Name: _____

Teacher: _____

NORTH SYDNEY GIRLS HIGH SCHOOL

2023

Year 11

Assessment Task 3

Chemistry

General Instructions

- Reading Time – 5 minutes
- Working Time – 2 hours
- Write using blue or black pen
- Draw diagrams using pencil
- Board-approved calculators may be used
- **Write your name and your teacher's name at the top of this booklet AND the multiple choice answer sheet**

Total Marks – 70

Weighting – 40 %

Section I 20 Marks

- Attempt Questions 1 – 20
- Allow about 35 minutes for this section

Section 2 50 Marks

- Attempt question 21 – 28
- Allow about 1 hour and 25 minutes for this section

Write your answers in the space provided. Adequate lines have been provided.

Section 1 **20 marks**

Attempt Questions 1 – 20
Allow about 35 minutes for this section

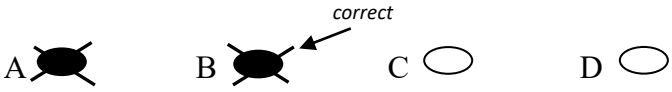
Use the multiple-choice answer sheet provided for Questions 1-20. If you must use blank paper instead, clearly indicate an answer of EITHER A, B, C or D for each question from 1-20.

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

If you have changed your mind and have crossed out what you consider to be the correct answer, then indicate this by writing the word *correct* and drawing an arrow as follows:



1. What is the IUPAC name of P_2I_4?
   A. Potassium iodide
   B. Diphosphorus iodate
   C. Phosphorous iodide
   D. Diphosphorous tetraiodide

2. Which of the following chemical species features a double bond?
   A. NH_3
   B. O_2
   C. CH_4
   D. N_2

3. Which of the following statements describing the periodic table is incorrect?
   A. Atomic radius increases across a period.
   B. Atomic radius increases down a group.
   C. Number of valence electrons increases across a period.
   D. Number of electron shells increases down a group.

4. Which of the following determines the overall polarity of a molecule?
   A. Electronegativity difference between atoms in a covalent bond
   B. Presence of polar or non polar bonds
   C. Shape of the molecule
   D. All of the above

5. Two reactions and their enthalpy changes are shown below.

$$2C(s) + 2H_2(g) \rightarrow C_2H_4(g) \qquad \Delta H = +52.2 \text{ kJ mol}^{-1}$$

$$C_2H_2(g) + H_2(g) \rightarrow C_2H_4(g) \qquad \Delta H = -175.8 \text{ kJ mol}^{-1}$$

   What is the enthalpy change for the reaction below?

$$2C(s) + H_2(g) \rightarrow C_2H_2(g)$$

   A. -228.0 kJ mol^{-1}
   B. -123.6 kJ mol^{-1}
   C. $+123.6$ kJ mol^{-1}
   D. $+228.0$ kJ mol^{-1}

6. Which of the following samples contain the largest number of hydrogen atoms?
   A. 0.1000 mol of C_5H_{12}
   B. 0.2000 mol of C_4H_8
   C. 6.022×10^{23} hydrogen atoms
   D. 1.000 mol of hydrogen molecules

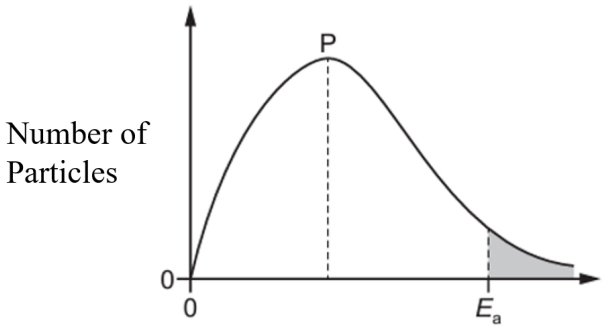
7. Which of the following molecules has the same shape as CO_2?
   A. HF
   B. H_2O
   C. NH_3
   D. CH_4

8. A 0.0780 mol sample of gas occupies 240 mL and has a pressure of 250 kPa. What is the temperature of the sample of gas?
   A. 92.5°C
   B. 92.5 K
   C. 366°C
   D. 366 K

9. Which of the following processes is most likely to have a positive ΔS?
   A. $H_2O(g) \rightarrow H_2O(l)$
   B. $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$
   C. $NaCl(aq) \rightarrow NaCl(s)$
   D. $MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$

10. Which statement about catalysts is correct?
    A. They change the reaction pathway by increasing the activation energy.
    B. They increase the rate of reaction by lowering the enthalpy change of the reaction.
    C. They increase the proportion of particles that have sufficient energy to react.
    D. They are used up as an extra reactant in the reaction.

11. The diagram below shows the Maxwell-Boltzmann distribution of energies in a gas. The gas undergoes a reaction with an activation energy, E_a. The peak of the distribution is labelled P.



If the same reaction is carried out at a lower temperature, which row correctly describes the changes to the graph?

	Position of P	Position of E_a
A.	Moves to the left	Moves to the left
B.	Moves to the right	Moves to the right
C.	Moves to the left	Remains the same
D.	Remains the same	Moves to the right

12. What is the minimum volume of oxygen required to ensure the complete combustion of 22 L of C_3H_8 measured at constant conditions of 35ºC and 102 kPa?

A. 22 L

B. 66 L

C. 110 L

D. 220 L

13. What is the oxidation number of sulfur in each of the chemical species below?

	H_2S	SO_2	H_2SO_3
A.	-2	+4	+4
B.	-2	+4	+6
C.	+2	-4	+4
D.	+2	-4	+6

14. Which of the following best defines the bond energy of the Br–Br covalent bond?

A. the energy required to produce one mole of bromine atoms in the gaseous state
B. the energy required to produce one mole of bromine atoms in the liquid state
C. the energy required to break one mole of Br–Br bonds in the gaseous state
D. the energy required to break one mole of Br–Br bonds in the liquid state

15. Hydrogen iodide reacts with concentrated sulfuric acid according to the chemical equation below.

$$8HI + H_2SO_4 \rightarrow H_2S + 4H_2O + 4I_2$$

Which element undergoes reduction?

A. Hydrogen
B. Iodine
C. Sulfur
D. Oxygen

16. The standard enthalpy changes of combustion of carbon, hydrogen and methanol are shown.

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\quad \Delta H^o_c = -394 \text{ kJ mol}^{-1}$

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ $\quad \Delta H^o_c = -286 \text{ kJ mol}^{-1}$

$CH_3OH(l) + 1\frac{1}{2}O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ $\quad \Delta H^o_c = -726 \text{ kJ mol}^{-1}$

Which expression below gives the standard enthalpy of formation of methanol?

A. (-394) + (-286) + (-726)(-1)
B. (-394) + (-286 x 2) + (-726)(-1)
C. (-394) + (-286 x 2) + (-726)
D. (-1)(-394) + (-1)(-286 x 2) + (-726)

17. At 550°C, nitrogen dioxide reacts with unburnt hydrocarbon fragments such as CH_3 in the catalytic converter of a motor vehicle.

$$8CH_3 + 14NO_2 \rightarrow 7N_2 + 8CO_2 + 12H_2O$$

Which of the following statements could be used to explain the exothermic nature of the reaction above?

