Part A
Blacken the letter of your answer on the answer sheet provided.
Each question is worth three (3) marks.

1 Which of the following statements would be considered to be part of the **Kinetic Molecular Theory of Gases**?

1. Gases consist of extremely small particles.
2. The distances between gas molecules are very large compared to the size of the molecules themselves.
3. All gas molecules move at the same speed, depending on the temperature.
4. Gas molecules are in constant motion; they move in straight lines in all directions.
5. Gas molecules collide among themselves and with the walls of their container.

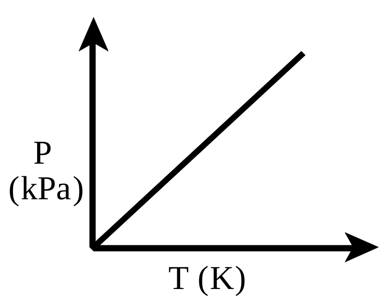
A) 1, 2 and 3

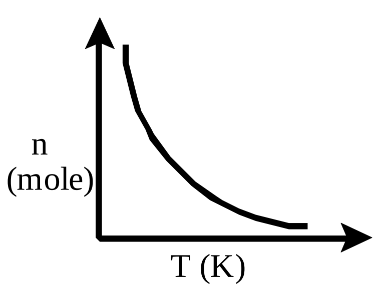
B) 2, 4 and 5

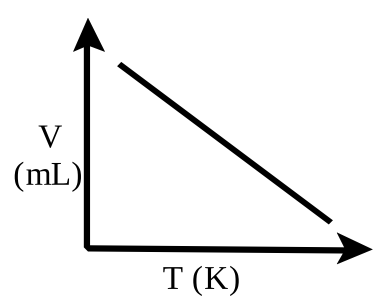
C) 1, 2, 4 and 5

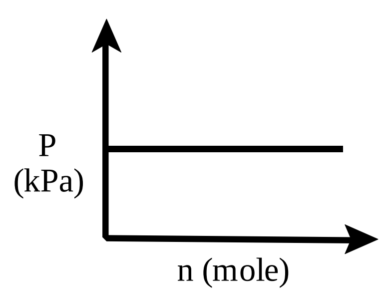
D) 1, 2, 3, 4 and 5

2 Examine the graphs below. Which one of the graphs illustrates a gas law?
(**note**: For each graph, all other factors are constant.)

A)


B)


C)


D)


3 A chemistry student decides to regularly monitor the pressure in the tires of her car. She knows that poor tire pressure will rapidly wear out the tires.

During the summer, the average temperature was 26.0°C and the tire pressure was 1.020×10^3 kPa. What will her tire pressure be during the winter if the average temperature is -20.0°C?

A) 7.85×10^2 kPa

B) 8.63×10^2 kPa

C) 1.04×10^3 kPa

D) 1.33×10^3 kPa

4 The average velocity of four gases was measured at the same temperature and pressure.

The four gases are: **He, Ne, CH_4, and CO_2.**

In which of the following are the gases arranged in **increasing order** of their average velocity?

A) He, Ne, CH_4, CO_2

B) CO_2, Ne, CH_4, He

C) CO_2, CH_4, Ne , He

D) Ne, He, CH_4, CO_2

5 A balloon is filled with an ideal gas and the initial pressure is recorded. Then, the absolute temperature is tripled, the volume is tripled, and the number of molecules is also tripled.

Which of the following best describes the final pressure of the gas?

A) The final pressure is 3 times higher.

B) The final pressure is 9 times higher.

C) The final pressure is 9 times lower.

D) The final pressure is 27 times higher.

6 Which of the following best describes an **exothermic** reaction?

A) The ΔH is positive.

