Lester B. Pearson School Board

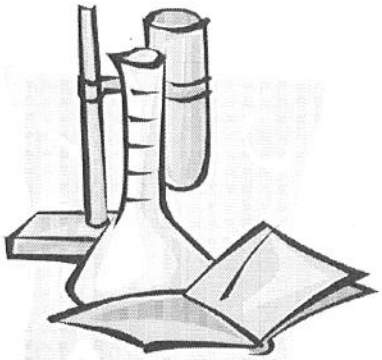
Commission scolaire Lester-B.-Pearson

JUNE 2014

CHEMISTRY

Secondary 5
551-504

Theory Examination



Answer Booklet

Name: Dill Rae Date: _____ Group: _____

Part A:	____ / 40
Part B:	____ / 60
Total:	____ /100

Time: 3 hours

Part A ***Multiple-Choice Questions***

Questions 1 to 10

Shade the letter that corresponds to your answer.

Each question is worth 4 marks.

Question 1 [A] [B] [C] [D]

Question 2 [A] [B] [C] [D]

Question 3 [A] [B] [C] [D]

Question 4 [A] [B] [C] [D]

Question 5 [A] [B] [C] [D]

Question 6 [A] [B] [C] [D]

Question 7 [A] [B] [C] [D]

Question 8 [A] [B] [C] [D]

Question 9 [A] [B] [C] [D]

Question 10 [A] [B] [C] [D]

/40

Part A ***Multiple-Choice Questions***

Questions 1 to 10

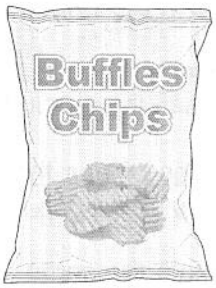
Answer all questions in the ***Answer Booklet***.

Each question is worth four marks.

Question 1

Food companies use nitrogen gas, N_2, to fill in the empty space in food packaging.

Example of Nitrogen Gas Used in Food Packaging



What property of nitrogen gas makes it a good choice for use in food packaging?

A) Nitrogen gas acts as a catalyst and prolongs the shelf-life of foods.

B) Nitrogen gas reacts with the oxygen gas in air and prevents food spoilage.

C) Nitrogen gas reacts with the water vapour in air and prevents food spoilage.

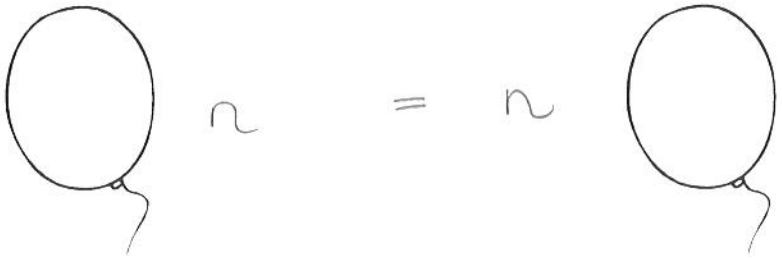
D) Nitrogen gas is chemically inactive due to its triple bond and prolongs the shelf-life of foods.

Question 2

Two identical balloons were filled to the same pressure, temperature and volume with different gases.

Balloon A
Nitrogen Gas, N_2 — 28 g/mol

Balloon B
Carbon Dioxide Gas, CO_2 — 44 g/mol



Which of the following statements about the gases in the two balloons is TRUE?

A) Balloon A contains more moles of gas than Balloon B and the mass of the gas in Balloon A is equal to the mass of the gas in Balloon B.

B) Balloon A contains fewer moles of gas than Balloon B and the mass of the gas in Balloon A is less than the mass of the gas in Balloon B.

C) Balloon A and Balloon B contain the same number of moles of gas and the mass of the gas in Balloon A is less than the mass of the gas in Balloon B.

D) Balloon A and Balloon B contain the same number of moles of gas and the mass of the gas in Balloon A is equal to the mass of the gas in Balloon B.

Question 3

V

$P = 101.3\ kPa = P_1$

Helium gas is used to fill balloons because it is inert and has a low density.

At a winter carnival a 255 L helium tank was used to fill 250 balloons. Once filled, each balloon contained 17.3 L of helium gas at STP.