A. Heat energy from the surroundings is absorbed.
B. Chemical energy of the products is greater than that of the reactants.
C. Double bonds are broken in NO_2.
D. The N≡N bond energy is very high.

18. Which of the following statements is correct?
A. Br^- ions will reduce Cl_2 but not I_2.
B. Cl_2 will oxidise Br^- ions but not I^-.
C. F_2 is the weakest oxidant out of F_2, Cl_2, Br_2 and I_2.
D. I^- ions are the weakest reductant out of F^-, Cl^-, Br^- and I^-.

19. A sample of a gas takes up a volume of 400 mL at 300 K and 101 kPa. If the gas has a mass of 0.647 g, which is the most likely identity of the gas?
A. Helium
B. Neon
C. Argon
D. Chlorine

20. A solution of sodium hydroxide reacts with 3 mol of chlorine gas under certain conditions. The reaction produces 5 mol of sodium chloride, 1 mol of Compound X and a certain amount of water.

What is the formula of Compound X?

A. $NaClO_4$
B. $NaClO_3$
C. $NaClO_2$
D. NaClO

Section 2 **50 marks**

Attempt Questions 21 – 28
Allow about 1 hour and 25 minutes for this section

Please write all answers clearly in the spaces provided and show ALL working. The number of lines indicates the expected length of your response.

Question 21 (2 marks)

Write the chemical equations for the following reactions.

a) the neutralisation of a barium hydroxide solution by dilute hydrochloric acid **1**

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b) copper(II) nitrate reacting with potassium carbonate to form a precipitate **1**

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Question 22 (3 marks)

Diamond is an allotrope of carbon. The mass of a diamond can be measured in carats. One carat is 0.200 g of carbon.

Calculate the mass of 1.806×10^{22} carbon atoms in carats. **3**

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Question 23 (6 marks)

The table below shows data on three substances X, Y and Z, each of a different chemical structure.

Test	X	Y	Z
Melting point (°C)	1713	44	963
Electrical conductivity as a solid	Nil	Nil	Nil
Electrical conductivity as an aqueous solution	Nil	Nil	High

a) Identify the chemical structure of substance X and Y by circling the correct response. **2**

X: ionic lattice covalent network covalent molecular metallic structure

Y: ionic lattice covalent network covalent molecular metallic structure

b) A student claimed that Z must be an ionic lattice. Justify this claim using the data and your knowledge of structure and bonding. **4**

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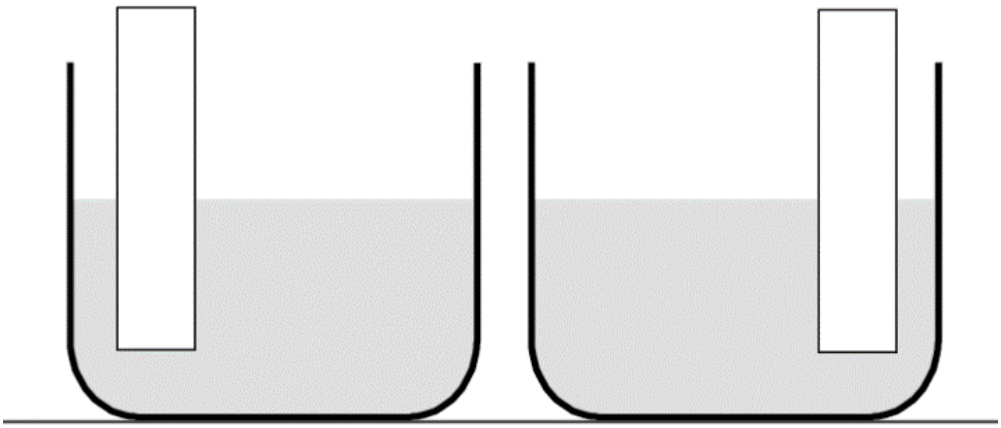
Question 24 (8 marks)

A student set up a galvanic cell with the following components:

- copper half cell using 1 mol L^{-1} copper(II) nitrate and a copper electrode
- tin half cell using 1 mol L^{-1} tin nitrate and a tin electrode
- potassium nitrate salt bridge

a) Complete the diagram below to show the galvanic cell described above. In your diagram, clearly label the following including the specific chemical species mentioned above: **5**

- Anode and cathode
- Salt bridge
- Solutions
- Direction of electron flow
- Direction of ion flow across the salt bridge



Question 24 continues on the next page.

b) Write the oxidation and reduction half equations. **2**

Oxidation: ……

Reduction: ……

c) Calculate the theoretical E^o value of the cell. **1**

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Question 25 (3 marks)

When 0.033 mol of ethanol (C_2H_5OH) is used to heat 100.0 g of water, the temperature of the water increases by 12.0ºC. The theoretical enthalpy of combustion of ethanol is -1364 kJ mol^{-1}.

Assuming only complete combustion had occurred, calculate the amount of heat lost to the environment. **3**

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Question 26 (5 marks)

Hydrazine, N_2H_4, reacts with dinitrogen tetraoxide, N_2O_4, to form nitrogen gas and water vapour.

$$2N_2H_4(l) + N_2O_4(g) \rightarrow 3N_2(g) + 4H_2O(g)$$

The relevant thermochemical data is shown below.

$N_2H_4(l)$: $\Delta H°_f = 50.6$ kJ mol^{-1}

$N_2O_4(g)$: $\Delta H°_f = 9.16$ kJ mol^{-1}

$H_2O(g)$: $\Delta H°_f = -285.83$ kJ mol^{-1}

$N_2H_4(l)$: $S° = 223.0$ J mol^{-1} K^{-1}

$N_2O_4(g)$: $S° = 304.7$ J mol^{-1} K^{-1}

$N_2(g)$: $S° = 191.6$ J mol^{-1} K^{-1}

$H_2O(g)$: $S° = 188.8$ J mol^{-1} K^{-1}

Determine the Gibbs Free Energy change, and therefore spontaneity, of the reaction at -100ºC using the data provided. **5**

