_3O^+ and Cl^-
    b. Mg^{2+} and HO^-
    c. H_3O^+ and NO_3^-
    d. Ca^{2+} and HCO_3^-

25. The reducing agent in the reaction $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$ is:
    a. Zn
    b. Cu^{2+}
    c. Zn^{2+}
    d. Cu

26. Which salt is acidic when dissolved in water?
    a. NH_4Cl
    b. NaCl
    c. KNO_3
    d. Na_2CO_3

27. In an acid/base titration, the end point is reached:
    a. when the unknown solution becomes neutral
    b. when the indicator changes colour
    c. when the acid reacts completely
    d. when base reacts completely

28. Which reaction produces a gas?
    a. $Na_2CO_3 + HCl \rightarrow$
    b. $NaOH + HCl \rightarrow$
    c. $AgNO_3 + NaCl \rightarrow$
    d. $BaCl_2 + Na_2SO_4 \rightarrow$

29. Which one is an example of a redox reaction?
    a. $Fe + O_2 \rightarrow Fe_2O_3$
    b. $HCl + NaOH \rightarrow NaCl + H_2O$
    c. $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$
    d. Both a and c

30. Which chemical acts as an oxidizing agent?
    a. Zn
    b. H_2
    c. Cu^{2+}
    d. Fe

31. The pH of a 0.001 M NaOH solution is approximately:
    a. 3
    b. 7
    c. 11
    d. 13

32. A bottle of wine is labelled 13% (v/v) of ethanol. Given that the density of ethanol is 0.789 g/mL, the concentration can also be expressed as:
    a. 1.3 ppm
    b. 0.13 ppm
    c. 13% (m/m)
    d. 10.3% (m/v)

33. How many molecules are present in 0.5 mol CO_2?
    a. 3.01×10^{24}
    b. 6.02×10^{23}
    c. 1.20×10^{24}
    d. 3.01×10^{23}

34. What volume, in litres, does 0.200 grams of H_2 gas occupy at SLC?
    a. 22.4
    b. 13.2
    c. 1.00
    d. 4.96

35. Which salt is insoluble in water?
    a. NaCl
    b. $Mg(NO_3)_2$
    c. KNO_3
    d. AgCl

36. In the reaction $2H_2 + O_2 \rightarrow 2H_2O$, the oxidizing agent is:
    a. H_2
    b. H_2O
    c. O_2
    d. None of the above

37. Which is the conjugate base of H_2SO_4?
    a. HSO_4^-
    b. SO_4^{2-}
    c. H_2SO_4
    d. $H_3SO_4^+$

38. Which statement correctly distinguishes a standard solution from a primary standard?

    a. A standard solution is a solution of known concentration, whereas a primary standard is a highly pure solid used to prepare standard solutions.

    b. A primary standard is always an acid, while a standard solution is always a base.

    c. A standard solution is less accurate than a primary standard.

    d. A primary standard is a solution, while a standard solution is used to make a primary standard.

39. A fertiliser is labelled as containing 0.25 % (m/m) of calcium (Ca). It can also be labelled as containing what concentration of calcium?
    a. 10% (m/m)
    b. 0.25 ppm
    c. 2500 ppm
    d. 25 ppm

40. 2.00 mol of liquid fuel was burned to heat 100 grams of water at 25.0°C to 45.0°C. What is the calculated energy content of the liquid fuel?

    a. 4.180 J/g
    b. 4180 kJ/g
    c. 4.18 kJ/mol
    d. 8.36 kJ/mol

41. A 0.500 g sample of fuel with an energy density of 23.6 kJ/g burns completely to heat 50.0 g of water initially at 25°C. Which statement is most correct, assuming no energy is lost to the environment?
    a. The water would reach a temperature close to 33 °C
    b. The water would reach a temperature close to 56 °C
    c. The water would reach a temperature close to 41 °C
    d. The water would reach a temperature close to 82 °C