$V \times 250 = 4325\ L = V_1$

What was the initial pressure of the full helium tank?
Assume the temperature remains constant, no gas is lost, and that the tank is completely emptied.

A) 1.01×10^2 kPa

B) 1.72×10^3 kPa

C) 1.90×10^3 kPa

D) 3.70×10^5 kPa

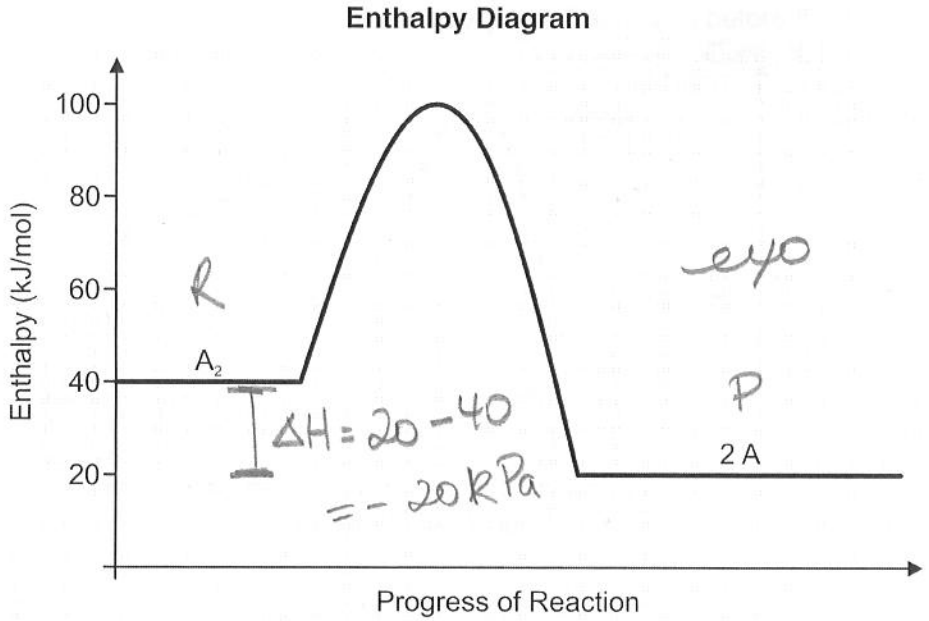
$V_1 P_1 = V_2 P_2$

$$\frac{(4325\ L)(101.3\ kPa)}{(255\ L)} = P_2$$

$P_2 = 1718\ kPa$

Question 4

The enthalpy diagram for the decomposition of a molecule is shown below:



Which of the equations below correctly represents the decomposition of the molecule shown in the diagram?

A) $A_2 \rightarrow 2\ A + 20\ kJ$ exo $\Delta H = -20$

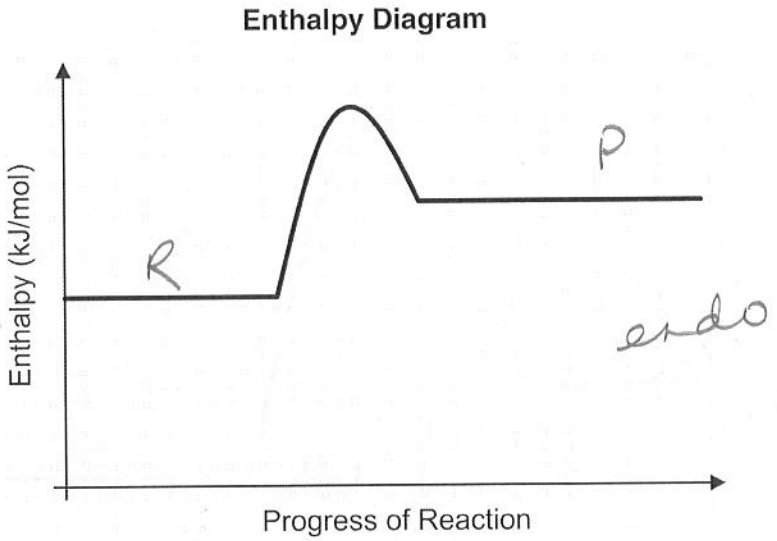
B) $A_2 \rightarrow 2\ A + 60\ kJ$ exo $\Delta H = -60$

C) $A_2 + 20\ kJ \rightarrow 2\ A$ endo $\Delta H = +20$

D) $A_2 + 60\ kJ \rightarrow 2\ A$ endo $\Delta H = +60$

Question 5

The enthalpy diagram for the dissolution of a salt in water is shown below:



Which of the following statements about the dissolution of this salt is TRUE?