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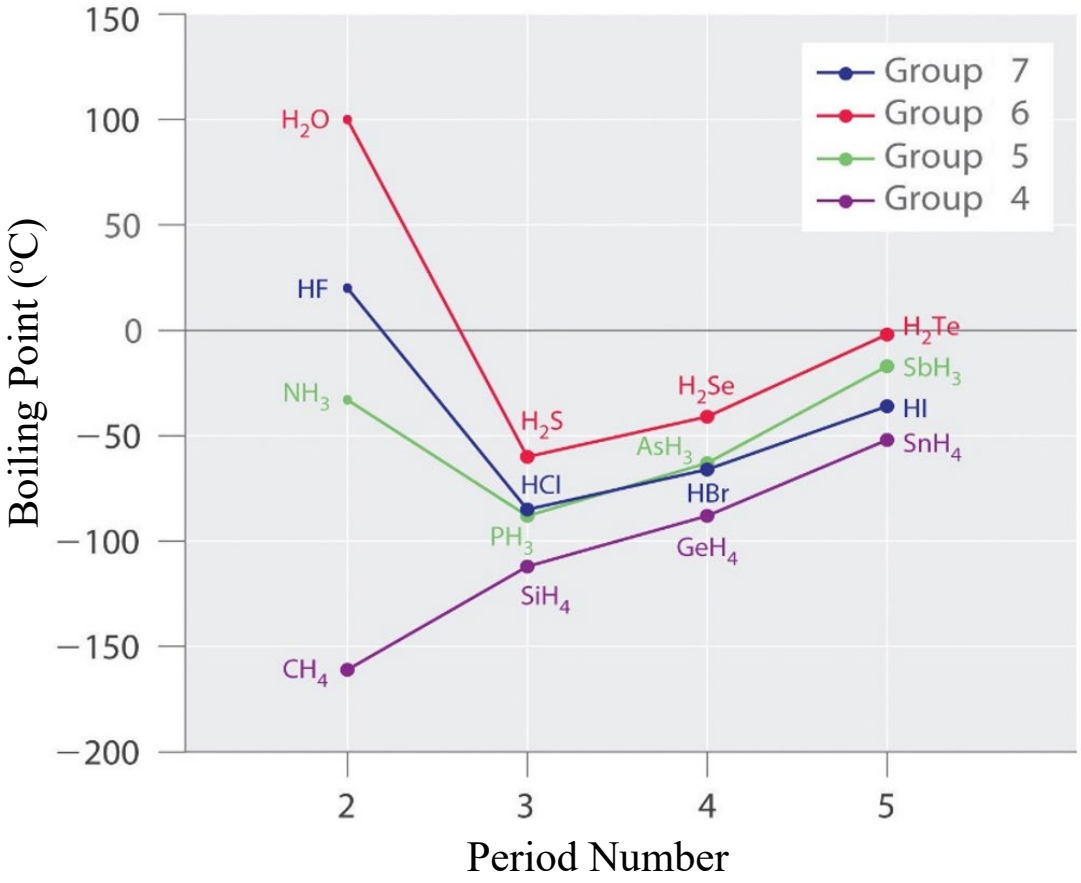
Question 27 (10 marks)

The graph below shows the boiling point for a variety of hydrides.



a) Complete the table below. **3**

	NH_3	SiH_4
Lewis Dot Diagram		
Name of Molecular Shape	……	……

Question 27 continues on the next page.

b) Explain the trend for the Group 4 hydrides. **2**

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c) Explain the differences between the trend in b) to the trend for the Group 6 hydrides. **5**

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Question 28 (13 marks)

A 3.70 g piece of magnesium carbonate is added to 25.0 mL of 2.00 mol L^{-1} hydrochloric acid, producing magnesium chloride, carbon dioxide and water. This is shown in the equation below.

$$MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + CO_2(g) + H_2O(l)$$

a) Calculate the volume of gas produced at standard laboratory conditions. **5**

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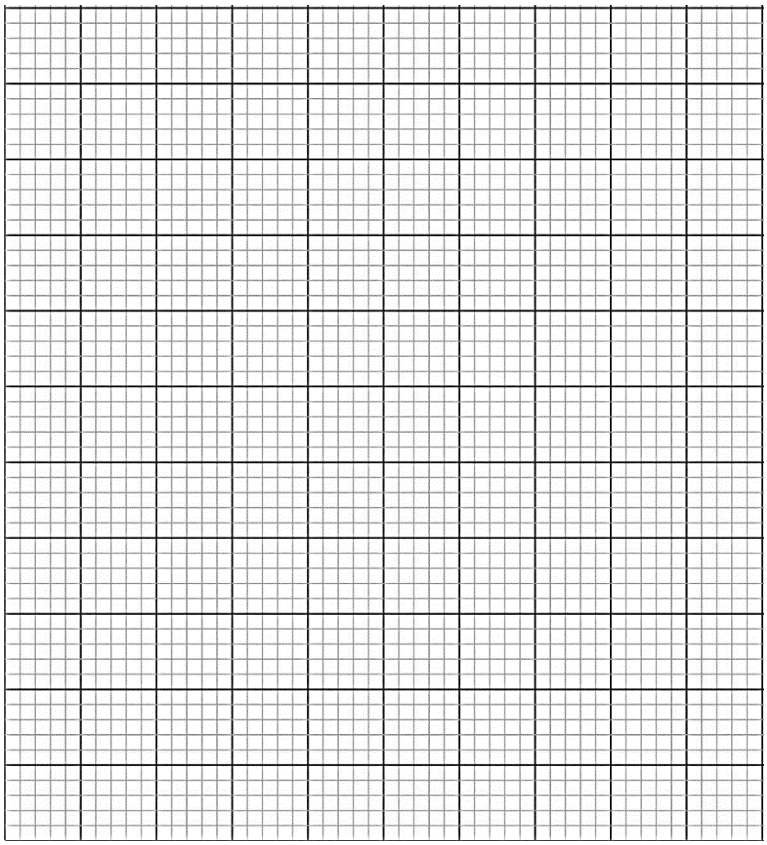
Question 28 continues on the next page.

b) Another mass of magnesium carbonate was reacted with hydrochloric acid. The volume of gas produced over time is shown in the table below. **4**

Time (s)	Volume of Gas Produced (mL)
25	20
50	50
75	68
125	95
150	100
200	100
225	100

Construct a graph for the data above.



Question 28 continues on the next page.

c) Using your understanding of collision theory, explain the trend in the graph. **4**

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END OF TEST

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Name: _____

Teacher: _____

NORTH SYDNEY GIRLS HIGH SCHOOL

2023

Year 11

Assessment Task 3

Chemistry

General Instructions

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Section 2 50 Marks

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Section 1 **20 marks**

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Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

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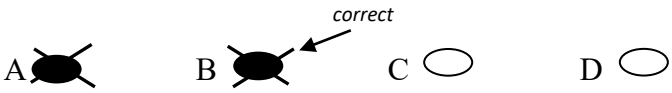


1. What is the IUPAC name of P_2I_4?
   A. Potassium iodide
   B. Diphosphorus iodate
   C. Phosphorous iodide
   D. Diphosphorous tetraiodide

   IUPAC naming rules for covalent compounds

2. Which of the following chemical species features a double bond?
   A. NH_3 single bonds only
   B. O_2
   C. CH_4 single bonds only
   D. N_2 triple bond

   If in doubt, draw a Lewis dot diagram!

3. Which of the following statements describing the periodic table is **incorrect**?
   A. Atomic radius increases across a period.
   B. Atomic radius increases down a group.
   C. Number of valence electrons increases across a period.
   D. Number of electron shells increases down a group.