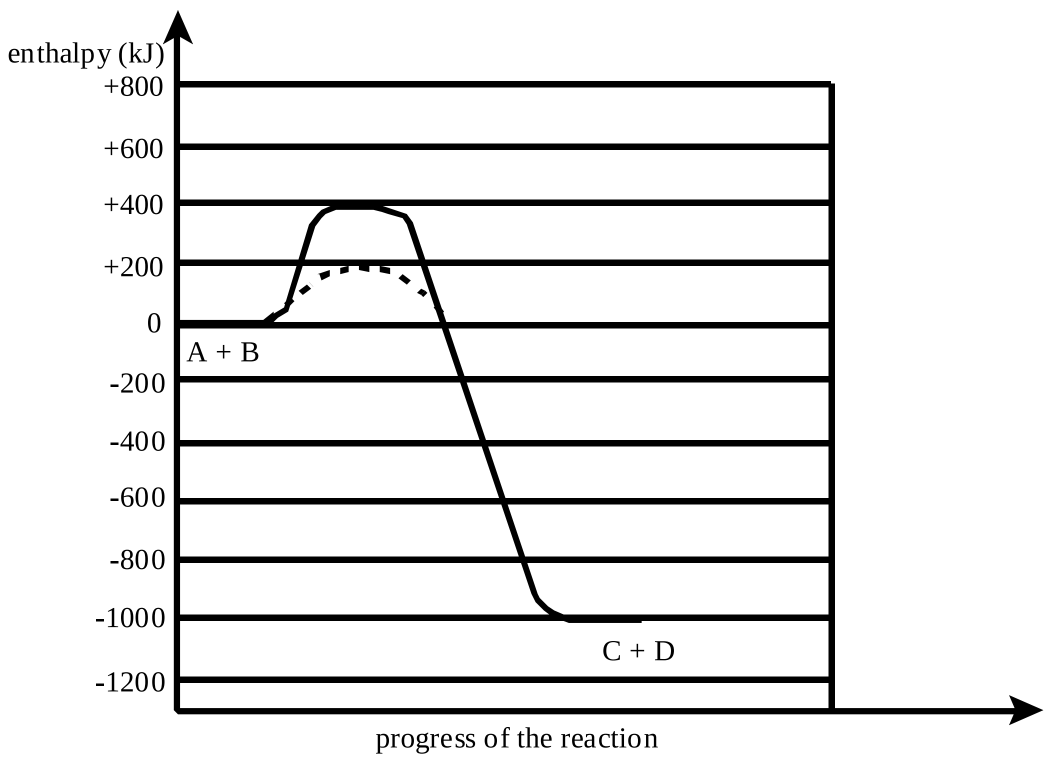
B) The ΔH is negative.

C) The system absorbs heat energy from the surroundings.

D) The enthalpy of the products is greater than the enthalpy of the reactants.

7 The graph below shows the potential energy changes for both the catalyzed and uncatalyzed chemical reactions represented by the following equation:

$$A + B \rightarrow C + D$$



What is the activation energy of the reverse uncatalyzed reaction?

A) 200 kJ

B) 400 kJ

C) 1 200 kJ

D) 1 400 kJ

8 Examine the following heats of formation.

$$2\ Al_{(s)} + 3/2\ O_{2(g)} \rightarrow Al_2O_{3(s)} \qquad \Delta H = -\ 1675\ kJ/mol$$

$$2\ Fe_{(s)} + 3/2\ O_{2(g)} \rightarrow Fe_2O_{3(s)} \qquad \Delta H = -\ 838\ kJ/mol$$

Use these heats of formation to calculate the unknown ΔH for the reaction given below.

$$Fe_2O_3(s) + 2\ Al_{(s)} \rightarrow Al_2O_{3(s)} + 2\ Fe_{(s)} \quad \Delta H = ?$$

A) -837 kJ/mol

B) +837 kJ/mol

C) -2514 kJ/mol

D) +2514 kJ/mol

9 A 4.00×10^2 g piece of iron at 22.0°C is heated in a bomb calorimeter until the temperature is 250.0°C.

If the iron absorbs 41.04 kJ of heat, what is the specific heat capacity of the iron?

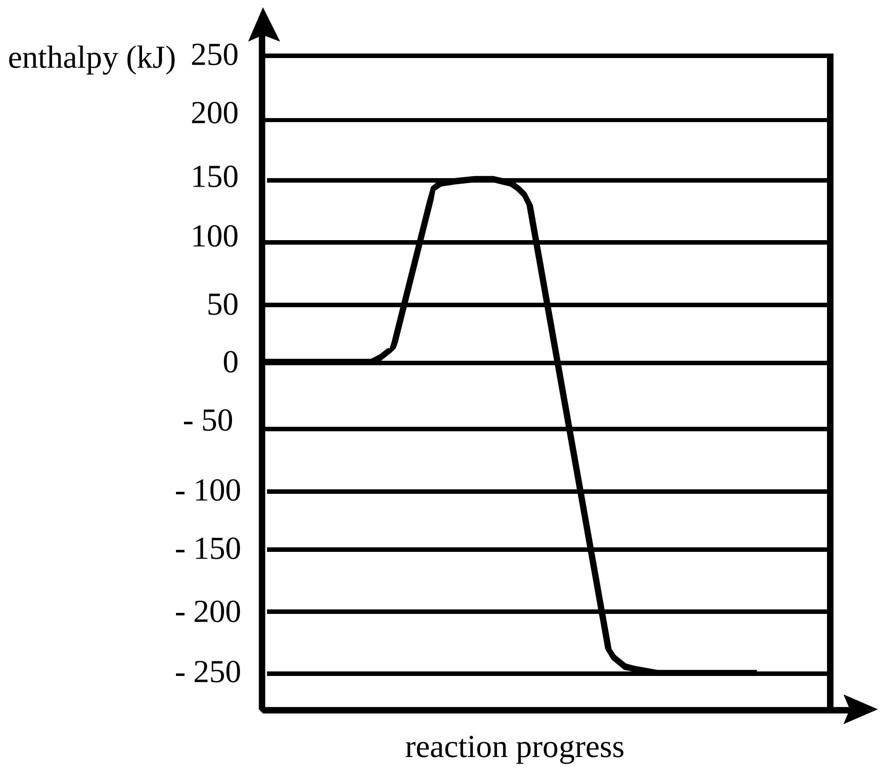
A) 4.5×10^{-4} J/(g•°C)

B) 4.5×10^{-1} J/(g•°C)

C) 4.5 J/(g•°C)

D) 4.5×10^{1} J/(g•°C)

10 Which of the statements about the following enthalpy diagram is **FALSE**?



A) The ΔH of this reaction is -250 kJ.