A) The system lost energy and the ΔH of the dissolution is positive.

B) The system lost energy and the ΔH of the dissolution is negative.

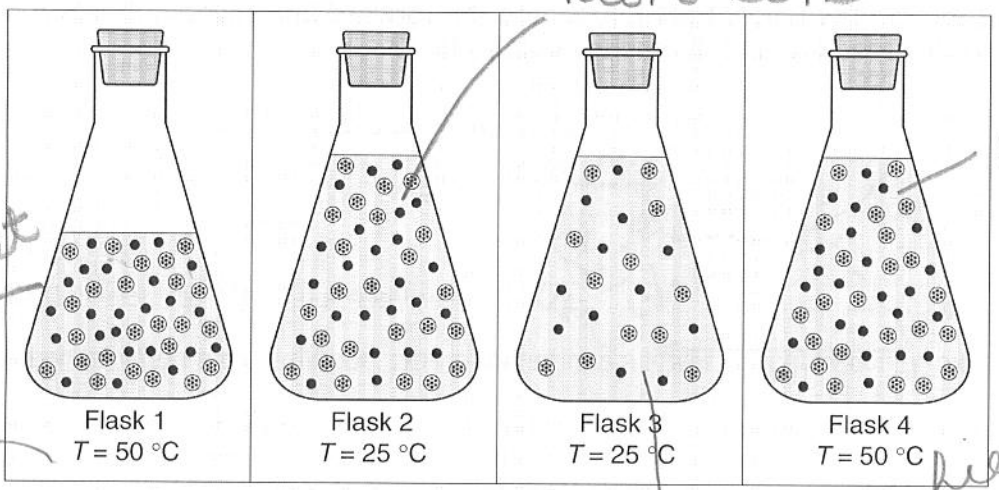
C) The system gained energy and the ΔH of the dissolution is positive.

D) The system gained energy and the ΔH of the dissolution is negative.

Question 6

The same chemical reaction is carried out in solution in four separate flasks under different conditions.

The diagrams below illustrate the reactant molecules in each flask before the reaction begins.



Which of the following combinations lists the reaction in each flask in order, from slowest to fastest?

A) Flask 1, Flask 4, Flask 2, Flask 3

B) Flask 2, Flask 3, Flask 1, Flask 4

C) Flask 3, Flask 2, Flask 1, Flask 4

D) Flask 3, Flask 2, Flask 4, Flask 1

Question 7

At a given temperature, the rate law for an elementary reaction is:

$$r = k\,[C]^2\,[D]$$

Which of the elementary reactions below is represented by the rate law above?

A) $C_2D_{(s)} \rightarrow 2\ C_{(g)} + D_{(g)}$

B) $2\ C_{(g)} + D_{(g)} \rightarrow C_2D_{(g)}$

C) $C_{2(g)} + D_{(g)} \rightarrow C_2D_{(g)}$

D) $C_2D_{(s)} \rightarrow C_{2(g)} + D_{(g)}$

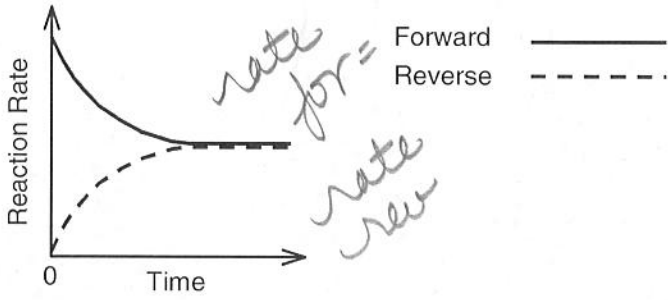
Question 8

Steam, $H_2O_{(g)}$, and carbon monoxide, $CO_{(g)}$, are placed in a closed vessel at a high temperature and allowed to reach equilibrium.