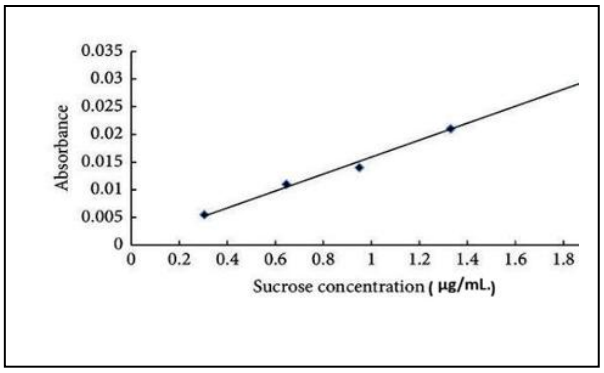
42. Iron(III) oxide reacts with zinc metal in the presence of water according to the reaction shown below.

$$Fe_2O_3(s) + 3Zn(s) \rightarrow 3ZnO(s) + 2Fe(s)$$

Which one of the following options represents the oxidation reaction?

a. $Fe_2O_3(s) + 6H^+(aq) + 2e^- \rightarrow 3H_2O(l) + 2Fe(s)$
b. $Fe_2O_3(s) + 2H^+(aq) + 2e^- \rightarrow H_2O(l) + 2Fe(s)$
c. $Zn(s) + H_2O(l) \rightarrow Zn^{2+}(aq) + 2H^+(aq) + 2e^-$
d. $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$

The information shown below refers to questions 43, 44 and 45.
Consider the calibration curve shown below of absorbance, as measured by spectrophotometer and sucrose concentration.



43. An unknown solution has an absorbance of 0.02. The likely sucrose concentration of the unknown solution is:

a. 0.00014% (m/v)
b. 0.14 g/mL
c. 0.00014 ppm
d. 1.4 g/L

44. How many standard solutions were used to create this curve?

a. 5
b. 6
c. 4
d. 3

45. Which absorbance reading would give the most inaccurate concentration reading?

a. 0.01
b. 0.02
c. 0.03
d. 0.015

The following information relates to questions 46, 47 and 48.

Hydrogen and nitrogen gases react to form ammonia (NH_3) at SLC, according to the reaction shown below.

$3H_2(g) + N_2(g) \rightarrow 2NH_3(g)$

8 mol of hydrogen gas is mixed with 3 mol of nitrogen gas

46. What volume of ammonia is produced?
    a. $8\ X\ \frac{2}{3}\ X\ 24.8$ L
    b. $3\ X\ 2\ X\ 24.8$ L
    c. $3\ X\ \frac{2}{3}\ X\ 24.8$ mL
    d. $8\ X\ \frac{2}{1}\ X\ 24.8$ mL

47. Which statement is true?
    a. Nitrogen gas is in excess by approximately 3 mol.
    b. Nitrogen gas is in excess by approximately 0.3 mol.
    c. Hydrogen gas is in excess by approximately 0.3 mol.
    d. Hydrogen gas is in excess by approximately 5 mol.

48. In another experiment 3.0 grams of N_2 and 3 grams of H_2 are mixed in a sealed vessel and allowed to react. What mass of ammonia (NH_3 , 17.0 g/mol) is formed?
    a. Approximately 3.0 grams of NH_3 will form where N_2 is the limiting reactant.
    b. Approximately 6.0 grams of NH_3 will form as the law of conservation of mass is maintained.
    c. Approximately 3.0 grams of NH_3 will form where H_2 is the limiting reactant.
    d. Approximately 3.6 grams of NH_3 will form, where N_2 is the limiting reactant.

49. A sample of waste water contains lead metal as well as copper and cobalt. Which of the following solutions can be used to remove the lead (Pb^{2+}) metal only?
    a. Sodium phosphate.
    b. Sodium nitrate
    c. Potassium sulfate
    d. Potassium hydroxide

50. Which of the following best represents the formula for Iron(II) phosphate?
    a. $FePO_4$
    b. $Fe_2(PO_4)_3$
    c. $Fe_3(PO_4)_2$
    d. Fe_2PO_4

51. What is the primary cause of acid rain?
    a. Carbon dioxide (CO_2) emissions
    b. Nitrogen oxides (NO_x) and sulfur dioxide (SO_2) emissions
    c. Methane (CH_4) release
    d. Ozone (O_3) depletion