4. Which of the following determines the overall polarity of a molecule?
   A. Electronegativity difference between atoms in a covalent bond
   B. Presence of polar or non polar bonds
   C. Shape of the molecule
   D. All of the above

5. Two reactions and their enthalpy changes are shown below.

(1) $2C(s) + 2H_2(g) \rightarrow C_2H_4(g)$ $\Delta H = +52.2$ kJ mol^{-1}

(2) $C_2H_2(g) + H_2(g) \rightarrow C_2H_4(g)$ $\Delta H = -175.8$ kJ mol^{-1}

What is the enthalpy change for the reaction below?

$$2C(s) + H_2(g) \rightarrow C_2H_2(g)$$

A. –228.0 kJ mol^{-1}

B. –123.6 kJ mol^{-1}

C. +123.6 kJ mol^{-1}

D. +228.0 kJ mol^{-1}

ΔH = (1) + (2) x -1

6. Which of the following samples contain the largest number of hydrogen atoms?

A. 0.1000 mol of C_5H_{12} = 0.1000 x 12 mol

B. 0.2000 mol of C_4H_8 = 0.2000 x 8 mol

C. 6.022 x 10^{23} hydrogen atoms = 6.022 x 10^{23} / 6.022 x 10^{23} mol

D. 1.000 mol of hydrogen molecules = 1.000 x 2 mol

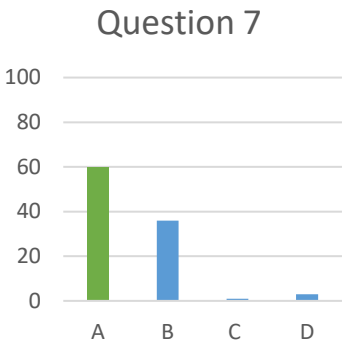
7. Which of the following molecules has the same shape as CO_2?

A. HF linear

B. H_2O bent

C. NH_3 trigonal pyramidal

D. CH_4 tetrahedral



8. A 0.0780 mol sample of gas occupies 240 mL and has a pressure of 250 kPa. What is the temperature of the sample of gas?

A. 92.5°C

B. 92.5 K

C. 366°C

D. 366 K

PV = nrT ➔ (250)(0.240) = (0.0780)(8.314)T ➔ rearrange to find answer in Kelvin

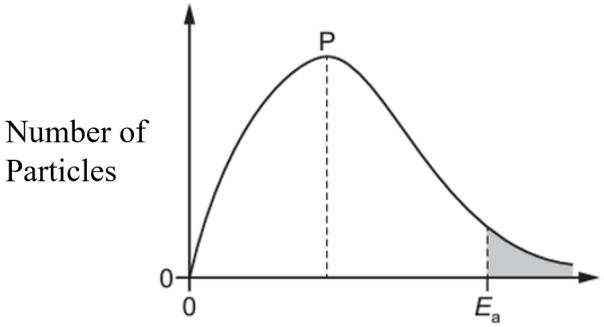
9. Which of the following processes is most likely to have a positive ΔS?

   A. $H_2O(g) \rightarrow H_2O(l)$ g ➔ l
   B. $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$ 3 mol ➔ 2 mol
   C. $NaCl(aq) \rightarrow NaCl(s)$ aq ➔ s
   D. $MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$ 1 mol ➔ 2 mol; s ➔ g

10. Which statement about catalysts is correct?

   A. They change the reaction pathway by ~~increasing~~ decreasing the activation energy.
   B. They increase the rate of reaction by lowering the enthalpy change of the reaction. No change to enthalpy!
   C. They increase the proportion of particles that have sufficient energy to react.
   D. They are NOT used up as an extra reactant in the reaction.

11. The diagram below shows the Maxwell-Boltzmann distribution of energies in a gas. The gas undergoes a reaction with an activation energy, E_a. The peak of the distribution is labelled P.



If the same reaction is carried out at a lower temperature, which row correctly describes the changes to the graph?

	Position of P	Position of E_a
A.	Moves to the left	Moves to the left
B.	Moves to the right	Moves to the right
C.	Moves to the left	Remains the same
D.	Remains the same	Moves to the right

12. What is the minimum volume of oxygen required to ensure the complete combustion of 22 L of C_3H_8 measured at constant conditions of 35°C and 102 kPa?

A. 22 L

B. 66 L

C. 110 L

D. 220 L

$C_3H_8 + 5O_2 \rightarrow 3O_2 + 4H_2O$

$v(O_2) = v(C_3H_8) \times 5 = 22 \times 5$ L

13. What is the oxidation number of sulfur in each of the chemical species below?

	H_2S	SO_2	H_2SO_3
A.	-2	+4	+4
B.	-2	+4	+6
C.	+2	-4	+4
D.	+2	-4	+6

Assume oxidation state of H = +1 and O = -2 and solve for S in each case.

14. Which of the following best defines the bond energy of the Br–Br covalent bond?

A. the energy required to produce one mole of bromine atoms in the gaseous state

B. the energy required to produce one mole of bromine atoms in the liquid state

C. the energy required to break one mole of Br–Br bonds in the gaseous state

D. the energy required to break one mole of Br–Br bonds in the liquid state

15. Hydrogen iodide reacts with concentrated sulfuric acid according to the chemical equation below.

$$8HI + H_2SO_4 \rightarrow H_2S + 4H_2O + 4I_2$$

Which element undergoes reduction?

A. Hydrogen
B. Iodine
C. Sulfur
D. Oxygen

Determine oxidation numbers for each element on either side of the reaction.
H: +1 ➔ +1 therefore no redox
I: -1 ➔ 0 therefore oxidation
S: +6 ➔ -2 therefore reduction
O: -2 ➔ -2 therefore no redox

16. The standard enthalpy changes of combustion of carbon, hydrogen and methanol are shown.

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H^o_c = -394$ kJ mol^{-1}

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ $\Delta H^o_c = -286$ kJ mol^{-1}

$CH_3OH(l) + 1\frac{1}{2}O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ $\Delta H^o_c = -726$ kJ mol^{-1}

Which expression below gives the standard enthalpy of formation of methanol?

A. (-394) + (-286) + (-726)(-1)
B. (-394) + (-286 x 2) + (-726)(-1)
C. (-394) + (-286 x 2) + (-726)
D. (-1)(-394) + (-1)(-286 x 2) + (-726)

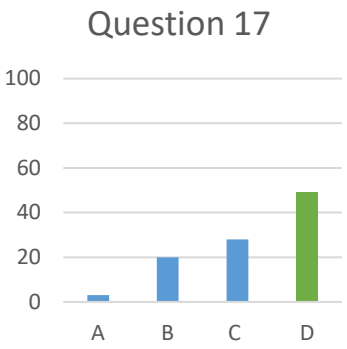
Manipulate equations to generate the reaction below:

$C(s) + \frac{1}{2}O_2(g) + 2H_2(g) \rightarrow CH_3OH(l)$

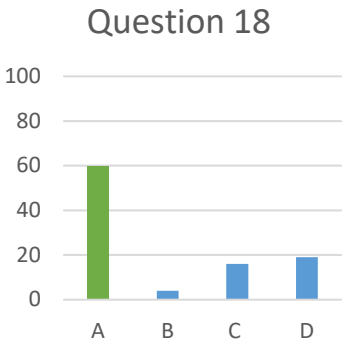
17. At 550°C, nitrogen dioxide reacts with unburnt hydrocarbon fragments such as CH_3 in the catalytic converter of a motor vehicle.

$$8CH_3 + 14NO_2 \rightarrow 7N_2 + 8CO_2 + 12H_2O$$

Which of the following statements **could be used to explain the exothermic** nature of the reaction above?