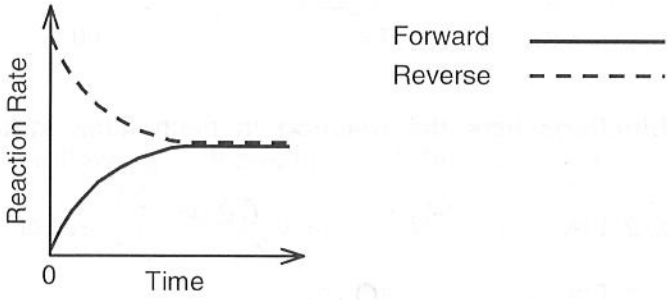
$$H_2O_{(g)} + CO_{(g)} \rightleftharpoons H_{2(g)} + CO_{2(g)}$$

Which of the graphs below best represents the forward and reverse reaction rates from the start of the reaction until it reaches equilibrium?

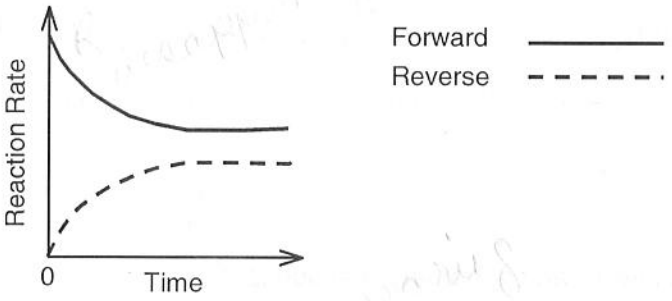
A)



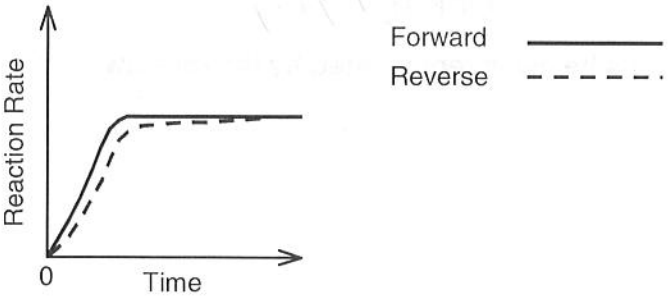
B)



C)



D)



Question 9

The red blood cells in the human body pick up oxygen from the lungs and deliver it to the body's cells. This process is possible because the hemoglobin molecule on red blood cells combines with oxygen molecules to form oxyhemoglobin.

This reaction at equilibrium is shown below:

$$Hb_{(aq)} + 4\ O_{2(g)} \rightleftharpoons Hb(O_2)_{4(aq)}$$

Hemoglobin — Oxyhemoglobin

either ↓Hb or ↓O_2 as a stress

Four conditions are listed below.

1. Inhaling pure oxygen from a pressurized tank.
2. A person hiking at a high altitude, where the air has a lower concentration of oxygen.
3. A person with Thalassemia, a genetic disorder that results in the reduction in the amount of functional hemoglobin.
4. A person born and raised at a high altitude, resulting in the production of more hemoglobin in the blood than a person born and raised at a low altitude.

Which of the conditions described above would lead to the reaction shifting to the left?

A) 1 and 3

B) 1 and 4

C) 2 and 3

D) 2 and 4

Question 10

Several different acids contribute to the formation of acid rain.

The table below describes five of these acids.

Acids that Contribute to Acid Rain

Acid	Formula	pH	K_a at 25 °C
Carbonic Acid	H_2CO_3	5.3	4.4×10^{-7}
Nitric Acid	HNO_3	6.0	2.4×10^{1}
Sulfuric Acid	H_2SO_4	5.5	1.0×10^{3}
Sulfurous Acid	H_2SO_3	5.2	1.3×10^{-2}

highest Ka

Which are the strongest and weakest acids?

lowest Ka

A) Strongest: Sulfurous Acid — Weakest: Nitric Acid

B) Strongest: Nitric Acid — Weakest: Sulfurous Acid

C) Strongest: Carbonic Acid — Weakest: Sulfuric Acid

D) Strongest: Sulfuric Acid — Weakest: Carbonic Acid

Part B ***Constructed-Response Questions***

Questions 11 to 25

Show all the work needed to solve the problem:
data given, formulas and calculations.