52. Which Green Chemistry principle most directly helps reduce emissions causing acid rain and ocean acidification?
    a. Design for energy efficiency
    b. Use of renewable feedstocks
    c. Prevent waste
    d. Safer solvents and auxiliaries

53. Ocean acidification mainly impacts marine invertebrates by:
    a. creating murky waters that light cannot penetrate
    b. dissolving plant food sources
    c. reducing the amount of oxygen dissolved in ocean waters
    d. reducing the amount of $CO_3^{2-}(aq)$ available for shell or skeletal formation

54. Which solution will exhibit the highest conductivity?
    a. 2.0 M Na_2CO_3
    b. 0.1 M HCl
    c. 2.0 M KCl
    d. 1.9 M Na_3PO_4

55. The active ingredient in a popular brand of antacid is $NaHCO_3$. Which statement best represents the reaction taking place in the stomach to alleviate the symptoms of high stomach acid when a solid tablet is ingested?
    a. $NaHCO_3(l) + HCl(aq) \rightarrow CO_2(g) + H_2O(l) + NaCl(s)$
    b. $2NaHCO_3(aq) + H_2SO_4(aq) \rightarrow 2CO_2(g) + 2H_2O(l) + Na_2SO_4(aq)$
    c. $NaHCO_3(s) + HCl(aq) \rightarrow H_2(g) + CO_2(g) + NaOCl(aq)$
    d. $NaHCO_3(s) + HCl(aq) \rightarrow CO_2(g) + H_2O(l) + NaCl(aq)$.

Section B

Question 1 (9 marks)

A student was tasked with experimentally determining the empirical formula of magnesium oxide. The setup used is shown in fig. 1. The table of results , table 1, shows the results from three different trials.

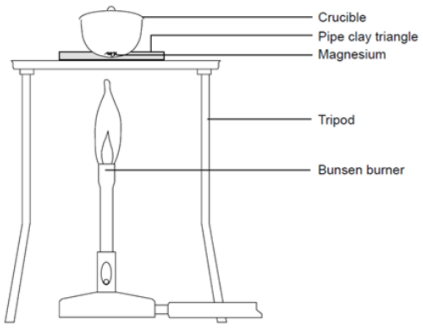


Figure 1 – empirical formula of magnesium oxide setup.

Trial	Mass of Empty Crucible (g)	Mass of Crucible + Magnesium (g)	Mass of Crucible + Magnesium Oxide (g)	Mass of Magnesium Oxide (g)
1	25.00	25.27	25.45	0.59
2	25.00	25.31	25.69	0.69
3	25.00	25.29	25.35	0.35

Table 1 – experimental results.

a. Using the results from trial 1 calculate the following.

i. The mass of Mg used 1 mark

25.27-25.00 = 0.27 g

ii. The mass of oxygen that reacted 1 mark

Mass of oxygen = Mass of MgO – Mass of Mg
= (Mass crucible + MgO – Mass crucible) – Mass of Mg
= (25.45 – 25.00) – 0.27 => 0.45 g – 0.27 g = 0.18 g

iii. Calculate the mol of Magnesium in the crucible 1 mark

= 0.27 g / 24.3 g/mol = 0.011 mol

iv. Calculate the mol of oxygen that reacted 1 mark

= 0.18 g / 16.0 g/mol = 0.011 mol

v. Calculate the empirical formula of magnesium oxide 1 mark

Moles Mg : Moles O
= 0.011 : 0.011 => 1:1 => MgO

b. The mass of magnesium oxide formed in trial 3 differs markedly from trials 1 and 2. Give a possible error that may have resulted in the low yield of oxide?

1-----mark => any valid error, such as:
- The magnesium may not have fully reacted with oxygen, meaning incomplete combustion.
- Magnesium oxide might have been lost during handling due to opening the lid and allowing the MgO powder to escape.