A. Heat energy from the surroundings is absorbed. endothermic
B. Chemical energy of the products is greater than that of the reactants. endothermic
C. Double bonds are broken in NO_2. Breaking double bonds involves consuming a lot of energy ➔ does not explain the exothermic nature
D. The N≡N bond energy is very high. Making the high energy bond involves releasing lots of energy ➔ could explain exothermic!



18. Which of the following statements is correct?
A. Br^- ions will reduce Cl_2 but not I_2.
B. Cl_2 will oxidise Br^- ions but not I^-.
C. F_2 is the weakest oxidant out of F_2, Cl_2, Br_2 and I_2.
D. I^- ions are the weakest reductant out of F^-, Cl^-, Br^- and I^-.

Use data sheet ➔ higher up, stronger reductant and therefore will undergo oxidation.

Note: Content not as crucial for Year 12 but the skill of reviewing course terminology is!

19. A sample of a gas takes up a volume of 400 mL at 300 K and 101 kPa. If the gas has a mass of 0.647 g, which is the most likely identity of the gas?
A. Helium
B. Neon
C. Argon
D. Chlorine

PV = nRT ➔ (101)(0.4) = n(8.314)(300)
n = 0.0161… mol
M = 0.647 / 0.0161… = 39.94… g/mol

20. A solution of sodium hydroxide reacts with 3 mol of chlorine gas under certain conditions. The reaction produces 5 mol of sodium chloride, 1 mol of Compound X and a certain amount of water.

What is the formula of Compound X?

A. $NaClO_4$

B. $NaClO_3$

C. $NaClO_2$

D. NaClO

__NaOH + $3Cl_2$ ➔ 5NaCl + $NaClO_x$ + __H_2O

Coefficient for NaOH must balance 6Na atoms on the products side.

Therefore, 6NaOH + $3Cl_2$ ➔ 5NaCl + $NaClO_x$ + __H_2O

Coefficient for H_2O must balance 6H atoms on the reactants side.

Therefore, 6NaOH + $3Cl_2$ ➔ 5NaCl + $NaClO_x$ + $3H_2O$

X + 3O (from H_2O) must balance 6O atoms on the reactants side.

Section 2 **50 marks**

Attempt Questions 21 – 28
Allow about 1 hour and 25 minutes for this section

Please write all answers clearly in the spaces provided and show ALL working. The number of lines indicates the expected length of your response.

Question 21 (2 marks)

Write the chemical equations for the following reactions.

1 mark per correct chemical equation (balanced, states, formulae) – no half marks

a) the neutralisation of a barium hydroxide solution by dilute hydrochloric acid **1**

$Ba(OH)_2(aq) + 2HCl(aq) \rightarrow BaCl_2(aq) + 2H_2O(l)$

b) copper(II) nitrate reacting with potassium carbonate to form a precipitate **1**

$Cu(NO_3)_2(aq) + K_2CO_3(aq) \rightarrow CuCO_3(s) + 2KNO_3(aq)$

Question 22 (3 marks)

Diamond is an allotrope of carbon. The mass of a diamond can be measured in carats. One carat is 0.200 g of carbon.

Calculate the mass of 1.806×10^{22} carbon <u>atoms</u> in carats. **3**

1 mark calculates mol of carbon

$n(C) = N / N_A = 1.806 \times 10^{22} / 6.022 \times 10^{23} = 0.02999\ldots$ mol

1 mark calculates mass of carbon

$m(C)$ in g $= n \times M = 0.02999\ldots \times 12.01 = 0.3601\ldots$ g

1 mark calculates carats

$m(C)$ in carats $= 0.3601\ldots / 0.200 = 1.80$ carats

Mark deduction for incorrect SIG FIGS

NOTE: Sometimes it is just an easy question. No tricks. No struggle. Just multiply and divide.

Question 23 (6 marks)

The table below shows data on three substances X, Y and Z, each of a different chemical structure.

Test	X	Y	Z
Melting point (°C)	1713	44	963
Electrical conductivity as a solid	Nil	Nil	Nil
Electrical conductivity as an aqueous solution	Nil	Nil	High

a) Identify the chemical structure of substance X and Y by circling the correct response. **2**

Can't be ionic as the next question says Z is and all are different types

Can't be molecular as these have low MP

Can't be metallic as these conduct electricity in solid

X: ionic lattice covalent network covalent molecular metallic structure

Y: ionic lattice covalent network covalent molecular metallic structure

b) A student claimed that Z must be an ionic lattice. Justify this claim using the data and your knowledge of structure and bonding. **4**

1 mark - correct use of terminology in describing chemistry, e.g. "ions", not "electrons" in solution, int**ra**molecular bonding, not int**er**molecular bonding, etc.

1 mark - links high melting point to strong ionic "int**ra**molecular" bonding between the cation and anion

1 mark - links inability to conduct electricity as a solid due to either immobile ions **or** electrons trapped in valance shells **or** no mobile charge carriers

1 mark - links high conductivity as aqueous solution due to mobile ions in solution

NOTE:

- Students that wrote "allowing ions or electrons to move through solution" were given the mark but will not in HSC course. Last warning!
- NO INTRO SENTENCES. Waste of precious lines and time.
- Justify is a verb which means, "This statement is correct! Show that it is correct."
- Students that linked High MP to High thermal energy had better answers. This was not needed here but needed in HSC course.
- Many, oh so many, confused BP with MP in their writings. Try not to mind dump and think about what is given.
- BROWN DOG – To define a brown dog you must provide evidence about the brown dog, not how the dog is not a red cat. "The substance is ionic because it is not metallic."

knowledge of structure and bonding.

Z must be an ionic lattice. From the data, Z doesn't conduct electricity as a solid but does as in aqueous form. This reflects the structure and bonding of an ionic lattice: in solid form, the substance exists as a rigid 3D lattice of alternating anions and cations. The ions are held firmly in place by electrostatic attraction, preventing the movement of charged particles and hence preventing electrical conductivity. Additionally, these strong forces of electrostatic attraction mean to separate the ions, a relatively high amount of thermal energy is needed, hence its relatively high melting point (963°C). Finally, in an aqueous solution the ions dissociate, meaning movement of charged particles exists and the substance can conduct electricity, as reflected by the data. Hence, substance Z's relatively high melting point and electrical conductivity characteristics mean it's an ionic lattice.