Write your answer with the correct units in the space provided.

You will be given no marks if you provide the right answer without showing your work. However, you will be given part marks for work that is partially correct.

Significant figures will only be evaluated in questions 14 and 15.

Question 11

Using the Kinetic Molecular Theory, explain the following observations:

a) Gases can diffuse from the swim bladder to the blood.

- gas particles are in constant motion
- no F of attraction btw particles
- they can move across membranes

2	1	0

b) The swim bladder decreases in size when the water pressure increases.

- P is caused by particles hitting the sides of a container
- fewer particles = less P
- less P = ↑ volume
- vol of gas particles negligible
- can compress particles
- major distances btw particles

2	1	0

Question 12

What volume of carbon dioxide gas did Hannah collect at 25.0 °C and 90.0 kPa?

Show all your work.

$$CaCO_{3(s)} + 2\ HCl_{(aq)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$$

$T = 25.0\,^{\circ}C + 273 = 298.0\,^{\circ}C$

$P = 90.0\ kPa$

$50.0\,mL \times \frac{1\,L}{1000\,mL} \times \frac{3.0\,mol\ HCl}{1\,L} \times \frac{1\,mol\ CO_2}{2\,mol\ HCl} =$

$n\,CO_2 = 0.075\ mol$

$PV = nRT$

$\frac{PV}{P} = \frac{nRT}{P}$

$V = \frac{nRT}{P} = \frac{(0.075\,mol)(8.314\,\frac{kPa\,L}{mol\,K})(298.0\,K)}{90.0\,kPa}$

$V = 2.1\,L$

Answer

The volume of the carbon dioxide gas collected was 2.1 L.

4	3	2	1	0

$$\frac{P_1}{n_1} = \frac{P_2}{n_2}$$

Question 13

What is the minimum mass of water required to produce enough hydrogen gas for one cylinder of the gas mixture?
Assume no gas is lost.

Show all your work.

1) $P_1 + P_2 = P_T - P_1 = P_2 = P_{H_2}$

$1.5 \times 10^4 kPa - 13500 kPa = P_{H_2} = 1500 kPa$

2) $PV = nRT$

$n = \frac{PV}{RT} = \frac{(1500 kPa)(50.0 L)}{\left(8.314 \frac{kPa\,L}{mol\,K}\right)(15.0°C + 273)}$

$n = 31.3 mol\ H_2$

$31.3 mol\ H_2 \times \frac{2 mol\ H_2O}{2 mol\ H_2} \times \frac{18 g\ H_2O}{1 mol\ H_2O} = 563 g\ H_2O$

Answer

The minimum mass of water required is 563 g H_2O.

4	3	2	1	0

Question 14

What was the volume of the balloon when it was in the equipment lock?
Assume no gas escapes from the balloon.
Significant figures will be evaluated in this question.

Show all your work.

$$\frac{T_2}{P_2} \times \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \times \frac{T_2}{P_2}$$

$$\frac{T_2 P_1 V_1}{T_1 P_2} = V_2 =$$

$$\frac{(305.0\,K)(101.3\,kPa)(0.2500\,L)}{(298.0\,K)(70.3\,kPa)} = V_2$$

$$V_2 = 0.3687\,L$$

$P_1 = 101.3\,kPa$
$T_1 = 25.0°C + 273$
$= 298.0\,K$
$V_1 = 250.0\,mL$
$= 0.2500\,L$
$P_2 = 70.3\,kPa$
$T_2 = 32.0°C + 273$
$= 305.0\,K$

Answer

The volume of the balloon was 0.369 L = 369 mL.

4	3	2	1	0

Question 15

Determine the molar heat of dissolution of lithium chloride.
Significant figures will be evaluated in this question.

Show all your work.

1) $Q_{water} = (1000\ g)\left(\frac{4.19\ J}{g \cdot C}\right)(0.50\ °C)$

$= 2.1 \times 10^3\ J$

2) $Q_{sub} = -2.1 \times 10^3\ J = -2.1\ kJ$

3) $n\ LiCl = 2.5\ g \times \frac{1\ mol}{42.5\ g} = 0.059\ mol$

4) $\Delta H = \frac{-2.1\ kJ}{0.059\ mol}$

$= -36\ \frac{kJ}{mol}$

Answer

The molar heat of dissolution of lithium chloride is $-36\ kJ/mol$.

