Teacher: _____

Student: _____

NORTH SYDNEY GIRLS HIGH SCHOOL

2019
Preliminary Course
Examination

Chemistry

General Instructions
Reading Time – 5 minutes
Working Time – 2 hours
Write using black or blue pen
Draw diagrams using pencil
Calculators may be used
Write your teachers name and your own name at the top of this booklet AND the multiple choice answer sheet.

Total Marks – 70

Part A – 20 Marks
Attempt questions 1-20
Allow about 35 minutes for this part
Record your answer on the Multiple Choice Answer Sheet

Part B – 50 marks
Attempt questions 21-33
Allow about 1 hour and 25 minutes for this part
Write your answers in the space provided. Adequate lines have been provided.

Chemistry

Part A – 20 marks
Attempt Questions 1-20
Allow about 35 minutes for this part

Use the multiple-choice answer sheet provided for Questions 1-20

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1. Which of the following equations correctly represents the reaction of magnesium carbonate with sulfuric acid?

(A) $MgCO_{3(s)} + H_2SO_{4(aq)} \rightarrow MgSO_{4(aq)} + H_2O_{(l)} + CO_{2(g)}$

(B) $MgCO_{3(s)} + H_2SO_{4(aq)} \rightarrow MgSO_{4(aq)} + H_2O_{(l)}$

(C) $MgCO_{3(s)} + H_2SO_{4(aq)} \rightarrow MgSO_{4(aq)} + H_{2(g)}$

(D) $MgCO_{3(s)} + H_2SO_{4(aq)} \rightarrow MgSO_{4(aq)} + H_{2(g)} + CO_{2(g)}$

2. What is the number of chloride ions in 4.0 moles of $CaCl_2$?

(A) 4.82×10^{24}

(B) 6.022×10^{23}

(C) 2.41×10^{24}

(D) 1.20×10^{24}

3. The melting point of magnesium oxide is 2852°C. When strongly heated this compound melts before it decomposes.

What is the main reason magnesium oxide has such a high melting point?

(A) Strong covalent bonds between atoms

(B) Strong ionic bonds between ions

(C) Strong metallic bonds between ions

(D) Very strong intramolecular bonds

Questions 4 and 5 refer to the following information

A class of chemistry students designed the following experiment to investigate the relationship between the concentration of a solution in a reaction and how fast a product is produced.

Different concentrations of hydrochloric acid were added to a standardised sodium thiosulfate solution. The reaction produced solid sulfur, as shown in the equation below.

$2HCl\ (aq) + Na_2S_2O_3\ (aq) \rightarrow 2NaCl(aq) + SO_2\ (g) + H_2O(l) + S(s)$

A piece of paper with a cross was placed beneath the conical flask containing the reaction mixture. As soon as the reactants were added and mixed, the conical flask was placed on top of the cross, and the time taken for the cross to disappear due to the formation of the sulfur was timed with a stopwatch.

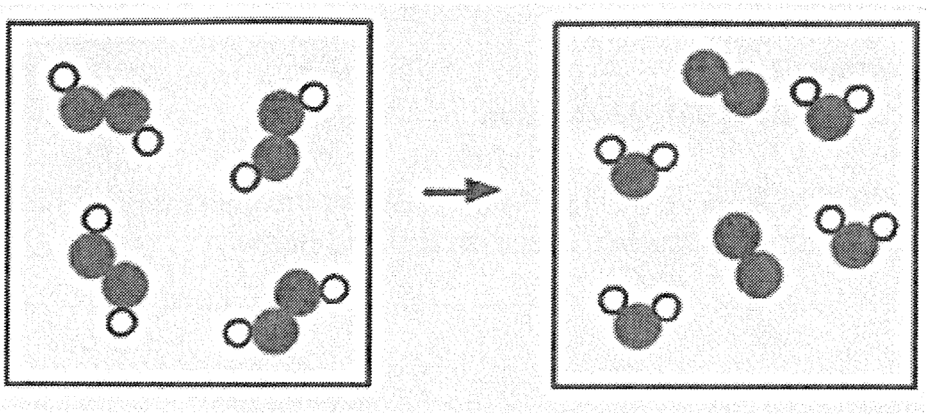
4. What is the *dependent* variable for the student's investigations?

(A) The time taken for the cross to disappear
(B) The total volume of liquids in the conical flask
(C) The concentration of hydrochloric acid
(D) The mass of sulfur produced

5. What is the *independent* variable for the student's investigations?

(A) The time taken for the cross to disappear
(B) The total volume of liquids in the conical flask
(C) The concentration of hydrochloric acid
(D) The volume of sulphur dioxide produced

6. What type of chemical reaction is represented by the model?



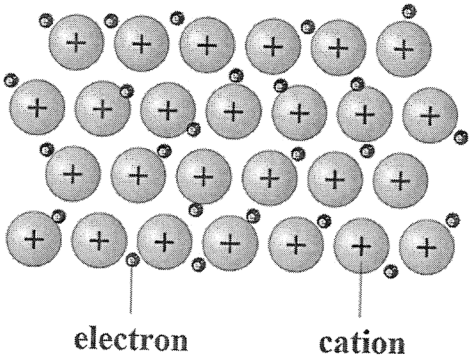
(A) Precipitation

(B) Synthesis

(C) Decomposition

(D) Combustion

7. The diagram shows the model of a chemical structure.



Which substance could this structure represent?

(A) Sodium chloride

(B) Potassium

(C) Chlorine

(D) Argon

8. Two identical flasks, X and Y, respectively contain 1.70 g of nitrogen gas and 4.91 g of an unknown gas. The gases in both flasks are held at the same temperature and atmospheric pressure. From this data, which of the following gases could occupy flask Y?

(A) helium

(B) oxygen

(C) sulfur dioxide

(D) hydrogen bromide

9. Which of the following is the most likely reason for differences between laboratory (experimental) and literature (theoretical) values of the enthalpy of combustion of a liquid fuel?

(A) The calorimeter used in school laboratory is not efficient.

(B) The purity of the fuel investigated is not high enough in a school laboratory.

(C) The amount of fuel burned in a school laboratory is too small.

(D) The thermometers used in school laboratories are not very accurate.

10. A solution is made by completely dissolving equal numbers of moles of sodium hydroxide and barium hydroxide in water.

Note: Square brackets denotes "concentration of....".

Which of the following conditions must be true regarding the concentrations of each ion in the solution formed?

(A) $[Na^+] = [Ba^{2+}] = [OH^-]$

(B) $[Na^+] = [Ba^{2+}] = 3[OH^-]$

(C) $[Na^+] + [Ba^{2+}] = 3[OH^-]$

(D) $[Na^+] + 2[Ba^{2+}] = 3[OH^-]$

11. Three metals, "X", "Y" and "Z" were tested to compare their reactivity. Samples of each metal were placed separately into test tubes, each containing a nitrate solution of the other metal ions. The results are shown below.

	X (s)	**Y (s)**	**Z (s)**
$\mathbf{X^{2+}}$		no reaction	no reaction
$\mathbf{Y^{2+}}$	Solid Y forms		Solid Y forms
$\mathbf{Z^{2+}}$	Solid Z forms	no reaction	

Based on these results, which of the following shows the metals in order of decreasing reactivity?