B) The product of this reaction is stable.

C) The ΔH of this reaction is +250 kJ

D) The enthalpy of the products is -250 kJ

11 When 4.0 g of potassium hydroxide, KOH, is dissolved in 200.0 mL of water in a calorimeter, the temperature increases from 25.0°C to 31.5°C. Calculate the molar heat of solution of the potassium hydroxide.

A) +5.4 kJ/mol

B) -5.4 kJ/mol

C) +76 kJ/mol

D) -76 kJ/mol

12 The reaction between zinc and a 0.50 mol/L solution of hydrochloric acid produces a solution of zinc chloride and releases hydrogen gas as shown in the chemical equation below.

$$Zn_{(s)} + 2\,HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$$

Which of the following **will not** affect the rate of the reaction?

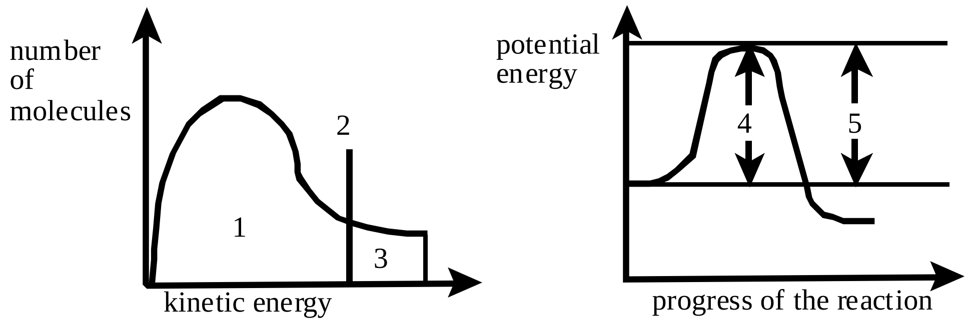
A) The surface area of the metal

B) The volume of the HCl solution

C) The concentration of the HCl solution

D) The temperature of the HCl solution

13 The graphs below represent the same chemical reaction.



According to these graphs, which of the following statements is FALSE ?

A) Number 4 represents the activation energy.

B) Area 3 represents the molecules which will likely form an activated complex.

C) Number 5 represents the ΔH of the forward reaction.

D) Number 2 on the first graph, corresponds to number 4 on the second graph.

14 Which of the following properties are characteristic of a system at equilibrium?

1. The system is closed.
2. The reactants are completely transformed into products.
3. The temperature is constant.
4. The reaction is reversible.
5. It is always a gaseous system.

A) 1, 3, and 4

B) 1, 3, and 5

C) 1, 4, and 5

D) 2, 3, and 4

15 Which chemical reaction corresponds to the equilibrium expression below?

$$K_{(eq)} = \frac{[CO_{2(g)}]^3\,[H_2O_{(g)}]^4}{[C_3H_{8(g)}]\,[O_{2(g)}]^5}$$

A) $3\ CO_{2(g)} + 4\ H_2O_{(g)} \leftrightarrow C_3H_{8(g)} + 5\ O_{2(g)}$

B) $C_3H_{8(g)} + O_{2(g)} \leftrightarrow 3\ CO_{2(g)} + 4\ H_2O_{(g)}$

C) $3\ CO_{2(g)} + H_2O_{(g)} \leftrightarrow C_3H_{8(g)} + 5\ O_{2(g)}$

D) $C_3H_{8(g)} + 5\ O_{2(g)} \leftrightarrow 3\ CO_{2(g)} + 4\ H_2O_{(g)}$

16 In which of the following equilibrium systems would an increase in pressure favour the formation of products?

1. $CH_3OH_{(g)} \leftrightarrow CO_{(g)} + 2\ H_{2(g)}$
2. $2\ H_2O_{(l)} + 2\ Cl_{2(g)} \leftrightarrow 4\ HCl_{(g)} + O_{2(g)}$
3. $N_{2(g)} + 2\ O_{2(g)} \leftrightarrow 2\ NO_{2(g)}$
4. $H_{2(g)} + ½\ O_{2(g)} \leftrightarrow H_2O_{(g)}$

A) 1 and 2 C) 2 and 3

B) 1 and 4 D) 3 and 4

17 Which of the following are **TRUE** characteristics of a strong acidic solution?

1. The Ka value is very large.
2. It does not conduct electricity.
3. $[H^+] > [OH^-]$.
4. pH > 7.
5. The K_a value is very small.