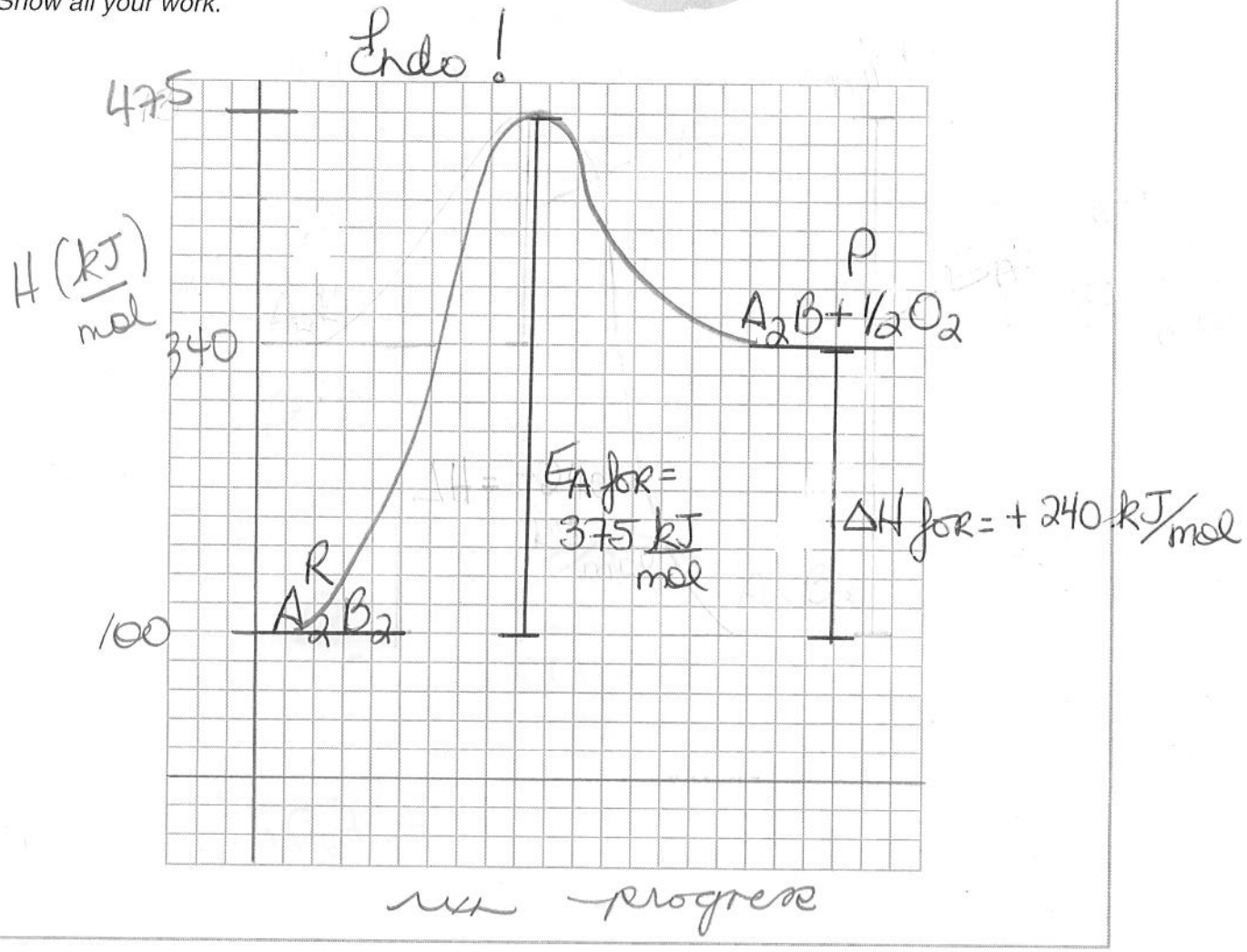
4	3	2	1	0

Question 16

a) Draw a complete enthalpy diagram for the decomposition of A_2B_2. Label the heat of reaction, ΔH, and the activation energy, E_a, for the reaction.