1----mark => error must cause a decrease in the calculated MgO.

c. The error given as the answer to question b. is what type of error. Justify your answer.
1-----mark => Random error
1----mark for a valid explanation such as suggesting that random errors are unforeseen errors that occur at random and cannot be totally eliminated.
- *uncontrollable factors like slight differences in heating time, uneven oxygen supply, or measurement inconsistencies. These cause inconsistent results that vary trial to trial without a fixed direction.*

Question 2 (12 marks)

A laboratory was asked to verify the concentration of ethanoic acid found in a Coles brand double strength white vinegar. Volumetric analysis of the vinegar was undertaken and the following steps taken.



Figure 2 – commercial brand of white vinegar.

i. Place 20.00 mL aliquot of the sample vinegar into a 200 mL volumetric flask.
ii. Add water to the volumetric flask until the liquid level reaches the calibration mark.
iii. Take a 20.00 mL aliquot from the volumetric flask and place it in a 100mL conical flask.
iv. Add 2 drops of indicator.
v. Titrate against a standard 0.112 M Na_2CO_3 solution until the end point is reached.
vi. Repeat steps iii – v until concordant results are achieved.

The reaction between the vinegar and the sodium hydrogen carbonate ($NaHCO_3$) is given below.

$$CH_3COOH(aq) + NaHCO_3(aq) \rightarrow NaOOCCH_3(aq) + CO_2(g) + H_2O(l)$$

a. Assuming the average titre was found to be 23.50 mL, calculate the amount, in mol, of $NaHCO_3$ in an average titre. 2 marks

1-----mark => 0.112 mol/L × (23.50 mL / 1000) L
1-----mark => 0.112 × 0.0235 = 0.00263 mol

b. Calculate the amount, in mol, of vinegar present in the 20.00 mL sample placed in the conical flask. 1 mark

0.00263 mol
1:1 ratio with $NaHCO_3$

c. Find the concentration, mol/L, of ethanoic acid in the volumetric flask. 2 marks

1-----mark 0.002632 mol / 0.020 L = 0.132 M
1-----mark 3 sig figs

d. Find the concentration of ethanoic acid in the original sample. 2 marks

1-----mark => $C_1V_1 = C_2V_2$ => $C_1 = 0.132\ X\ \frac{200}{20}$

1-----mark => 1.32 M

e. Assuming phenolphthalein was used as the indicator what colour change would indicate the end point?

_____*Colourless -> pink*_____

f. Why is the $NaHCO_3$ solution referred to as a standard solution?

its concentration is known accurately and precisely

g. What is the solid $NaHCO_3$, used to make the standard solution, referred to.

_____*primary standard*_____

h. Name two properties that the $NaHCO_3$ used to make the standard solution should have.

1 mark for each of the two properties. Properties such as:

- *High purity*
- *Does not chemically react with water or gases in the air.*
- *Does no decompose over time*
- *Known chemical formula*

  any other valid property.

Question 3 (12 marks)

An unknown fuel was analysed for its energy content using the apparatus shown in fig. 3.

A mass of 200 grams of water was placed in a metal can and heated using a spirit burner filled with the unknown fuel.

The spirit burner and fuel was weighed before and after burning and found to have lost 3.15 grams of mass.

The temperature of the water increased by 23.4 °C. (Δ T).

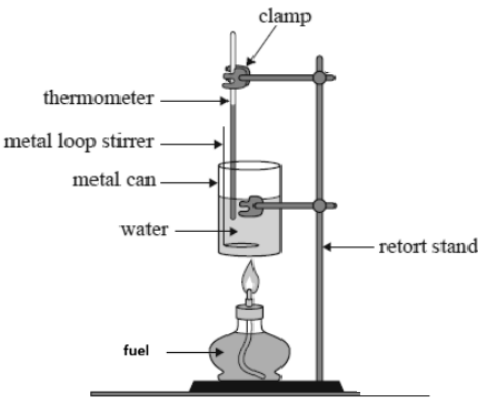


Figure 3 – Apparatus used to measure the energy content of a liquid fuel.

a. Find the energy, joules (J), absorbed by the water. 2 marks

1-----mark => Q = 200 g × 4.18 J/g°C × 23.4 °C
1-----mark => Q = 200 × 4.18 × 23.4 = 1.96 X 10^4

b. Find the mass of fuel that burned. 1 mark

1-----mark => 3.15g

c. Find the energy density of the fuel in kJ/kg 3 marks

energy density = energy released / mass burned
1-----mark => convert energy to kJ: 19,570.56 J = 19.57 kJ
1-----mark => mass burned in kg, 3.15 g = 0.00315 kg
1-----mark => energy density = 19.57/ 0.00315 kg = 6.21 X 10^3 J/kg

d. The thermometer was found to be poorly calibrated and always gave a temperature reading 2.00 °C above the actual temperature of the water. What impact would this have on the answer given to question c. above? Justify your answer.