A) 1 and 3 C) 2 and 5

B) 1 and 4 D) 3, 4 and 5

18 An unknown acid, $HZ_{(aq)}$, has an equilibrium concentration of 1.0×10^{-2} mol/L.

The concentration of H^+ ions in the solution is 1.0×10^{-3} mol/L.

If the dissociation is as shown below, what is the $\mathbf{K_a}$ value of this acid?

$$HZ_{(aq)} \leftrightarrow H^+_{(aq)} + Z^-_{(aq)}$$

A) 1.0×10^{-7}

B 1.0×10^{-6}

C) 1.0×10^{-5}

D) 1.0×10^{-4}

19 Which of the following statements about an electrochemical cell is **TRUE**?

A) The oxidizing agent undergoes oxidation.

B) The reducing agent undergoes reduction.

C) The oxidizing agent undergoes reduction.

D) The reducing agent gains electrons.

20 During an experiment, a student makes the following observations:

$$X^{2+}_{(aq)} + Z_{(s)} \rightarrow Z^{2+}_{(aq)} + X_{(s)}$$

$$Z^{2+}_{(aq)} + Y_{(s)} \rightarrow \text{no reaction}$$

$$Y^{2+}_{(aq)} + X_{(s)} \rightarrow X^{2+}_{(aq)} + Y_{(s)}$$

Arrange the solids in order of their **decreasing** tendency to undergo oxidation.

A) X, Y, Z

B) Y, X, Z

C) Z, X, Y

D) Z, Y, X

Part B
This part of the examination consists of questions 21, 22, 23 and 24.
Choose any three (3) of these questions and answer them in the answer booklet provided.
Each question is worth five (5) marks.

21 A chemist was given a sample of a pure unknown gas. In order to identify the gas, the chemist proceeded as follows:

The mass of an empty syringe with a volume of 1.40×10^2 mL was determined.

The syringe was then filled with the unknown gas and a second reading for the mass was taken.

The following data was obtained:

Temperature	25.0°C
Pressure	101.3 kPa
Mass of empty syringe	76.52 g
Mass of syringe and gas	76.70 g

Using this information, which of the following gases is the unknown?

He, Ne, CO_2, O_2, N_2, H_2, CH_4

22 Hummingbirds have an extremely rapid metabolic rate. In order to maintain it, they must consume approximately one third their body mass in sugar every day.

Energy is produced when sugar is broken down during cellular respiration.

Cellular respiration occurs according to the following equation:

$$C_6H_{12}O_{6(aq)} + 6\ O_{2(g)} \rightarrow 6\ CO_{2(g)} + 6\ H_2O_{(l)} + \text{energy}$$

If a hummingbird burns 1.00 gram of sugar, $C_6H_{12}O_6$, during cellular respiration, what is the volume of $CO_{2(g)}$ produced at 37.0°C and 101.3 kPa?

23 A 34.0 mL cylinder is filled with oxygen. The valve placed on the cylinder is defective and, as a result, the oxygen slowly escapes.

On Monday morning, the lab technician registered a pressure of 4.52×10^2 kPa and a temperature of 23.0°C.

After four days the pressure decreased to 4.02×10^2 kPa and the temperature was 18.0°C.

What mass of oxygen gas escaped from the cylinder during the four day period?

24 Use your knowledge of the gas laws to complete the following chart.

	V_1	**T_1**	**P_1**	**V_2**	**T_2**	**P_2**
Reaction **A**	152 mL	27.0°C	100.6 kPa	?	0.0°C	101.3 kPa
Reaction **B**	1.26 mL	20.0°C	99.7 kPa	1.33 mL	?	101.3 kPa
Reaction **C**	210 mL	22.0°C	101.8 kPa	228 mL	273 K	?

Part C
This part of the examination consists of questions 25, 26 and 27.
Choose any two (2) of these questions and answer them in the answer booklet provided.
Each question is worth five (5) marks.

25 The *Café Entropy* makes cappuccino.
Cappuccino is a mixture of coffee and milk.

The *Café Entropy* has determined that the best temperature for cappuccino is 55.5°C.

The initial temperature of hot coffee without milk is 80.5°C.

What volume of milk, at 2.0°C, must be added to 160.0 mL of hot coffee in order to obtain the desired temperature of 55.5°C?

(**note:** Assume coffee and milk have the same density and specific heat capacity as water.)

26 In order to determine how much heat is released during the combustion of candle wax, $C_{25}H_{52}$, a burning candle is used to heat some water in a metal can that serves as a calorimeter.

The following data is obtained:

Volume of water heated	355.0 mL
Initial mass of candle	136.0 g
Final mass of candle	112.0 g
Initial temperature of the water	15.4°C
Final temperature of the water	23.0°C

Calculate the molar heat of combustion of the candle wax.