4

6

Question 24 (8 marks)

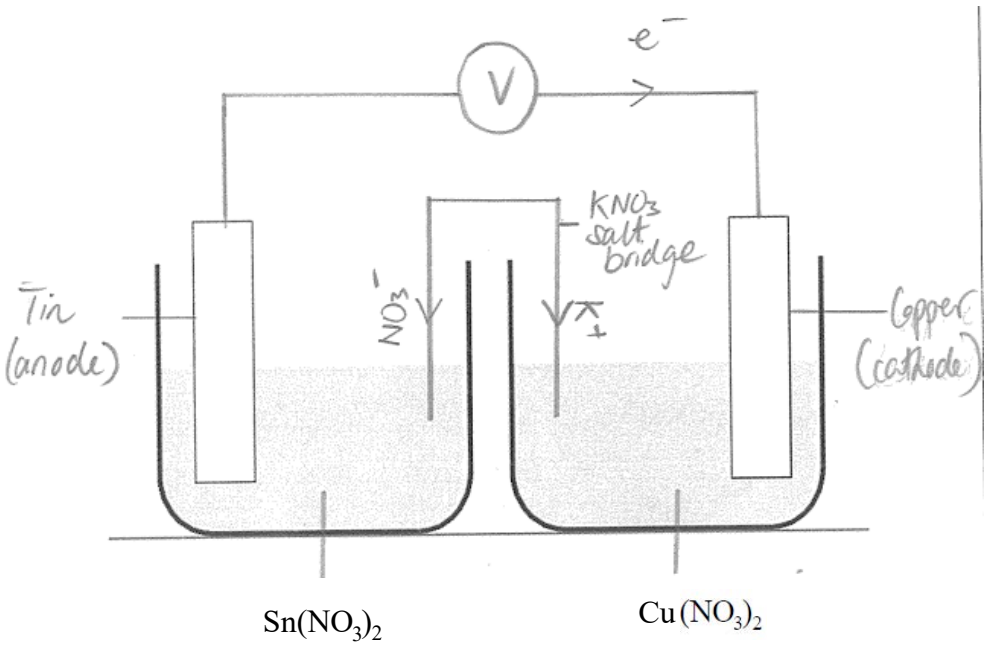
A student set up a galvanic cell with the following components:

- copper half cell using 1 mol L^{-1} copper(II) nitrate and a copper electrode
- tin half cell using 1 mol L^{-1} tin nitrate and a tin electrode
- potassium nitrate salt bridge

a) Complete the diagram below to show the galvanic cell described above. In your diagram, clearly label the following including the specific chemical species mentioned above:

- Anode and cathode – 1 mark
- Salt bridge – 1 mark
- Solutions – 1 mark
- Direction of electron flow – 1 mark
- Direction of ion flow across the salt bridge – 1 mark

No half marks



b) Write the oxidation and reduction half equations.

Oxidation: $Sn(s) \rightarrow Sn^{2+} + 2e^-$

Reduction: $Cu^{2+} + 2e^- \rightarrow Cu(s)$

1 mark per correct half equation (states must be included for solid species)

Mark deducted once for swapped half equations

c) Calculate the theoretical E^o value of the cell.

1 mark calculates E^o value

$E^o = -(-0.14) + (0.34) = 0.48$ V

Mark deducted for incorrect or missing UNITS.
Students often calculated a negative value for voltage which is incorrect, that would make it a non-spontaneous chemical reaction (such as charging a battery).
Common mistakes/feedback:

Part a and b.

- Copper anode and Tin cathode was commonly drawn. Copper has a higher reduction potential, and as such, will be the cathode. REDCAT/ANOX.
- $CuNO_3$ is not the correct ionic formula for "Copper (II) nitrate". Tin unknown oxidation state therefore not deducted if incorrect.
- Direction of ions of the salt bridge are for both the K^+ and NO_3^- ions. These ions exist to balance the charge of the half-cells.
- Direction of electron flow was giving based on consistency for answer with part b. If you said that the electrons from the copper to tin and then showed the oxidation of copper in your answer to b, you would get a mark for this.
- Salt bridge needed to be in the water (otherwise it doesn't work…)
- Solutions should contain both ions of the ionic compound. I.e., you need Cu^{2+} and NO_3^-

Part c.

- Many students used the reduction potential of Cu^+ rather than Cu^{2+}. Read the question and chemical species carefully.
- Many students did not use a formula correctly, to calculate the galvanic cell potential you need to either use:
    - $E°_{cell} = E_{reduction,cathode} - E_{reduction,anode}$
    - $E°_{cell} = E_{oxidation,anode} - E_{oxidation,cathode}$
    - $E°_{cell} = E_{oxidation,anode} + E_{reduction,\ cathode}$ or its inverse

Question 25 (3 marks)

When 0.033 mol of ethanol (C_2H_5OH) is used to heat 100.0 g of water, the temperature of the water increases by 12.0°C. The theoretical enthalpy of combustion of ethanol is -1364 kJ mol^{-1}.

Assuming only complete combustion had occurred, calculate the amount of heat lost to the environment. **3**

1 mark calculates energy absorbed by the water

$q = mc\Delta T = (100.0 \times 10^{-3})(4.18 \times 10^{3})(12.0) = 5016$ J absorbed

1 mark calculates energy released using theoretical

$q = - n \times \Delta H = -(0.033)(-1364) = 45.012$ kJ released

1 mark calculates energy lost

Energy lost = energy released – energy absorbed = $45.012 - 5016 \times 10^{-3} = 40$ kJ

Mark deduction for missing or incorrect UNITS.

NOTES:

- A tiny few people found the energy loss as a percentage, this was accepted.
- MOST marks were lost by people converting 12°C to kelvin. Just for future reference, if the temp increases from 30°C to 42°C the $\Delta T = (42-30) = 12$°C, in kelvin (273+30°C= 303K) to (273+42°C=315K) the $\Delta T=(315 - 303) = 12$K. It's the same change.
- Some of the answers produced energies rivalling the sun! Check the plausibility of your answers before moving on.

Question 26 (5 marks)

Hydrazine, N_2H_4, reacts with dinitrogen tetraoxide, N_2O_4, to form nitrogen gas and water vapour.

$$2N_2H_4(l) + N_2O_4(g) \rightarrow 3N_2(g) + 4H_2O(g)$$

The relevant thermochemical data is shown below.

$N_2H_4(l)$: $\Delta H°_f = 50.6$ kJ mol^{-1}

$N_2O_4(g)$: $\Delta H°_f = 9.16$ kJ mol^{-1}

$H_2O(g)$: $\Delta H°_f = -285.83$ kJ mol^{-1}

$N_2H_4(l)$: $S° = 223.0$ J mol^{-1} K^{-1}

$N_2O_4(g)$: $S° = 304.7$ J mol^{-1} K^{-1}

$N_2(g)$: $S° = 191.6$ J mol^{-1} K^{-1}

$H_2O(g)$: $S° = 188.8$ J mol^{-1} K^{-1}

Determine the Gibbs Free Energy change, and therefore spontaneity, of the reaction at -100°C using the data provided. **5**

1 mark calculates enthalpy of reaction

$\Delta H = [(3 \times 0) + (4 \times -285.83)] - [(2 \times 50.6) + (9.16)] = -1253.68$ kJ mol^{-1}

1 mark calculates entropy of reaction

$\Delta S = [(3 \times 191.6) + (4 \times 188.8)] - [(2 \times 223.0) + (304.7)] = 579.3$ J mol^{-1} K^{-1}