1-----mark => no impact.
1-----mark => for a valid explanation.
=>Since both the initial and final temperature readings are 2.00 °C too high, when calculating temperature change (final – initial) the error cancels out. Therefore, the calculated temperature change (ΔT) remains accurate and there is no significant effect on the calculated energy density.

e. Whilst conducting the investigation the stirrer was not used throughout the course of heating the water and the thermometer was placed so that it touched the bottom of the metal can.

i. What impact would this have the final answer given in question c above? Justify your answer.

1-----mark => Increase the value of the energy density.

1-----mark => Not stirring the thermometer does not distribute the heat energy evenly and may give a higher than normal temperature difference. The high temperature is not representative of the average temperature of the entire mass of water.

ii. Comment on how this impacts the validity of the results obtained. Justify your answer.

1-----mark => decreases validity.

1-----mark => the ΔT measured is not representative of the average temperature of the water.

Question 4 (10 marks)

Consider the galvanic cell shown in fig 4 below.

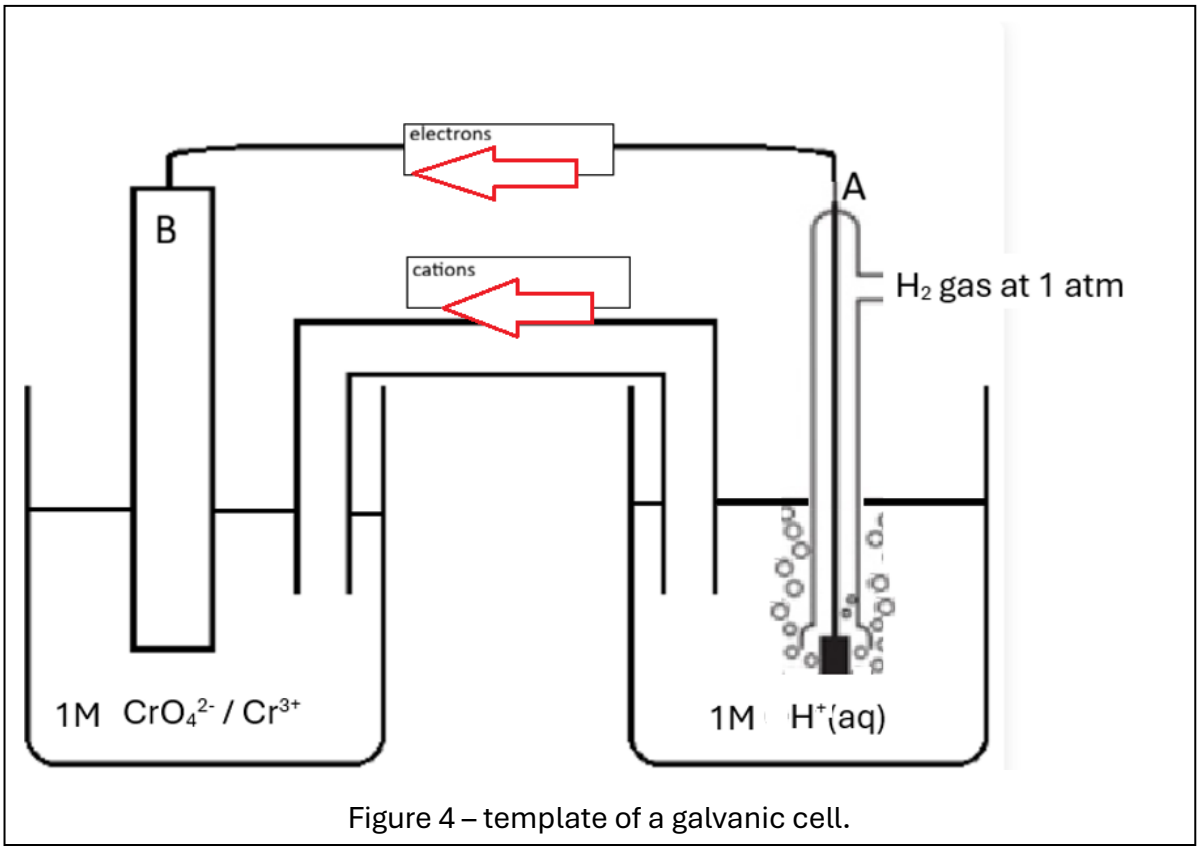


Figure 4 – template of a galvanic cell.

a. Label the following in the box provided in the image. 2 marks

i. Direction of electron flow.

ii. Direction of cation flow.

b. What material are the following electrodes made of?
Electrode A _____*Pt*
Electrode B _____*Graphite or Pt*

c. Given that the CrO_4^{2-} / Cr^{3+} half-cell has a standard electrode potential of +1.33 V, calculate the theoretical cell EMF in volts. 2 marks

1-----mark => EMF = oxidant – reductant (V) => +1.33 - 0 = +1.33 V

d. Write the balanced reduction half equation

1-----mark => correctly balanced for elements
1-----mark => balanced for charge and correct states

$$8H^+(aq) + 3e^- + CrO_4^{2-}(aq) \rightarrow Cr^{3+}(aq) + 4H_2O(l)$$

e. Write the balanced overall redox equation for the cell.
1-----mark => correctly balanced for elements