(A) Y > X > Z

(B) X > Z > Y

(C) Z > X > Y

(D) Y > Z > X

12. Calcium reacts with water as shown:

$$Ca_{(s)} + 2H_2O_{(l)} \rightarrow Ca(OH)_{2(aq)} + H_{2(g)}$$

What volume of hydrogen would be liberated at 25ºC and 100kPa when 16 g of calcium reacts with excess water?

(A) 16 L

(B) 22.79 L

(C) 10.5 L

(D) 9.90 L

13. Dispersion forces are the dominant force between atoms or molecules of:

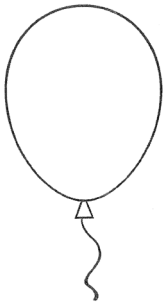
(A) covalent molecular substances whose atoms or molecules are polar.

(B) metals.

(C) covalent molecular substances whose atoms or molecules are non-polar.

(D) covalent network substances.

14. A balloon is filled with 0.500 moles of helium gas.



What is the volume of the balloon if the gas pressure is 100 kPa and the temperature is 35.0°C?

(A) 2.1 L

(B) 11.4 L

(C) 12.4 L

(D) 12.8 L

15. Use the standard potential table provided. Which reaction from A, B, C or D will occur spontaneously?

(A) $Fe^{3+}_{(aq)} + Cl_{2(g)}$

(B) $Mg^{2+}_{(aq)} + Fe^{2+}_{(aq)}$

(C) $Pb^{2+}_{(aq)} + Sn^{2+}_{(aq)}$

(D) $Ni^{2+}_{(aq)} + Mg_{(s)}$

16. In which reaction is there an increase in entropy?

(A) $PCl_{3(l)} + Cl_{2(g)} \rightarrow PCl_{5(s)}$ ΔH = -ve

(B) $2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)}$ ΔH = -ve

(C) $(NH_4)_2SO_{4(s)} + 2NaOH_{(s)} \rightarrow Na_2SO_{4(s)} + 2NH_{3(g)} + 2H_2O_{(g)}$ ΔH = +ve

(D) $2NO_{2(g)} \rightarrow N_2O_{4(g)}$ ΔH = -ve

17. The decomposition of hydrogen peroxide into oxygen and water proceeds very slowly at room temperature. However, the addition of a small amount of manganese dioxide

(MnO_2), causes the hydrogen peroxide to bubble vigorously due to the rapid production of oxygen.

$2H_2O_{2(aq)} \rightarrow O_{2(g)} + 2H_2O_{(l)}$ very slow

$2H_2O_{2(aq)} \xrightarrow{MnO_2} O_{2(g)} + 2H_2O_{(l)}$ vigorous

The best explanation for this is:

(A) the manganese dioxide acts as a catalyst, providing an alternative reaction pathway that has a lower activation energy.

(B) the manganese dioxide increases the temperature of the reaction thereby increasing the collision rate of the molecules.

(C) the manganese dioxide increases the collision rate between reacting molecules simply by causing an increase in the total number of molecules in the solution.

(D) the manganese dioxide increases the collision energy of the hydrogen peroxide molecules.

18. If an endothermic reaction is spontaneous at temperature T_1 but is not spontaneous at temperature T_2, which statement is true?

(A) ΔH is positive and T_1 is higher than T_2.

(B) ΔH is positive and T_1 is lower than T_2.

(C) ΔH is negative and T_1 is higher than T_2.

(D) ΔH is negative and T_1 is lower than T_2.

19. Use the following bond energy data to determine the enthalpy change for the reaction

$$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$$

Average bond energy in kJ mol^{-1}			
C-H 414	O-O 144	O-H 463	C= O 804
C-C 346	O=O 498	C-O 358	C=C 614

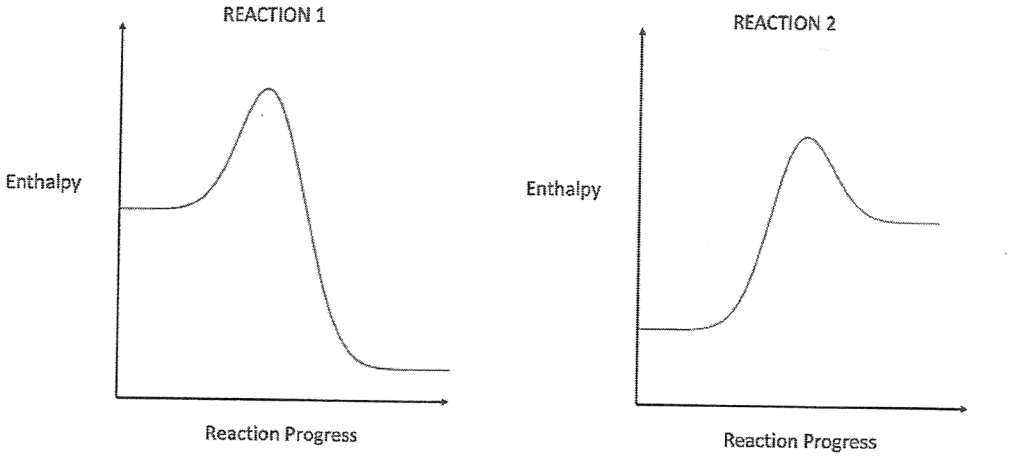
(A) $\Delta H = -380$ kJ mol^{-1}

(B) $\Delta H = -808$ kJ mol^{-1}

(C) $\Delta H = +158$ kJ mol^{-1}

(D) $\Delta H = +808$ kJ mol^{-1}

20. The enthalpy change in two different reactions are graphed below. The scale on the axis are the same.



Which of the following statements is true?

(A) Reaction 1 is exothermic and has a higher activation energy than reaction 2.

(B) Reaction 1 is endothermic and has a higher activation energy than reaction 2.

(C) Reaction 2 is exothermic and has a higher activation energy than reaction 1.

(D) Reaction 2 is endothermic and has a higher activation energy than reaction 1.

Part B – 50 marks

Attempt Questions 21-33

Question 21 (4 marks)

Complete the table below using IUPAC naming conventions.

Name	Formula
Calcium sulfide	
	NO_2
Nitric acid	
	NaH

Question 22 (3 marks)

Use the data provided to find the enthalpy change for the following reaction, by applying Hess's Law.

$$\mathbf{CS_2(l) + 3O_2(g) \rightarrow CO_2(g) + 2SO_2(g)}$$

Reaction	ΔH (kJ/mol)
$C(s) + O_2(g) \rightarrow CO_2(g)$	- 394
$S(s) + O_2(g) \rightarrow SO_2(g)$	- 297
$C(s) + 2S(s) \rightarrow CS_2(l)$	+ 88

Show your working.

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Question 23 (3 marks)

Infants and children require a daily allowance of 0.52mg of copper per kg of body weight.

(a) Calculate for a 12kg infant the number of moles of copper required per day. **2**

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(b) Calculate the number of atoms of copper required per day. **1**

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Question 24 (5 marks)

Aluminium oxide can be produced by aluminium metal reacting with oxygen gas.

(a) Write a balanced equation for the formation of aluminium oxide from aluminium and oxygen. **1**

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(b) How many moles of $Al_2O_{3(s)}$ can be produced when a mixture of 0.36 moles of aluminium and 0.36 moles of oxygen is ignited? **2**

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(c) Using the information above in (b), which substance and how much of it is in excess of that required when producing the $Al_2O_{3(s)}$? **2**

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Question 25 (4 marks)

The dichromate ion found in compounds such as potassium dichromate ($K_2Cr_2O_7$) is such a powerful oxidant that it can oxidise inert metals such as platinum to form its ion (Pt^{2+}). The reduction potential of platinum has been measured at 1.2V.