1 mark converts temperature to Kelvin AND enthalpy/entropy to corresponding units (shown separately OR in Gibbs Free calculation)

1 mark substitutes into Gibbs Free Equation

$\Delta G = \Delta H - T\Delta S = (-1253.68) - (-100 + 273.15)(579.3 \times 10^{-3}) = -1.35 \times 10^3$ kJ mol^{-1}

1 mark concludes spontaneity of the reaction using ΔG

$\Delta G < 0$ therefore reaction is spontaneous

Common mistakes/feedback:

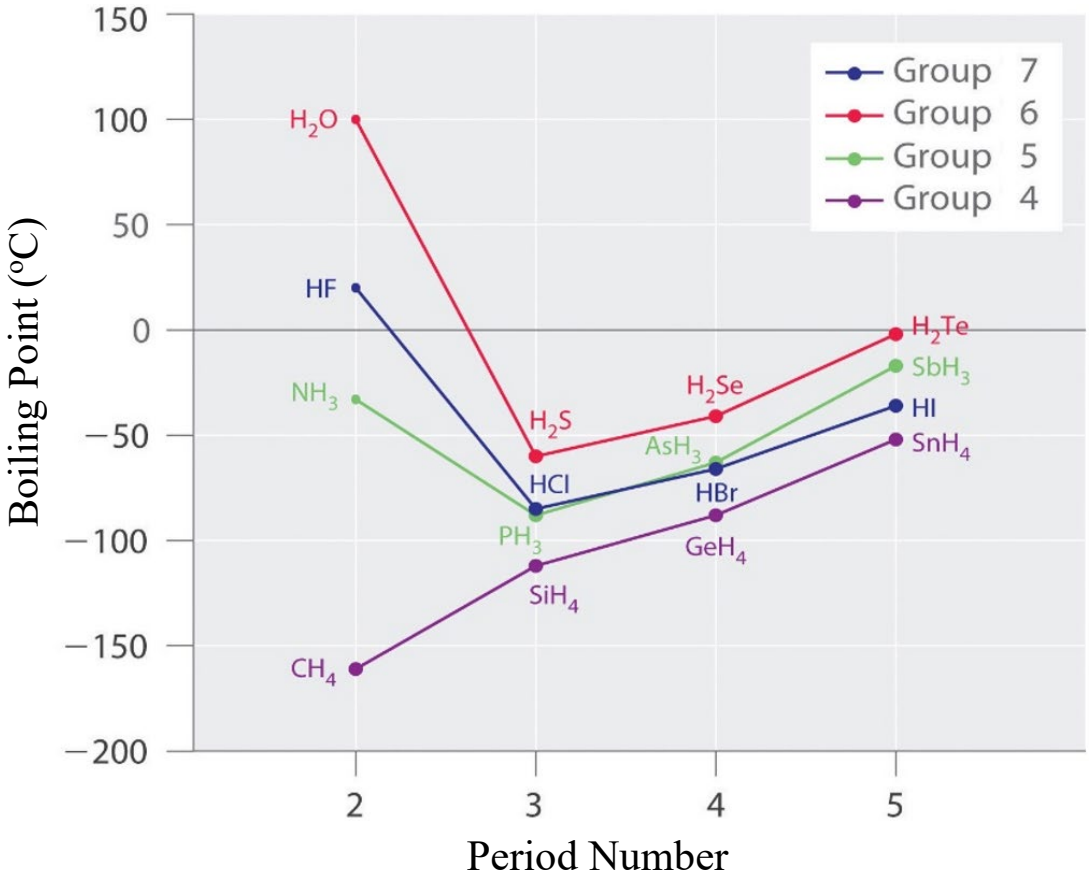
- Not converting enthalpy and entropy to be consistent units. In other words, did not times entropy by 10^{-3}.
- Not identifying whether reaction was spontaneous/non-spontaneous. Answer the question!
- Not identifying that the provided temperature was in ***Celsius (° C)*** but the Gibbs' Free Energy equation ($\Delta G = \Delta H - T\Delta S$) requires temperature in ***Kelvin (K)***.
- Reminder that enthalpy of formation of an element is 0 kJ mol^{-1}.

- Reminder that to find ΔS_{rxn} from standard entropies or ΔH_{rxn} from standard enthalpies of formation, you need to subtract the Σ(products) – Σ(reactants). This means you need to be careful with the order of calculations. You should include brackets around each individual component.

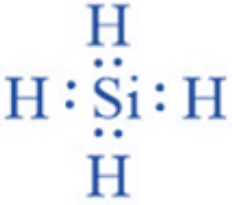
Overall, answered to a high standard with clear working out.

Question 27 (10 marks)

The graph below shows the boiling point for a variety of hydrides.



a) Complete the table below. **3**

	NH_3	SiH_4
Lewis Dot Diagram		
Name of Molecular Shape	Trigonal pyramidal	Tetrahedral

1 mark per correct Lewis Dot Diagram (dots or crosses accepted; not lines)

1 mark correct shapes identified (no half marks)

Question 27 continues on the next page.

b) Explain the trend for the Group 4 hydrides. **2**

1 mark describes the trend e.g.

As period number increases, boiling point increases.

1 mark explains the trend e.g.

This is because the strength of dispersion forces increases as molecular size increases down a group. (Polarisability of electron distribution). Please note students wrote that dispersion forces increase with mass, but generally as size increases so does mass.

c) Explain the differences between the trend in b) to the trend for the Group 6 hydrides. **5**

1 mark identifies the higher trendline for Group 6 hydrides vs Group 4 hydrides e.g.

The trendline for boiling points of the Group 6 hydrides is consistently higher than the trendline in part a.

1 mark explains the above difference in trend wrt IMF present in Group 4 hydrides e.g.

This is because Group 6 hydrides are polar molecules and therefore have dipole-dipole forces that are stronger and require more energy to separate than the…

1 mark explains the above difference in trend wrt IMF present in Group 6 hydrides e.g.

…non-polar Group 4 hydrides that only have the weaker dispersion forces.

1 mark identifies the much higher bp of H_2O in comparison to the other Group 6 hydrides e.g.

The boiling point of H_2O does not follow the trend in part a; it is much higher than the other Group 6 hydrides.

1 mark explains the above wrt to the type of IMF present in H_2O e.g.

This is because there are hydrogen bonds between the molecules – the strongest intermolecular force of them all.

Examiners Comment: Many students said that water has both dipole -dipole attraction and Hydrogen bonding, please be aware that Hydrogen Bonding is a particularly strong example of dipole -dipole attraction.

Students need to take care when discussing “breaking of bonds” as there is an implication of breaking intramolecular bonds rather than intermolecular forces. Some students spoke of “breaking oxygen – hydrogen bonds”.