1-----mark => balanced for charge and correct states

$$10H^+(aq) + 3H_2(g) + 2CrO_4^{2-}(aq) \rightarrow 2Cr^{3+}(aq) + 8H_2O(l)$$

Question 5 (10 marks)

Acetic acid (CH_3COOH) reacts with sodium hydroxide (NaOH) according to the reaction below.

$$CH_3COOH\,(aq) + NaOH\,(aq) \rightarrow NaOOCH_3\,(aq) + H_2O\,(l)$$

a. Select the type of acid represented by acetic acid by circling the correct response/s from the list below. 1 mark

Strong **weak** **triprotic** **amphiprotic** **monoprotic**

b. Two solutions, 1 M CH_3COOH and 1M HNO_3 , were tested for electrical conductivity using the same ammeter. The results are shown in fig. 5.



A



B

Figure 5 – shows the reading from the same ammeter when testing the conductivity of two solutions of equal molarity.

Which reading, A or B, belongs to the HNO_3 solution?
Justify your answer

1-----mark => B belongs to HNO_3 because it is the strongest acid out of the two.
1-----mark => Strong acids fully ionise and hence create more ions in solution than weaker acids at the same concentration.

c. Phosphoric acid (H_3PO_4) reacts with sodium oxide (Na_2O).

i. Assuming the acid fully ionises, write the overall balanced chemical equation, states included.

1-----mark => correct species and chemical formulas

1-----mark => correct balance of species

1-----mark => correct states.

$2H_3PO_4(aq) + 3Na_2O(aq) \rightarrow 2Na_3PO_4(aq) + 3H_2O(l)$

ii. Write the net ionic equation for this reaction.

1-----mark => correct species and chemical formulas with charge showing on all ions

1-----mark => correct balance of charge and correct states.

$2H^+(aq) + O^{2-}(aq) \rightarrow H_2O(l)$

d. Consider a 0.0523 M HCl solution at 25^0C.

i. Calculate the pH of the solution to the right number of significant figures

2 marks

1-----mark => HCl is a strong acid, fully dissociates: $[H^+] = 0.0523$ M

1-----mark => $pH = -\log[H^+] = -\log(0.0523) = 1.28$

ii. Calculate the $[OH^-]$ 2 marks

1-----mark => $K_w = [H^+][OH^-] = 1.0 \times 10^{-14}$

1-----mark => $[OH^-] = K_w / [H^+] = 1.0 \times 10^{-14} / 10^{-1.28} = 1.91 \times 10^{-13}$ M or $10^{-12.72}$M