(a) Write an oxidation half-equation to represent the oxidation of Pt as described above. **1**

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(b) The half-equation for the reduction of $Cr_2O_7^{2-}$ is shown on the data sheet. Use this to determine the *change* in oxidation state that chromium undergoes in the reduction. **1**

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(c) Combine the equations in (a) and (b) to produce a balanced net ionic equation for the reaction that would occur when platinum metal was placed into a solution of potassium dichromate and hydrogen ions. **1**

Show your working.

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(d) A galvanic cell was produced from coupling a standard Pt/Pt^{2+} half cell with a standard half cell for $Cr_2O_7^{2-}/Cr^{3+}$.

What was the maximum theoretical voltage produced? **1**

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Question 26 (3 marks)

A 14.6 g sample of a compound containing carbon and hydrogen only (which could be represented as C_xH_y) was burnt in excess oxygen to produce 44.0 g of carbon dioxide (CO_2) and 24.0 g of water vapour.
Determine an empirical formula for this compound, showing your working.

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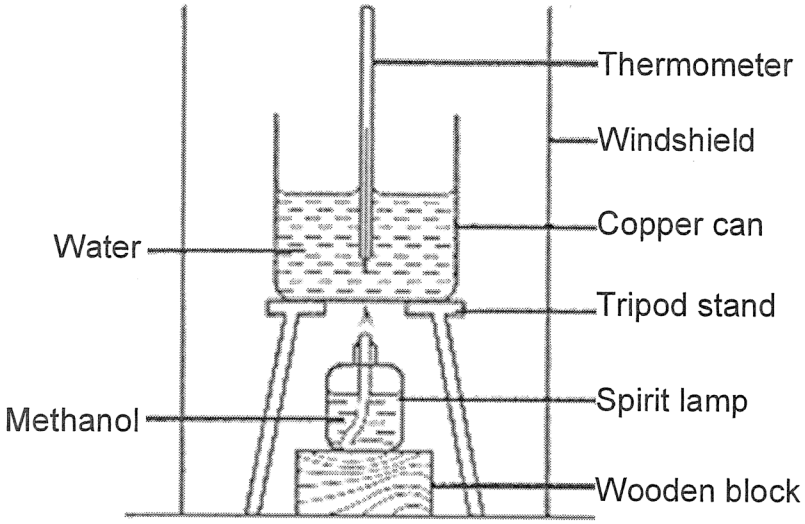
Question 27 (2 marks)
An investigation was carried out to determine the molar heat of combustion of methanol (CH_3OH).



The results are below.

Mass of Water	200g
Mass of Methanol Combusted	1.78g
Initial temperature of water	20.0ºC
Final temperature of water	42.5ºC

Calculate the molar heat of combustion of methanol.

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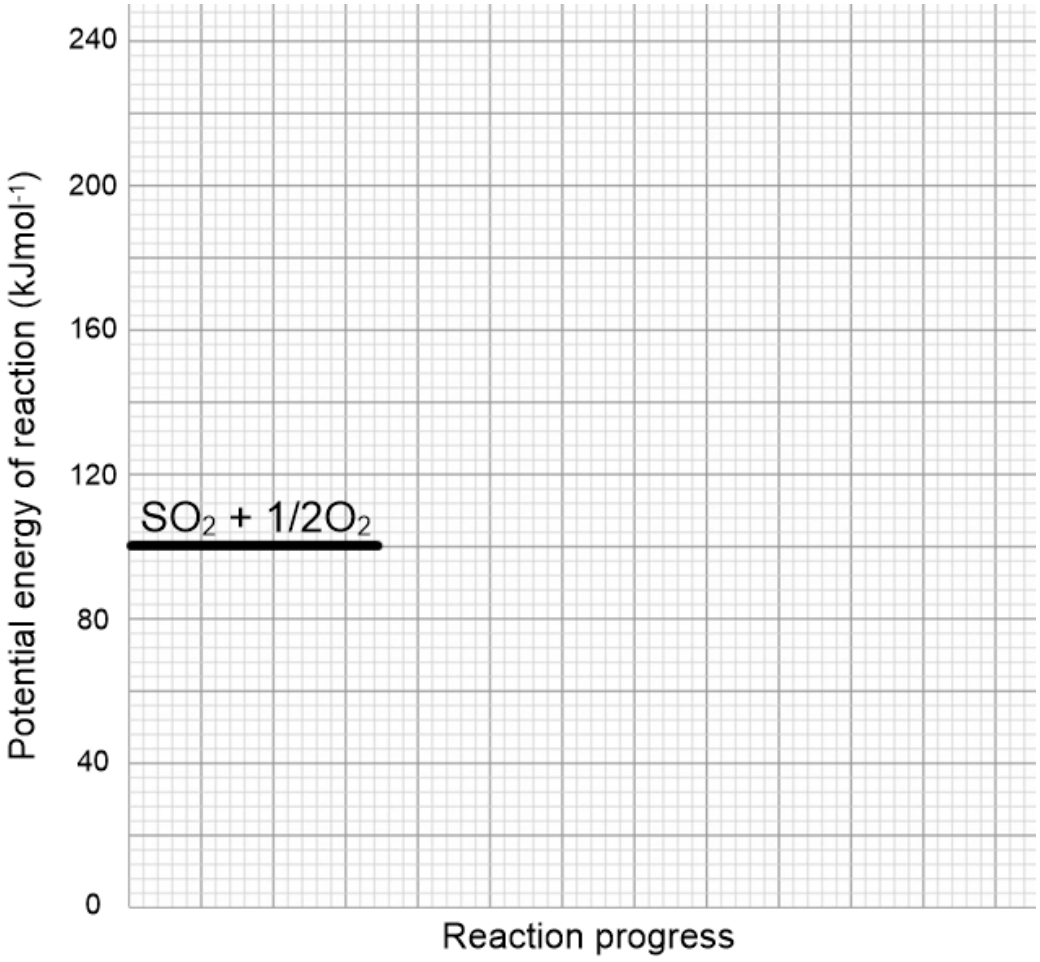
Question 28 (3 marks)

Sulfur dioxide gas can react with oxygen gas to form sulfur trioxide gas when heated. The temperature of the reaction vessel becomes hotter as the reaction proceeds. The activation energy for this reaction is 42 $kJmol^{-1}$ whist the change in enthalpy was 98 $kJmol^{-1}$.

(a) Sketch a labelled energy profile diagram for this reaction. **2**



(b) Use a dashed line on your diagram to illustrate the effect of a catalyst on this reaction **1**

Question 29 (5 marks)

The simplified solubility rules below may help you to answer this question.

General Rule	Exceptions
all Group I, nitrate and ammonium compounds are soluble	none
most chlorides are soluble	silver and lead (insoluble)
most sulfates are soluble	barium and lead (insoluble) calcium and silver (slightly soluble)
most hydroxides are insoluble	group I, ammonium and barium compounds (soluble) calcium (slightly soluble)
most carbonates are insoluble	group I and ammonium compounds

A science teacher mixes solutions of magnesium nitrate and sodium hydroxide.