27 When phosphorus is burned in an excess of oxygen, tetraphosphorus decoxide, P_4O_{10}, is formed as shown:

$$4\,P_{(s)} + 5\,O_{2(g)} \rightarrow P_4O_{10(s)} \qquad \Delta H_f = ?$$

Use the equations below to calculate the)*H* of formation of tetra phosphorus decoxide.

$$2\,PCl_{3(l)} + O_{2(g)} \rightarrow 2\,POCl_{3(l)} \qquad \Delta H = -587\text{ kJ}$$

$$P_4O_{10(s)} + 6\,PCl_{5(s)} \rightarrow 10\,POCl_{3(l)} \qquad \Delta H = -419\text{ kJ}$$

$$2\,P_{(s)} + 3\,Cl_{2(g)} \rightarrow 2\,PCl_{3(l)} \qquad \Delta H = -686\text{ kJ}$$

$$2\,P_{(s)} + 5\,Cl_{2(g)} \rightarrow 2\,PCl_{5(s)} \qquad \Delta H = -892\text{ kJ}$$

Part D
This part of the examination consists of questions 28 and 29.
Choose only one (1) of these questions and answer it in the answer booklet provided.
Each question is worth five (5) marks.

28 The combustion of methane gas, CH_4, is shown in the following equation:

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

A 4.00 g sample of methane gas was burned in oxygen. After 1 minute and 36 seconds, 0.75 g of methane remained. Calculate the average rate of combustion of methane gas in mol/s.

29 The decomposition of nitrogen dioxide gas, NO_2, is shown in the following equation:

$$2\ NO_{2(g)} \rightarrow 2\ NO_{(g)} + O_{2(g)}$$

The data table below indicates the concentration of oxygen gas as the reaction proceeds.

Time (minutes)	**Concentration of O_2 (mol/L)**
0	0
1	0.0160
2	0.0240
3	0.0288
4	0.0320

a) Calculate the average rate of formation of oxygen gas (O_2) between 1 and 4 minutes in $\frac{\text{mol/L}}{\text{s}}$.

b) Calculate the average rate of decomposition of nitrogen dioxide (NO_2) between 1 and 4 minutes in $\frac{\text{mol/L}}{\text{s}}$.

Part E
This part of the examination consists of questions 30, 31 and 32.
Choose only two (2) of these questions and answer them in the answer booklet provided.
Each question is worth five (5) marks.

30 Apply Le Chatelier's Principle to the following equilibrium system.

$$N_{2(g)} + 3\,H_{2(g)} \leftrightarrow 2\,NH_{3(g)} + 80\ \text{kJ/mol}$$

What effect will each of the following changes have on the concentration of ammonia, $NH_{3(g)}$?

State **one reason** that justifies each answer.

a) increasing the total pressure
b) increasing the temperature
c) increasing the volume of the container
d) adding an appropriate catalyst
e) increasing the concentration of $N_{2(g)}$

31 In order to examine an equilibrium system, a chemist places 1.0 mole of hydrogen chloride, $HCl_{(g)}$, and 1.0 mole of oxygen gas , $O_{2(g)}$, into a 1.0 L container at a constant temperature.

The container is sealed and a reaction occurs.

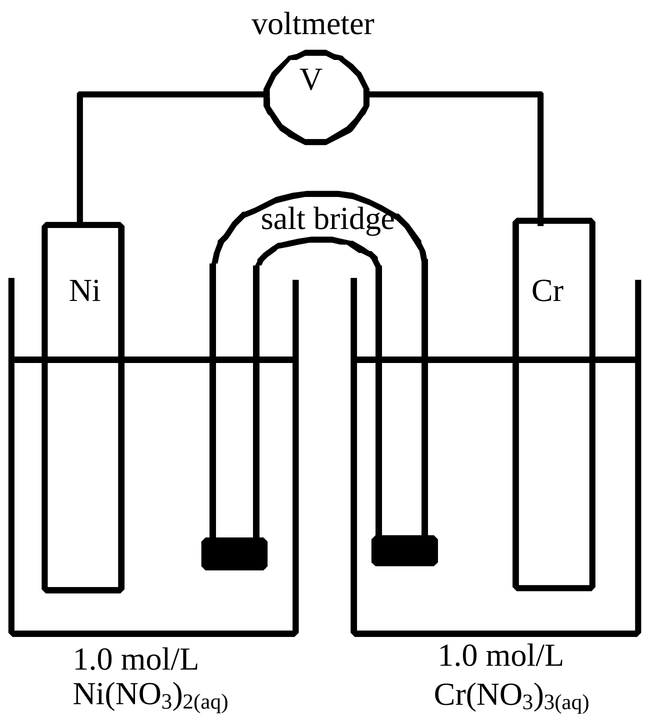
The equilibrium reaction is:

$$4\,HCl_{(g)} + O_{2(g)} \leftrightarrow 2\,H_2O_{(g)} + 2\,Cl_{2(g)} + 113\ \text{kJ}$$

Once equilibrium is established, analysis shows that there are 0.20 moles of water vapour, $H_2O_{(g)}$, present.