$\rightarrow A_2B + \frac{1}{2}O_2$

Show all your work.



b) Determine the value of ΔH and E_a of the decomposition reaction.

The heat of reaction, ΔH, for the decomposition of A_2B_2 is + 240 kJ/mol.

The activation energy, E_a, for the decomposition of A_2B_2 is +375 kJ/mol

4	3	2	1	0

Question 17

Determine the heat of reaction, ΔH, for the "cracking" of hexanol.

$$C_6H_{13}OH_{(l)} + 6\ H_{2(g)} \rightarrow 6\ CH_{4(g)} + H_2O_{(g)}$$

The thermochemical equations for several other reactions at SATP are shown below.

Enthalpy Values at SATP

Formation reaction					Enthalpy value
$C_{(s)}$	+	$O_{2(g)}$	→	$CO_{2(g)}$	$\Delta H = -393$ kJ/mol
$C_{(s)}$	+	$2\ H_{2(g)}$	→	$CH_{4(g)}$	$\Delta H = -76$ kJ/mol
$6\ C_{(s)}$	+	$7\ H_{2(g)}$ + $\frac{1}{2}\ O_{2(g)}$	→	$C_6H_{13}OH_{(l)}$	$\Delta H = -377$ kJ/mol
$H_{2(g)}$	+	$\frac{1}{2}\ O_{2(g)}$	→	$H_2O_{(g)}$	$\Delta H = -242$ kJ/mol
$H_{2(g)}$	+	$\frac{1}{2}\ O_{2(g)}$	→	$H_2O_{(l)}$	$\Delta H = -285$ kJ/mol

Show all your work.

$C_6H_{13}OH \rightarrow 6C + 7H_2 + \frac{1}{2}O_2$ $+377$

$6C + 6(2H_2) \rightarrow 6CH_4$ $6(-76) = -456$

$H_2 + \frac{1}{2}O_2 \rightarrow H_2O_{(g)}$ -242

$C_6H_{13}OH + 6H_2 \rightarrow 6CH_4 + H_2O_{(g)}$

$-321\ \frac{kJ}{mol}$

Answer

The heat of reaction, ΔH, for the "cracking" of hexanol is -321 kJ/mol.

4	3	2	1	0

Question 18

What is the final temperature of the water?
Assume no loss of heat and complete combustion.

Show all your work.

$$Q_{cal} = 0.287\,g \times -19.7\,\frac{kJ}{g}$$

$$= -5.65\,kJ$$

$$= -5650\,J$$

$$Q_{water} = +5650\,J$$

$$Q = m c \Delta T$$

$$\Delta T = \frac{Q}{mc} = \frac{5650\,J}{(250.0\,g)\left(4.19\,\frac{J}{g \cdot °C}\right)}$$

$$\Delta T = 5.39\,°C$$

$$\Delta T = T_f - T_i$$

$$T_f = \Delta T + T_i = 23.0\,°C + 5.39\,°C$$

$$T_f = 28.4\,°C$$

Answer

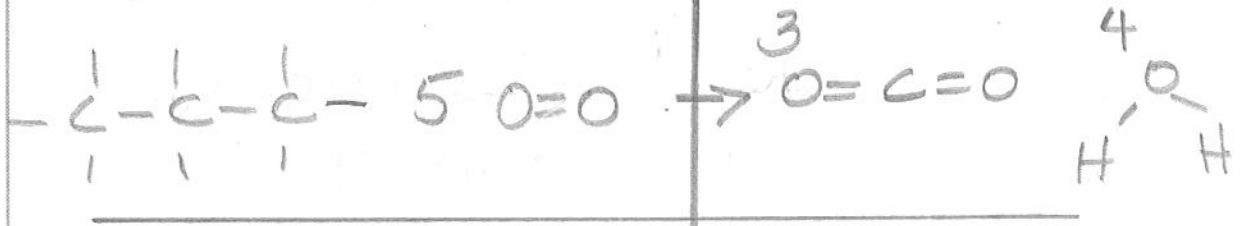
The final temperature of the water is 28.4 °C.

4	3	2	1	0

Question 19

Determine the molar heat for the combustion of propane using bond enthalpies.

Show all your work.