(a) Write a balanced chemical equation (including states) for the reaction that occurs. **1**

……...

(b) Write the net ionic equation for the reaction. **1**

……...

(c) Using the solubility rules above, suggest a method that could be followed to determine which of the compounds below is present in an unlabelled bottle known to contain **one** of these dissolved compounds. Explain how your observations would allow you to identify the unknown. **3**

potassium nitrate, sodium sulfate, lithium hydroxide

(Assume you have access to typical laboratory equipment, as well as dropper bottles, each containing 0.1M solutions of any chemical you require in your procedure.)

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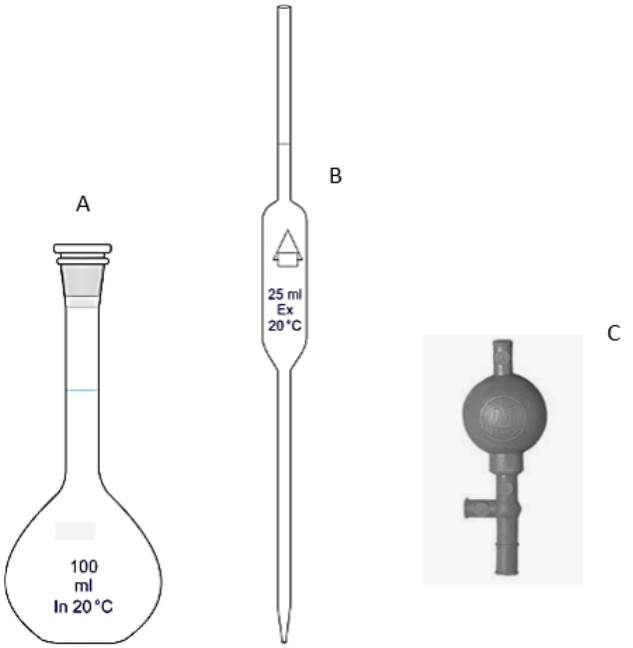
Question 30 (5 marks)

A student used the following pieces of equipment (labelled A, B and C) to produce a diluted solution of 0.050 $molL^{-1}$ barium hydroxide from a bottle containing 0.20 $molL^{-1}$ barium hydroxide.



Describe the procedure the student should have followed to produce the solution accurately and calculate its concentration in % (w/v), given the volumes shown on the equipment used.

Ensure equipment A to C is clearly identified in the procedure.

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Question 31 (4 marks)

Use the following equations that are **not** balanced to answer the questions below.

1. $CH_3CH_2OH_{(l)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(l)}$
2. $PbNO_{3(aq)} + Na_2CO_{3(aq)} \rightarrow PbCO_{3(s)} + NaNO_{3(aq)}$
3. $Na_{(s)} + Cl_{2(g)} \rightarrow NaCl_{(s)}$
4. $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$

(a) Which reaction from 1, 2, 3 or 4 is an example of a combustion reaction? **1**

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(b) Balance the equation in reaction 1. **1**

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(c) Which reaction is classified as a synthesis reaction? **1**

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Question 32 (3 marks)

(a) Draw the electron dot diagram (Lewis dot diagram) for hydrogen iodide (HI). **1**

(b) Explain why hydrogen chloride is considered a polar covalent molecule? **2**

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Question 33 (6 marks)

(a) Calculate the standard entropy change for the complete combustion of butane (C_4H_{10}) using the standard entropy values provided below. **2**

Substance	S^o (J K^{-1} mol^{-1})
$C_4H_{10\,(g)}$	310
$O_{2(g)}$	205
$CO_{2(g)}$	214
$CO_{(g)}$	198
$C_{(s)}$	6
$H_2O_{(g)}$	189

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(b) Calculate ΔH^o for the complete combustion of butane at 298K, then use this value along with the ΔS^o calculated in part (a) to calculate ΔG^o for the complete combustion of butane. Also predict if the reaction will go as written under standard conditions. Use the table below to calculate ΔH^o. **4**

Substance	ΔH^o_f (J K mol^{-1})
$C_4H_{10\,(g)}$	-126
$O_{2(g)}$	0
$CO_{2(g)}$	-394
$CO_{(g)}$	-111
$C_{(s)}$	0
$H_2O_{(g)}$	-136

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END OF PAPER

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(C) Strong metallic bonds between ions

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4. What is the *dependent* variable for the student's investigations?

(A) The time taken for the cross to disappear

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(C) The concentration of hydrochloric acid

(D) The mass of sulfur produced

5. What is the *independent* variable for the student's investigations?

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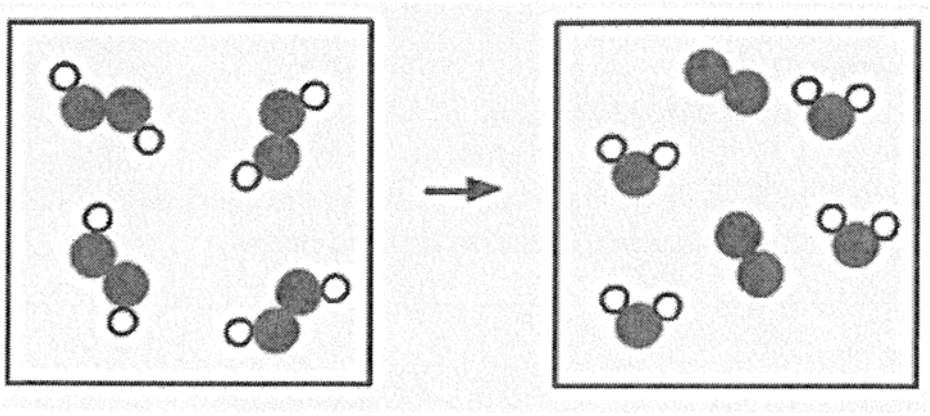
6. What type of chemical reaction is represented by the model?



(A) Precipitation

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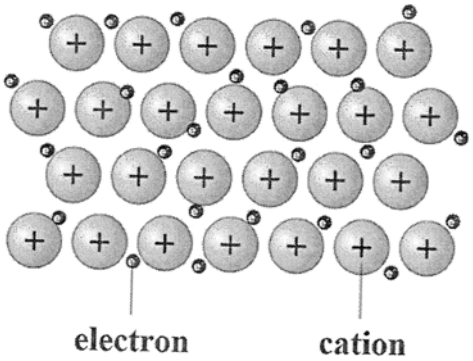
7. The diagram shows the model of a chemical structure.



Which substance could this structure represent?

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(B) Potassium

(C) Chlorine

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8. Two identical flasks, X and Y, respectively contain 1.70 g of nitrogen gas and 4.91 g of an unknown gas. The gases in both flasks are held at the same temperature and atmospheric pressure. From this data, which of the following gases could occupy flask Y?

(A) helium

(B) oxygen

(C) sulfur dioxide

(D) hydrogen bromide

9. Which of the following is the most likely reason for differences between laboratory (experimental) and literature (theoretical) values of the enthalpy of combustion of a liquid fuel?

(A) The calorimeter used in school laboratory is not efficient.

(B) The purity of the fuel investigated is not high enough in a school laboratory.

(C) The amount of fuel burned in a school laboratory is too small.

(D) The thermometers used in school laboratories are not very accurate.