Calculate the value of the equilibrium constant, $K_{(eq)}$, at this temperature.

32 Consider the following diagram of a spontaneous electrochemical cell.



$Cr_{(s)} \rightarrow Cr^{3+}_{(aq)} + 3\ e^-$ $E° = +0.74$ v

$Ni_{(s)} \rightarrow Ni^{2+}_{(aq)} + 2\ e^-$ $E° = +0.25$ v

a) Which metal is the cathode?

b) Electrons flow through the wire between the $Ni_{(s)}$ electrode and the $Cr_{(s)}$ electrode. Which of these electrodes is losing electrons?

c) At which electrode, the $Cr_{(s)}$ or the $Ni_{(s)}$, does oxidation take place?

d) Which ions migrate towards the $Cr_{(s)}$ electrode?

e) What is the value of the net cell potential?

CORRECTION KEY

Part A

3 marks or 0 marks

1 C

2 A

3 B

4 B

5 A

6 B

7 D

8 A

9 B

10 C

11 D

12 B

13 C

14 A

15 D

16 D

17 A

18 D

19 C

20 C

Part B

21 Volume of unknown gas = 1.40×10^2 mL = 0.140 L

Moles of unknown gas = $\dfrac{(101.3\,\text{kPa})\,(0.140\,\text{L})}{(8.31\,\text{kPa}\bullet\text{L /mol}\bullet\text{K})\,(298\,\text{K})}$ = 5.73×10^{-3} mol

Mass of unknown gas = 76.70 g - 76.52 g = 0.18 g

Molar mass of unknown gas = $\dfrac{0.18\,\text{g}}{5.73 \times 10^{-3}\ \text{mol}}$ = 31 g/mol

Compare molar masses :

Ne = 4.00 g/mol

Ne = 20.18 g/mol

CO_2 = 44.01 g/mol

O_2 = 32.00 g/mol ← **closest to calculated result**

N_2 = 28.02 g/mol

H_2 = 2.02 g/mol

CH_4 = 16.05 g/mol

Answer : **The unknown gas is : oxygen (O_2).**

22 $C_6H_{12}O_{6(aq)} + 6\ O_{2(g)} \rightarrow 6\ CO_{2(g)} + 6\ H_2O_{(l)} + \text{energy}$

mole ratio of $C_6H_{12}O_6 : CO_2$ is 1 : 6

moles of $C_6H_{12}O_6 = \dfrac{1.00\text{ g}}{180.18\text{ g/mol}} = 5.55 \times 10^{-3}$ mol

so, moles of $CO_2 = (5.55 \times 10^{-3}\text{ mol})\ (6) = 3.33 \times 10^{-2}$ mol

volume of $CO_2 = nRT/P$

$$\text{vol } CO_2 = \frac{(3.33 \times 10^{-2}\text{ mol})\,(8.31\text{ kPa}\bullet\text{L/mol}\bullet\text{K})\,(310\text{ K})}{101.3\text{ kPa}}$$

$= 0.847$ L of CO_2

Answer : The volume of CO_2 produced is : 0.847 L.

23 Initial moles of O_2 in cylinder :

$$\frac{(4.52 \times 10^{2}\ \text{kPa})\,(0.0340\,\text{L})}{(8.31\,\text{kPa}\bullet\text{L/mol}\bullet\text{K})\,(296\,\text{K})} = 6.25 \times 10^{-3}\ \text{mol}$$

Final moles of O_2 in cylinder :

$$\frac{(4.02 \times 10^{2}\ \text{kPa})\,(0.0340\,\text{L})}{(8.31\,\text{kPa}\bullet\text{L/mol}\bullet\text{K})\,(291\,\text{K})} = 5.62 \times 10^{-3}\ \text{mol}$$

Moles of O_2 that escaped :

$$6.25 \times 10^{-3}\ \text{mol} - 5.62 \times 10^{-3}\ \text{mol} = 0.63 \times 10^{-3}\ \text{mol}$$

Mass of O_2 that escaped :

$$(0.63 \times 10^{-3}\ \text{mol})\ (32.00\text{g/mol}) = 2.0 \times 10^{-2}\ \text{g}$$