Question 28 (13 marks)

A 3.70 g piece of magnesium carbonate is added to 25.0 mL of 2.00 mol L^{-1} hydrochloric acid, producing magnesium chloride, carbon dioxide and water. This is shown in the equation below.

$$MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + CO_2(g) + H_2O(l)$$

a) Calculate the volume of gas produced at standard laboratory conditions. **5**

1 mark (m) calculates moles of magnesium carbonate (**must show working for M**)

$n(MgCO_3) = m / M = 3.7 / (\mathbf{24.31 + 12.01 + 3 \times 16.00}) = 0.04388\ldots$ mol

1 mark (h) calculates moles of hydrochloric acid

$n(HCl) = c \times v = \underline{2.00} \times 25.0 \times \underline{10^{-3}} = 0.05$ mol

1 mark (l) determines limiting reagent with **clear** and **logical** working - accepted any of the following:

- Calculating AND **comparing** $n(CO_2)$ produced from available $n(MgCO_3)$ VS $n(CO_2)$ produced from available n(HCl)
- Calculating AND **comparing** $n(MgCO_3)$ required to fully react available n(HCl) to the $n(MgCO_3)$ available
- Calculating AND **comparing** n(HCl) required to fully react available $n(MgCO_3)$ to the n(HCl) available
- Calculating AND **comparing** available $n(MgCO_3)/2$ to available n(HCl) – NOT just $n(MgCO_3) > n(HCl)$ as this is an incorrect justification

  If we consume all n(HCl) available, we need

  $n(MgCO_3) = n(HCl) \times ½ = 0.05 \times ½ = \mathbf{0.025\ mol < 0.04388\ldots\ mol}$

  Therefore, $MgCO_3$ is in excess and HCl is limiting reagent.

1 mark (n) calculates moles of carbon dioxide formed

$n(CO_2) = n(HCl) \times ½ = 0.05 \times ½ = 0.025$ mol

1 mark (v) calculates volume of carbon dioxide using PV=nRT or molar volume at **SLC**

$v(CO_2) = n(CO_2) \times 24.79 = 0.025 \times 24.79 = 0.6197..$ L = 0.620 L

Mark deduction for missing or incorrect SIG FIGS and UNITS

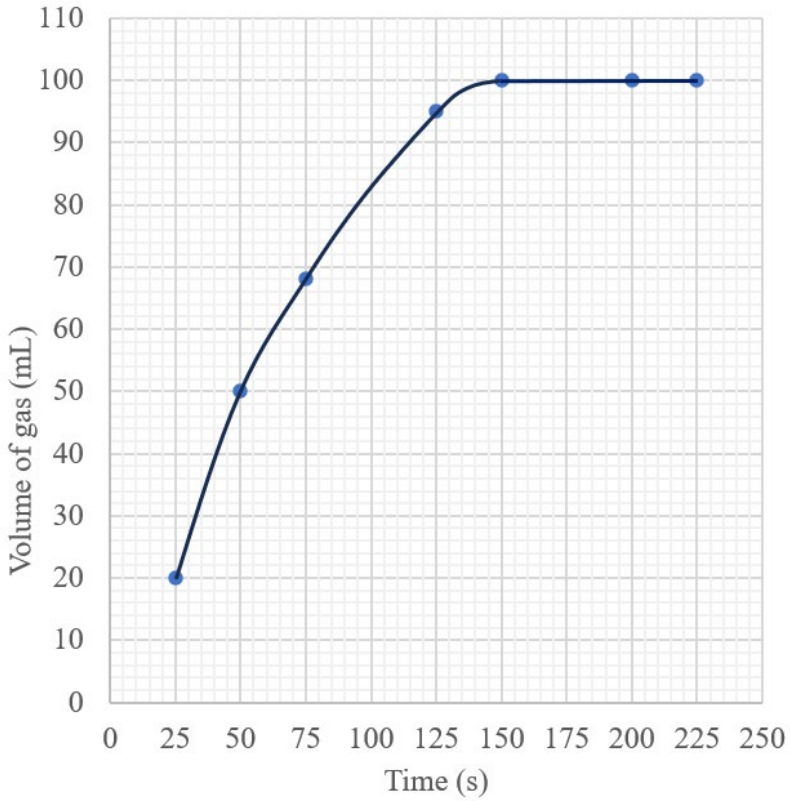
General comments:

- Overall improvement in the clarity and logical progression of working out! ☺
- Common mistakes/areas to work on:
  - Molar volume at STP used
  - Working out for determining limiting reagent
- In future, you may be penalised for:
  - Not showing ALL substitutions – although, much better this time
  - Rounding too early

b) Another mass of magnesium carbonate was reacted with hydrochloric acid. The volume of gas produced over time is shown in the table below. **4**

Time (s)	Volume of Gas Produced (mL)
25	20
50	50
75	68
125	95
150	100
200	100
225	100

Construct a graph for the data above.



1 mark axes labelled – just transcribe this from the table! **mL** NOT ml

1 mark appropriate scale – must label origin

1 mark plots – take your time plotting; better to stick with crosses (asterisks and dots often result in inaccurate data points)

1 mark curve of best fit – smooth curve that matches data points; most deductions occurred here…

Question 28 continues on the next page.

c) Using your understanding of collision theory, explain the trend in the graph. **4**

1 mark (T) describes trend in the graph i.e. increasing at a decreasing rate, reaching a plateau

NOT exponential increase

Allowed for mistake carried based on LOB in part b

2 marks explains the decreasing rate using collision theory e.g.

- (L) Amount/number/concentration of reactant particles decrease as they form products. This results in… Note: careful, during this section, reactant particles have NOT been used up yet.
- (F) … decreased **frequency** (or chance) of successful collisions, decreasing the rate of production of gas i.e. rate of reaction. Note: this mark could have been achieved if the response linked lots of reactant initially ➔ high frequency of collisions

1 mark (P) explains the plateau e.g. (one or both of the) **reactants** have been consumed so reaction has reached completion. Note: insufficient to only state 'because there are no more collisions' or 'particles used up' – product particles will still collide but these collisions are not reaction producing collisions.

General comments:

- When asked to explain the trend, describe the trend you see in the graph first.
- Stating collision theory in general terms does not gain any marks.
- Notation used in feedback – CF = collision frequency, CT = collision theory
- Incorrect chemistry resulted in mark deductions e.g.
  - *Reactants are used up so there is no kinetic energy*
  - *As concentration of reactants increases, proportion of successful collisions increases (only temperature and catalyst can do this!)*
  - *HCl acts as a catalyst*

Exemplar response:

The trend shows that as time increases, the volume of gas produced increases at a decreasing rate, eventually plateauing at 100mL. The rate at which gas ~~is~~ is produced decreases with time ~~as~~ since as the reaction progresses, more reactant particles are consumed in the reaction, and hence the concentration of the ~~magnesium carbonate and~~ hydrochloric acid decreases, and available $MgCO_3$ particles decreases. Since there are fewer reactant particles per unit area, the frequency of collisions decreases, and hence the frequency of successful collisions (which produce the gas) also does. Hence the rate of production of the gas decreases with time. Additionally, the graph plateaus at 100mLs after around 150 seconds. This occurs because ~~the~~ all particles of one of the reactants have been consumed, and the reaction terminates (and hence the production of gas does as well).

END OF TEST

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