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Note: Square brackets denotes "concentration of....".

Which of the following conditions must be true regarding the concentrations of each ion in the solution formed?

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(B) $[Na^+] = [Ba^{2+}] = 3[OH^-]$

(C) $[Na^+] + [Ba^{2+}] = 3[OH^-]$

(D) $[Na^+] + 2[Ba^{2+}] = 3[OH^-]$

IGNORE THIS QUESTION!!!

11. Three metals, "X", "Y" and "Z" were tested to compare their reactivity. Samples of each metal were placed separately into test tubes, each containing a nitrate solution of the other metal ions. The results are shown below.

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Based on these results, which of the following shows the metals in order of decreasing reactivity?

(A) Y > X > Z

(B) X > Z > Y

(C) Z > X > Y

(D) Y > Z > X

12. Calcium reacts with water as shown:

$$Ca_{(s)} + 2H_2O_{(l)} \rightarrow Ca(OH)_{2(aq)} + H_{2(g)}$$

What volume of hydrogen would be liberated at 25°C and 100kPa when 16 g of calcium reacts with excess water?

(A) 16 L

(B) 22.79 L

(C) 10.5 L

(D) 9.90 L

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(B) metals.

(C) covalent molecular substances whose atoms or molecules are non-polar.

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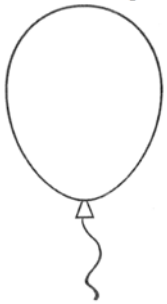


What is the volume of the balloon if the gas pressure is 100 kPa and the temperature is 35.0°C?

(A) 2.1 L

(B) 11.4 L

(C) 12.4 L

(D) 12.8 L

15. Use the standard potential table provided. Which reaction from A, B, C or D will occur spontaneously?

(A) $Fe^{3+}_{(aq)} + Cl_{2(g)}$

(B) $Mg^{2+}_{(aq)} + Fe^{2+}_{(aq)}$

(C) $Pb^{2+}_{(aq)} + Sn^{2+}_{(aq)}$

(D) $Ni^{2+}_{(aq)} + Mg_{(s)}$

16. In which reaction is there an increase in entropy?

(A) $PCl_{3(l)} + Cl_{2(g)} \rightarrow PCl_{5(s)}$ ΔH = -ve

(B) $2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)}$ ΔH = -ve

(C) $(NH_4)_2SO_{4(s)} + 2NaOH_{(s)} \rightarrow Na_2SO_{4(s)} + 2NH_{3(g)} + 2H_2O_{(g)}$ ΔH = +ve

(D) $2NO_{2(g)} \rightarrow N_2O_{4(g)}$ ΔH = -ve

17. The decomposition of hydrogen peroxide into oxygen and water proceeds very slowly at room temperature. However, the addition of a small amount of manganese dioxide (MnO_2), causes the hydrogen peroxide to bubble vigorously due to the rapid production of oxygen.

$$2H_2O_{2(aq)} \rightarrow O_{2(g)} + 2H_2O_{(l)} \qquad \text{very slow}$$

$$2H_2O_{2(aq)} \xrightarrow{MnO_2} O_{2(g)} + 2H_2O_{(l)} \qquad \text{vigorous}$$

The best explanation for this is:

(A) the manganese dioxide acts as a catalyst, providing an alternative reaction pathway that has a lower activation energy.

(B) the manganese dioxide increases the temperature of the reaction thereby increasing the collision rate of the molecules.

(C) the manganese dioxide increases the collision rate between reacting molecules simply by causing an increase in the total number of molecules in the solution.

(D) the manganese dioxide increases the collision energy of the hydrogen peroxide molecules.

18. If an endothermic reaction is spontaneous at temperature T_1 but is not spontaneous at temperature T_2, which statement is true?

(A) ΔH is positive and T_1 is higher than T_2.

(B) ΔH is positive and T_1 is lower than T_2.

(C) ΔH is negative and T_1 is higher than T_2.

(D) ΔH is negative and T_1 is lower than T_2.

19. Use the following bond energy data to determine the enthalpy change for the reaction

$$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$$

Average bond energy in kJ mol^{-1}			
C-H 414	O-O 144	O-H 463	C= O 804
C-C 346	O=O 498	C-O 358	C=C 614

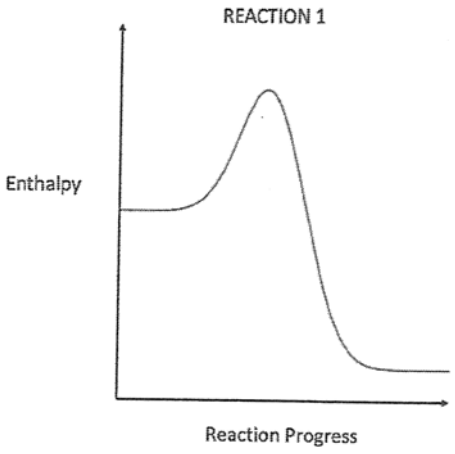
(A) $\Delta H = -380$ kJ mol^{-1}

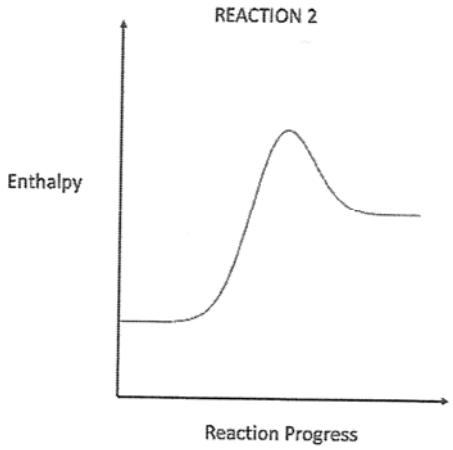
(B) $\Delta H = -808$ kJ mol^{-1}

(C) $\Delta H = +158$ kJ mol^{-1}

(D) $\Delta H = +808$ kJ mol^{-1}

20. The enthalpy change in two different reactions are graphed below. The scale on the axis are the same.





Which of the following statements is true?

(A) Reaction 1 is exothermic and has a higher activation energy than reaction 2.

(B) Reaction 1 is endothermic and has a higher activation energy than reaction 2.

(C) Reaction 2 is exothermic and has a higher activation energy than reaction 1.

(D) Reaction 2 is endothermic and has a higher activation energy than reaction 1.

Part B – 50 marks
Attempt Questions 21-33

Question 21 (4 marks)

Complete the table below using IUPAC naming conventions.

Name	Formula
Calcium sulfide	**CaS**
Nitrogen Dioxide	NO_2
Nitric acid	**HNO_3**
Sodium Hydride	NaH

Question 22 (3 marks)
Use the data provided to find the enthalpy change for the following reaction, by applying Hess's Law.

$$\mathbf{CS_2(l) + 3O_2(g) \rightarrow CO_2(g) + 2SO_2(g)}$$

Reaction	ΔH (kJ/mol)
$C(s) + O_2(g) \rightarrow CO_2(g)$	- 394
$S(s) + O_2(g) \rightarrow SO_2(g)$	- 297
$C(s) + 2S(s) \rightarrow CS_2(l)$	+ 88

Show your working.