Answer : **The mass of oxygen gas that escaped is : 2.0 $\times 10^{-2}$ g.**

24 Reaction A : $$\frac{(100.6\,\text{kPa})\,(152\,\text{mL})}{300\,\text{K}} = \frac{(101.3\,\text{kPa})\,(V_2)}{273\,\text{K}}$$

$$\frac{(100.6\,\text{kPa})\,(152\,\text{mL})\,(273\,\text{K})}{(300\,\text{K})\,(101.3\,\text{kPa})} = V_2$$

$$137\text{ mL} = V_2$$

Answer : **Reaction A : V_2 = 137 mL**

Reaction B : $$\frac{(99.7\,\text{kPa})\,(1.26\,\text{mL})}{293\,\text{K}} = \frac{(101.3\,\text{kPa})\,(1.33\,\text{mL})}{T_2}$$

$$\frac{(101.3\,\text{kPa})\,(1.33\,\text{mL})\,(293\,\text{K})}{(99.7\,\text{kPa})\,(1.26\,\text{mL})} = T_2$$

$$314\text{ K (or }41°\text{C)} = T_2$$

Answer : **Reaction B : T_2 = 314 K (41°C)**

Reaction C : $$\frac{(100.8\,\text{kPa})\,(210\,\text{mL})}{295\,\text{K}} = \frac{P_2\,(228\,\text{mL})}{273\,\text{K}}$$

$$\frac{(101.8\,\text{kPa})\,(210\,\text{mL})\,(273\,\text{K})}{(295\,\text{K})\,(228\,\text{mL})} = P_2$$

$$87\text{ kPa} = P_2$$

Answer : **Reaction C : P_2 = 87 kPa**

Part C

25

Heat lost by coffee = Heat gained by milk

$$-\Delta Q_{coffee} = +\Delta Q_{milk}$$

$$-(m)(c)(\Delta T) = +(m)(c)(\Delta T)$$

$$-(160.0\ g)(4.19\ J/g\bullet°C)(55.5°C - 80.5°C) = +(m)(4.19\ J/g\bullet°C)(55.5°C - 2.0°C)$$

The specific heat capacity (4.19 J/g•°C) cancels out :

$$-(160.0\ g)(55.5°C - 80.5°C) = +(m)(55.5°C - 2.0°C)$$

$$m = 75.0\ g$$

The density can be considered to be 1.00 g/mL.

Therefore, the volume of milk is 75.0 mL

Answer : **The volume of milk is : 75.0 mL.**

26 Heat gained by water = Heat lost by candle wax

$+\Delta Q_{water} = -\Delta Q_{wax}$

Heat gained by H_2O :

$+\Delta Q_{water}$ = (m) (c) (ΔT)

= (355.0 g) (4.19 J/g•°C) (23.0°C - 15.4°C)

= 11.3 kJ

Therefore, heat lost by wax :

$-\Delta Q_{wax}$ = -11.3 kJ

mass of wax burned = 136.0 g - 112.0 g = 24.0 g

moles of wax burned = mass of wax/molar mass of wax ($C_{25}H_{52}$)
= 24.0 g/352.0 g/mole
= 0.0682 mole $C_{25}H_{52}$

The molar heat of combustion = -11.3 kJ/0.0682 mole
= -166 kJ/mole

Answer : The molar heat of combustion is : -166 kJ/mole.

27 Method :

(mult x 5)	$2\ PCl_{3(l)} + O_{2(g)} \rightarrow 2\ POCl_{3(l)}$	ΔH = -587 kJ
(reverse)	$P_4O_{10(s)} + 6\ PCl_{5(s)} \rightarrow 10\ POCl_{3(l)}$	ΔH = -419 kJ
(mult x 5)	$2\ P_{(s)} + 3\ Cl_{2(g)} \rightarrow 2\ PCl_{3(l)}$	ΔH = -686 kJ
(reverse, mult x 3)	$2\ P_{(s)} + 5\ Cl_{2(g)} \rightarrow 2\ PCl_{5(s)}$	ΔH = -892 kJ

$\cancel{10\ PCl_{3(l)}} + \mathbf{5\ O_{2(g)}} \rightarrow \cancel{10\ POCl_{3(l)}}$ ΔH = -2935 kJ

$\cancel{10\ POCl_{3(l)}} \rightarrow \mathbf{P_4O_{10(s)}} + \cancel{6\ PCl_{5(s)}}$ ΔH = +419 kJ

4

$\cancel{\mathbf{10}}\ \mathbf{P_{(s)}} + \cancel{15\ Cl_{2(g)}} \rightarrow \cancel{10\ PCl_{3(l)}}$ ΔH = -3430 kJ

$\cancel{6\ PCl_{5(s)}} \rightarrow \cancel{6\ P_{(s)}} \rightarrow + \cancel{15\ Cl_{2(g)}}$ ΔH = +2676 kJ

$\mathbf{4\ P_{(s)} + 5\ O_{2(g)} \rightarrow P_4O_{10(s)}}$ ΔH_f = -3270 kJ

Answer : The ΔH_f is : -3270 kJ

Part D

28 Mass of methane burned = 4.00 g - 0.75 g = 3.25 g

Moles of methane burned = mass of methane/molar mass of methane
= 3.25 g/16.05 g/mole
= 0.203 mole

Average rate = moles of methane burned/time

= 0.203 mole/96 seconds

= 2.1×10^{-3} mol/s

Answer : The average rate of combustion is : 2.1×10^{-3} mol/s.