Marking Criteria	Marks
• Correctly calculates the enthalpy change of reaction.	**3**
• Response contains one error.	**2**
• Response contains one correct step.	**1**

Equation	ΔH (kJ/mol)	Comments
$CS_2(l) \rightarrow C(s) + 2S(s)$	-88	This is the reverse of the original equation, and of the sign on ΔH.
$C(s) + O_2(g) \rightarrow CO_2(g)$	-394	This is the equation as given.
$2S_2(g) + 2O_2(g) \rightarrow 2SO_2(g)$	-594	This is "double" the equation given, and double the ΔH value.
overall: **$CS_2(l) + 3O_2(g) \rightarrow CO_2(g) + 2SO_2(g)$**	**-1076 kJ/mol**	

Question 23 (3 marks)
Infants and children require a daily allowance of 0.52mg of copper per kg of body weight. (a)

Calculate for a 12kg infant the number of moles of copper required per day. **2**

.

Criteria	Marks
• Converts mg into grams and converts into grams per day based on 12kg body weight AND calculates the moles of Cu required per day	2
• Converts mg into grams and converts into grams per day based on 12kg body weight OR calculates the moles of Cu required per day	1

Sample answer
Convert mg into grams 0.52mg = 0.52×10^{-3} g.
Cu required for a 12 kg baby = $0.52 \times 10^{-3} \times 12$
= 6.2×10^{-3} g per day.
Moles of Cu in 6×10^{-3} g = 6.2×10^{-3} g/ 63.55
= 9.8×10^{-5} moles (2 sig figures)

(b) Calculate the number of atoms of copper required per day. **1**

Criteria	Mark
• Multiplies the moles in (a) by N_A number (6.023×10^{23})	1

Sample answer
No. of Cu atoms in 9.8×10^{-5} moles = $9.8 \times 10^{-5} \times 6.023\ 10^{23}$
= 5.9×10^{19} Cu atoms required.

Question 24 (5 marks)
Aluminium oxide can be produced by aluminium metal reacting with oxygen gas.

(a) Write a balanced equation for the formation of aluminium oxide from aluminium and oxygen. **1**

1 mark: correct equation

$4Al_{(s)} + 3O_{2(g)} \rightarrow 2Al_2O_{3(s)}$

(b) How many moles of $Al_2O_{3(s)}$ can be produced when a mixture of 0.36 moles of aluminium and 0.36 moles of oxygen is ignited? **2**

1 mark: Use the equation $4Al_{(s)} + 3O_{2(g)} \rightarrow 2Al_2O_{3(s)}$ and number of moles given to determine the element in excess (O_2)

1 mark: Moles of $Al_2O_{3(s)}$ formed is 0.18 moles.
Therefore from the eqn 2 mole of Al react with 1.5 mole of O_2 forming 1 mole of $Al_2O_{3(s)}$
Therefore 0.36 " " 0.27 " " 0.18 " "

(c) Using the information above in (b), which substance and how much of it is in excess of that required when producing the $Al_2O_{3(s)}$? **2**

1 mark: working out
1 mark: correct answer

Using the information above O_2 is in excess.
The amount of O_2 left over from the reaction = 0.36 mole initially – 0.27 mole reacted
= 0.09 moles of O_2 left over from the reaction.

Question 25 (4 marks)

The dichromate ion found in compounds such as potassium dichromate ($K_2Cr_2O_7$) is such a powerful oxidant that it can oxidise inert metals such as platinum to form its ion (Pt^{2+}). The reduction potential of platinum has been measured at 1.2V.

(a) Write an oxidation half-equation to represent the oxidation of Pt as described above. **1**

Marking Criteria	Marks
• Writes the correct half-equation.	1

$Pt(s) \rightarrow Pt^{2+} + 2e^-$

(b) The half-equation for the reduction of $Cr_2O_7^{2-}$ is shown on the data sheet. Use this to determine the *change* in oxidation state that chromium undergoes in the reduction. **1**

Marking Criteria	Marks
• Determines oxidation state change.	1

$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$
Change in oxidation state of +6 to +3.

(c) Combine the equations in (a) and (b) to produce a balanced net ionic equation for the reaction that would occur when platinum metal was placed into a solution of potassium dichromate and hydrogen ions. **1**

Show your working.

Marking Criteria	Marks
• Write a correct net ionic equation for the redox reaction.	1

$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$

$3Pt(s) \rightarrow 3Pt^{2+} + 6e^-$

Net ionic:
$Cr_2O_7^{2-} + 3Pt\ (s) + 14H^+ \rightarrow 2Cr^{3+} + 7H_2O + 3Pt^{2+}$

(d) A galvanic cell was produced from coupling a standard Pt/Pt^{2+} half cell with a standard half cell for $Cr_2O_7^{2-}/Cr^{3+}$.

What was the maximum theoretical voltage produced? **1**

Marking Criteria	Marks
• Calculates theoretical voltage.	1

-1.2 + 1.36 = 0.16V

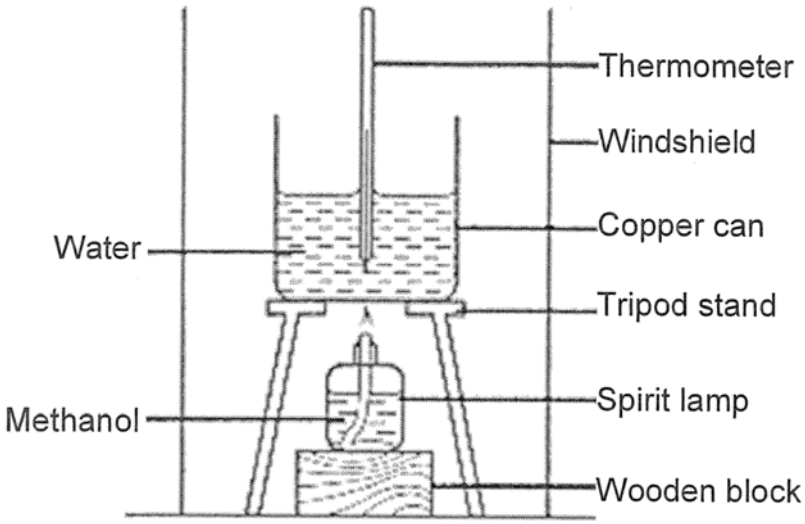
Question 26 (3 marks)

A 14.6 g sample of a compound containing carbon and hydrogen only (which could be represented as C_xH_y) was burnt in excess oxygen to produce 44.0 g of carbon dioxide (CO_2) and 24.0 g of water vapour.
Determine an empirical formula for this compound, showing your working.

Marking Criteria	Marks
• Determines the empirical formula of the compound, showing working.	**1**
• Writes a balanced chemical equation in terms of 'x' and 'y'	**1**
• Calculates the moles of CO_2 and H_2O produced.	**1**

$C_xH_y + O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$
$n(CO_2) = m/MM = 44/44 = 1$ mol
$n(H_2O) = n/MM = 24/18 = 1.33$ mol
Multiply by three to give whole number ratios:
$CO_2 = 3$
$H_2O = 4$
Equation becomes: $C_xH_y + O_2 \rightarrow 3CO_2 + 4H_2O$
x=3 H = 8
Empirical formula: C_3H_8

Question 27 (2 marks)
An investigation was carried out to determine the molar heat of combustion of methanol (CH_3OH).



The results are below.