29 a) Average rate =)$[O_2]/\Delta t$

$$\frac{(0.0320\ \text{mol/L}) - (0.0160\ \text{mol/L})}{(240\ \text{s} - 60\ \text{s})} = 8.89 \times 10^{-5}\ \frac{\text{mol/L}}{\text{s}}$$

Answer : The average rate of formation of O_2 is : $8.89 \times 10^{-5}\ \frac{\text{mol/L}}{\text{s}}$

b) Examination of the chemical reaction shows that the molar ratio of NO_2 to O_2 is a **2 :1 ratio**.

$$\mathbf{2\ NO_{2(g)}} \longrightarrow 2\ NO_{(g)} + \mathbf{O_{2(g)}}$$

Therefore the average rate of decomposition of NO_2 is twice the rate of formation of O_2.

so, $(8.89 \times 10^{-5}\ \frac{\text{mol/L}}{\text{s}}) \times 2 = 1.78 \times 10^{-4}\ \frac{\text{mol/L}}{\text{s}}$

Answer : The average decomposition of NO_2 is : $1.78 \times 10^{-4}\ \frac{\text{mol/L}}{\text{s}}$.

Part E

30 **a) Increasing the total pressure :** The mole ratio of gases in the reactant to gases in the product is 4 : 2 or 2 :1. The greater number of moles on the reactant side creates a greater number of collisions as the pressure is increased. This favours the products.

Therefore, the concentration of NH_3 will **increase.**

b) Increasing the temperature : The forward reaction is exothermic. The increase in temperature creates a stress on the equilibrium system which it alleviates by using up (absorbing) the added heat energy. This favours the endothermic direction. As a result, the reactants are favoured.

Therefore, the concentration of NH_3 will **decrease.**

c) Increasing the volume of the container : Since all the reactants and products are gases, increasing the volume will decrease the total pressure (according to Boyle's law). This has the reverse effect of the result in part a). This favours the reactants.

Therefore, the concentration of NH_3 will **decrease.**

d) Adding an appropriate catalyst : The catalyst will lower the activation energy for the reaction, thereby affecting both the forward and reverse reactions to the same degree. This does not affect the equilibrium and neither the products nor reactants are favoured.

Therefore, the concentration of NH_3 remains **unchanged**.

e) Increasing the concentration of N_2 : The increased concentration of N_2 will create a greater number of collisions between reactants. This will accelerate the rate of the forward reaction and favour the products.

Therefore, the concentration of NH_3 will **increase.**

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$$4\,HCL_{(g)} + O_{2(g)} \leftrightarrow 2\,H_2O_{(g)} + 2\,Cl_{2(g)}$$

	$4\,HCL_{(g)}$	$O_{2(g)}$	$2\,H_2O_{(g)}$	$2\,Cl_{2(g)}$
initial conc.	1.0 mol/L	1.0 mol/L	0	0
Δconc.	-4 x	- x	+ 2 x	+ 2 x
equil. conc.	1.0 -4 x	1.0 - x	0.20 mol/L	+ 2 x

Since 0.20 mol/L of $H_2O_{(g)}$ is present at equilibrium, then solve for **x**.

$$2\,\mathbf{x} = 0.20 \text{ mol/L}$$
$$\mathbf{x} = 0.10$$

Now, use **x** to solve for other substances at equilibrium :

$HCl_{(aq)}$ = 1.0 mol/L -4**x** = 1.0 mol/L - 4 (0.10) = **0.60 mol/L**

$O_{2(g)}$ = 1.0 mol/L -**x** = 1.0 mol/L - 0.10 = **0.90 mol/L**

$Cl_{2(g)}$ = 0 + 2**x** mol/L = 2(0.10) mol/L = **0.20 mol/L**

Use the equilibrium concentrations to solve for $K_{(eq)}$.

$$K_{(eq)} = \frac{[H_2O_{(g)}]^2\,[Cl_{2(g)}]^2}{[HCl_{(aq)}]^4\,[O_{2(g)}]}$$

$$= \frac{(0.20)^2\,(0.20)^2}{(0.60)^4\,(0.90)}$$

$$= 1.4 \times 10^{-2}$$

Answer : **The $K_{(eq)}$: 1.4×10^{-2}**

32 a) The cathode is : **The nickel electrode (Ni).**

b) The electrode that is losing electrons is: **The chromium electrode (Cr).**

c) The electrode at which oxidation takes place is: **The chromium electrode (Cr).**

d) The ions that migrate toward the Cr electrode are:

The anions, or the negative ions, or the NO_3^- ions.

e) The net cell potential is: **$E°_{net}$ = +0.74 v - 0.25 v = +0.49 v**