Mass of Water	200g
Mass of Methanol Combusted	1.78g
Initial temperature of water	20.0°C
Final temperature of water	42.5°C

Calculate the molar heat of combustion of methanol.

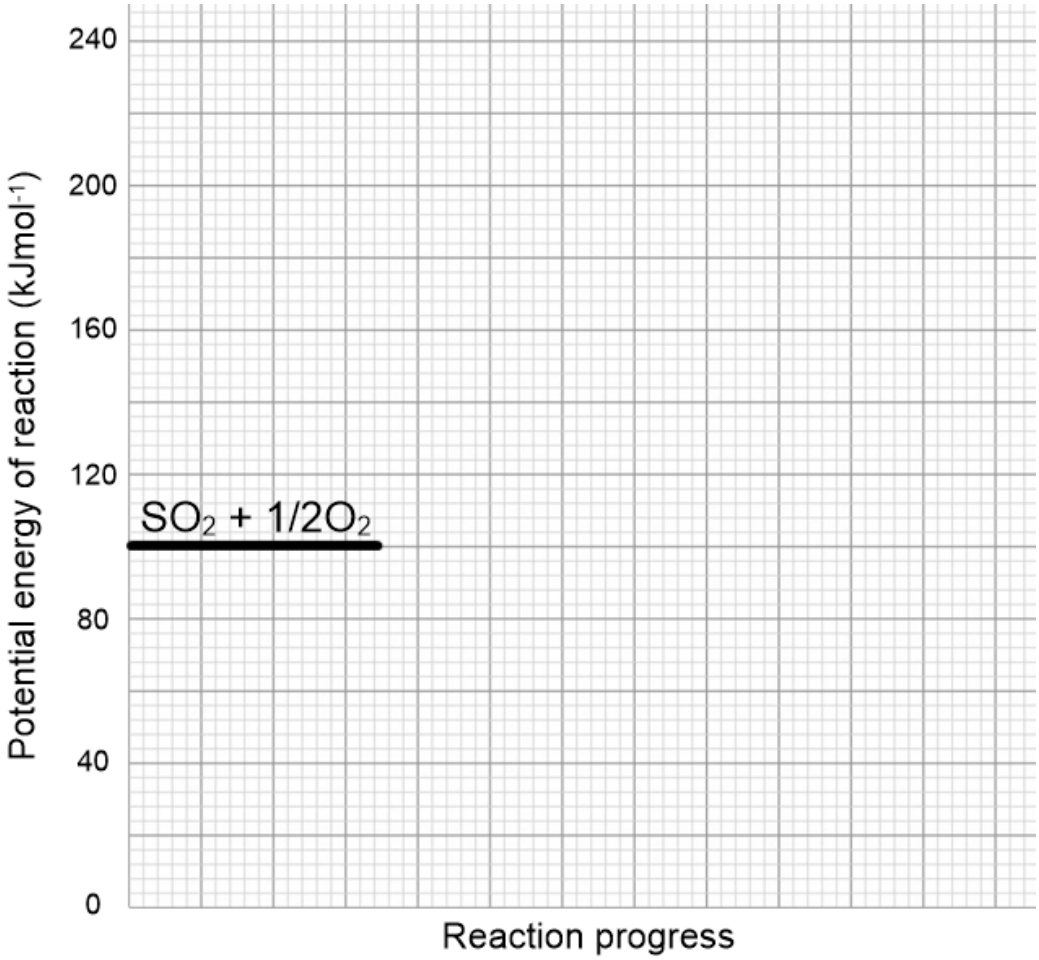
Criteria	Marks
• Determine experimental molar Heat of combustion	2
• Determine the amount of energy released OR the number of moles of methanol combusted	1

Use $\Delta H = - mC\Delta T$
$= - 0.200 \times 4.18 \times 10^3 \times 22.5$
$= -18{,}810$ J
no. moles methanol combusted $= 1.78/32 = 0.055625$
molar $\Delta H = -18{,}810 / 0.055625 = -338157.3034 = -338$ kJmol^{-1}

Question 28 (3 marks)

Sulfur dioxide gas can react with oxygen gas to form sulfur trioxide gas when heated. The temperature of the reaction vessel becomes hotter as the reaction proceeds. The activation energy for this reaction is 42 $kJmol^{-1}$ whist the change in enthalpy was 98 $kJmol^{-1}$.

(a) Sketch a labelled energy profile diagram for this reaction. **2**



1 mark- correctly labels ΔH and E_a on exothermic energy profile diagram.
1 mark- correct data point on graph for E_a and ΔH

(b) Use a dashed line on your diagram to illustrate the effect of a catalyst on this reaction
1 mark- correctly shows effect of catalyst

Question 29 (5 marks)

The simplified solubility rules below may help you to answer this question.

General Rule	Exceptions
all Group I, nitrate and ammonium compounds are soluble	none
most chlorides are soluble	silver and lead (insoluble)
most sulfates are soluble	barium and lead (insoluble) calcium and silver (slightly soluble)
most hydroxides are insoluble	group I, ammonium and barium compounds (soluble) calcium (slightly soluble)
most carbonates are insoluble	group I and ammonium compounds

A science teacher mixes solutions of magnesium nitrate and sodium hydroxide.

(a) Write a balanced chemical equation (including states) for the reaction that occurs. **1**

Marking Criteria	Marks
• Writes correctly balanced equation..	1

$Mg(NO_3)_2(aq) + 2NaOH(aq) \rightarrow Mg(OH)_2(s) + 2NaNO_3(aq)$

(b) Write the net ionic equation for the reaction. **1**

Marking Criteria	Marks
• Writes the correct net ionic equation based on the reaction from (a) above.	1

$Mg^{2+}(aq) + 2OH^-(aq) \rightarrow Mg(OH)_2(s)$

(c) Using the solubility rules above, suggest a method that could be followed to determine which of the compounds below is present in an unlabelled bottle known to contain **one** of these dissolved compounds.
Explain how your observations would allow you to identify the unknown. **3**

potassium nitrate, sodium sulfate, lithium hydroxide

(Assume you have access to typical laboratory equipment, as well as dropper bottles, each containing 0.1M solutions of any chemical you require in your procedure.)

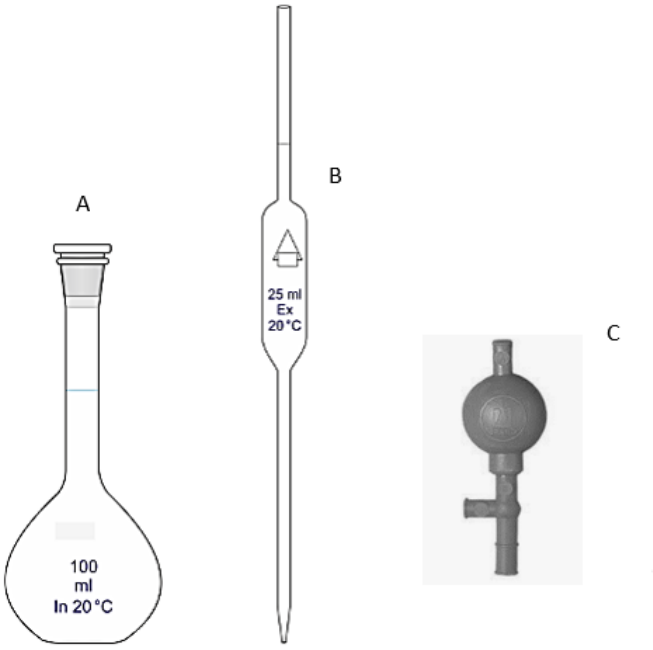
Marking Criteria	Marks
• Records a procedure that could be followed to identify which compound must be in the unlabelled bottle and explains how the results would lead to the identification of the compound, applying the solubility rules.	**3**
• Records a procedure that could be followed to identify which compound must be in the unlabelled bottle with insufficient explanation of how the results would lead to the identification.	**2**
• Shows some understanding of how the solubility rules could be used to identify the unknown.	**1**

1. Pour 1mL of the unknown solution into a test tube.
2. Add a few drops of $Ba(NO_3)_2$. If a precipitate forms, the solution can only be sodium sulfate, as $BaSO_4$ is insoluble but neither K_2SO_4 or $Ba(OH)_2$ are insoluble.
3. If no precipitate forms in Step 2, add a few drops of $Pb(NO_3)_2$. If a precipitate forms, the solution must be LiOH, as $Pb(OH)_2$ is insoluble but $Pb(NO_3)_2$ is soluble.

Since potassium nitrate is soluble with any combination of ions, if no precipitate forms from steps 2 and 3, this must be the unknown.

Question 30 (5 marks)

A student used the following pieces of equipment (labelled A, B and C) to produce a diluted solution of 0.050 $molL^{-1}$ barium hydroxide from a bottle containing 0.20 $molL^{-1}$ barium hydroxide.



Describe the procedure the student should have followed to produce the solution accurately and calculate its concentration in % (w/v), given the volumes shown on the equipment used.

Ensure equipment A to C is clearly identified in the procedure.

- 1 mark – Correct calculation of % (w/v) to be 0.86%.

Procedure outlines:

- 1 mark –rinsing pipette with barium hydroxide solution before use.
- 1 mark – Use suction bulb and volumetric pipette (bulb pipette) to measure up to mark with barium solution (25mL) and place in volumetric flask
- 1 mark – Fill volumetric flask up to mark with distilled/demineralised/tap water
- 1 mark – Stopper flask and swirl/invert/shake.

Note: No marks lost for incorrect naming of equipment however it was indicated when wrong. Calculation of volume exchange not needed but good to see people doing this in full. (Show all working!)

Question 31 (4 marks)
Use the following equations that are **not** balanced to answer the questions below.

1. $CH_3CH_2OH_{(l)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(l)}$
2. $PbNO_{3(aq)} + Na_2CO_{3(aq)} \rightarrow PbCO_{3(s)} + NaNO_{3(aq)}$
3. $Na_{(s)} + Cl_{2(g)} \rightarrow NaCl_{(s)}$
4. $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$

(a) Which reaction from 1, 2, 3 or 4 is an example of a combustion reaction? **1**

. Reaction 1.

(b) Balance the equation in reaction 1. **1**

$CH_3CH_2OH_{(l)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(l)}$
No half marks. No multiples higher than this, i.e. 6:4:6

(c) Which reaction is classified as a synthesis reaction? **1**
Equation 3

Question 32 (3 marks)

(a) Draw the electron dot diagram (Lewis dot diagram) for hydrogen iodide (HI). **1**

(b) Explain why hydrogen chloride is considered a polar covalent molecule? **2**

Criteria	Marks
• Explain covalent nature of bond and explain polarity of molecule	2
• Explain covalent nature of bond OR explain polarity of molecule	1

Sample answer
HCl is a covent molecule as an electron from the hydrogen and one from the chlorine are shared so as each has a full shell.
As the hydrogen is smaller and less electronegative, the shared electrons spend more time orbiting the chlorine rather than the hydrogen so a dipole exists which makes the molecule polar.

Question 33 (6 marks)

(a) Calculate the standard entropy change for the complete combustion of butane (C_4H_{10}) using the standard entropy values provided below. **2**

Substance	S^o (J K^{-1} mol^{-1})
$C_4H_{10\,(g)}$	310
$O_{2(g)}$	205
$CO_{2(g)}$	214
$CO_{(g)}$	198
$C_{(s)}$	6
$H_2O_{(g)}$	189

Criteria	Marks
• Derives a balanced combustion equation for butane AND transcribes correct values of ΔS^o AND uses correctly equation for S^o = Products - reactants	2
• Derives a balanced combustion equation for butane OR transcribes correct values of ΔS^o OR uses correctly equation for S^o = Products - reactants	1

Sample answer

$C_4H_{10(g)} + 13/2\ O_{2(g)} \rightarrow 4CO_{2(g)} + 5H_2O_{(g)}$

Therefore $\Delta S^o = 4S^o(CO_2) + 5S^o(H_2O) - 13/2S^o(O_2) - S^o(C_4H_{10})$

$= 4 \times 214 + 5 \times 189 - 13/2 \times 205 - 310$

$= 856 + 945 - 1332.5 - 310$

$= 158.5\ J\ K^{-1}\ mol^{-1}$

(b) Calculate ΔH^o for the complete combustion of butane at 298K, then use this value along with the ΔS^o calculated in part (a) to calculate ΔG^o for the complete combustion of butane. Also predict if the reaction will go as written under standard conditions. Use the table below to calculate ΔH^o. **4**

Substance	ΔH^o_f (J K mol^{-1})
$C_4H_{10\,(g)}$	-126
$O_{2(g)}$	0
$CO_{2(g)}$	-394
$CO_{(g)}$	-111
$C_{(s)}$	0
$H_2O_{(g)}$	-136

Criteria	Marks
• Uses the equation for ΔG AND uses the previous calculated value of ΔS^o (from 33(a)) converted to kJ mol^{-1} K^{-1} AND calculates correctly ΔH from ΔH_f table provided AND correctly transcribes ΔH, T in K and ΔS into equation $\Delta G = \Delta H - T\Delta S$ and therefore predicts if the reaction proceeds to completion	4
• Uses any 3 steps correctly from above	3
• Uses any 2 steps correctly from above	2
• Uses any 1 step correctly from above	1

Sample answer

$C_4H_{10(g)} + 13/2\ O_{2(g)} \rightarrow 4CO_{2(g)} + 5H_2O_{(g)}$.

Uses the equation $\Delta G = \Delta H - T\Delta S$ and if $\Delta G < 0$ then the reaction proceeds.

Using ΔS from 33(a) but as the units for ΔG and ΔH are in kJ mol^{-1} and ΔS is in J K^{-1} mol^{-1} , ΔS must be converted to kJ.

T in K = 298

So ΔS of 158.5 J K^{-1} mol^{-1} = 158.5/1000 kJ K^{-1} mol^{-1}

Calculate $\Delta H = \Delta H_f$ products - ΔH_f reactants.

ΔH_f products = 4 x -394 + 5 x -136 and ΔH_f reactants = -126

= -2256

$\Delta H = \Delta H_f$ products - ΔH_f reactants

= -2256 – (-126)

= -2130 kJ mol^{-1}

Substituting into the equation $\Delta G = \Delta H - T\Delta S$

= - 2130 – 298 x 158.5/1000

= - 2130 – 47.23

= - 2177.23 kJ mol^{-1}

Therefore as ΔG = - 2177.23 kJ mol^{-1} and $\Delta G < 0$ the reaction proceeds to completion.

END OF PAPER