$8\ C-H = (413)8 = 3304$

$2\ C-C = (347)2 = 694$

$5\ O=O = (498)5 = 2490$

$6488\ kJ$

$3 \times 2\ C=O = (745)6 = 4470$

$4 \times 2\ O-H = (460)8 = 3680$

$8150\ kJ$

$-1662\ kJ$

Answer

The molar heat for the combustion of propane is $-1662\ kJ$.

4	3	2	1	0

Question 20

Determine the factor by which the reaction rate increases under the new conditions.

Show all your work.

$r = k[NH_3]^2$

i) 2 × mass NH_3
$= 2 \times [NH_3]$

ii) $\downarrow V \frac{1}{2} = 2P = 2 \times [NH_3]$

$= 4 \times [NH_3]$

$r = k(4)^2$

$= k\,16$

$r = 16x$

Answer

The reaction rate will increase by a factor of 16 x.

4	2	0

Question 21

List four modifications of the reaction conditions which would result in manufacturers being able to produce more gallium arsenide in their factories. Explain your answer.

Modification	Explanation
1. ↑ [Ga] or [$AsCl_3$]	stress = ↑R want = ↓R shift = →
2. ↑ P by ↓ V	stress = ↑P want = ↓P shift = → to ↓ # gas n
3. ↓ T	stress = ↓T want = ↑T shift = → to produce HE
4. ↓ [Cl_2]	stress = ↓[Cl_2] want = ↑[Cl_2] shift = → to produce more Cl_2

4	3	2	1	0

weak base

Question 22

Determine the base dissociation constant, K_b, of ammonia at 25.0 °C

Show all your work.

$$K_b = \frac{[NH_4^+][OH^-]}{[NH_3]} = \frac{(2.51 \times 10^{-3})2}{(0.40)}$$

pH 11.4 $\Rightarrow$ $pH = -\log[H^+]$

$$[H^+] = 3.98 \times 10^{-12} \frac{mol}{L}$$

$$K_W = [H^+][OH^-]$$

$$[OH^-] = \frac{1 \times 10^{-14}}{3.98 \times 10^{-12} M}$$

$$= 2.51 \times 10^{-3} M = [NH_4^+]$$

$$K_b = 1.58 \times 10^{-5}$$

Answer

The base dissociation constant, K_b, of ammonia at 25 °C is 1.58×10^{-5}.

4	3	2	1	0

Question 23

Calculate the fluoride ion concentration in a saturated solution of calcium fluoride at 25 °C.

Show all your work.

$K_{sp} = [Ca^{2+}][F^-]^2$

$CaF_2(s) \rightleftharpoons Ca^{2+} + 2F^-$

x = solubility in mol/L

$x \qquad 2x$

$K_{sp} = (x)(2x)^2$

$K_{sp} = 4x^3$

$\sqrt[3]{\frac{3.45 \times 10^{-11}}{4}} = \sqrt[3]{\frac{4x^3}{4}}$

$x = 2.06 \times 10^{-4} M = [Ca^{2+}]$

$2x = 4.12 \times 10^{-4} M = [F^-]$

Answer

The fluoride ion concentration at 25 °C is 4.12×10^{-4} mol/L F^-.

4	3	2	1	0

Question 24

a) If the pH of the gastric juice is 2.4 before the food arrives in the stomach, what is the pOH and $[H^+]$ at that time?

Show all your work.

pH 2.4 → $[H+] = 3.98 \times 10^{-3} \frac{mol}{L}$

$pOH = 14 - 2.4 = 11.6$ → $[OH^-] = 2.5 \times 10^{-12} \frac{mol}{L}$

Answer

The pOH is 11.6.

The $[H^+]$ is 3.98×10^{-3} mol/L.

2	1	0

b) After the arrival of food, the pH rises to 4.6. What is the $[OH^-]$ of the gastric juice after the arrival of food?

Show all your work.

pH 4.6

$pOH = 14 - 4.6$

$= 9.4$

$[OH^-] = 3.98 \times 10^{-10} M$

Answer

The $[OH^-]$ is $3.98 \times 10^{-10} M$.

2	1	0

Question 25

a) Calculate the value of the equilibrium constant, K_c.

Show all your work.

$[H_2] = \frac{10\,mol}{2L} = 5M$

$[I_2] = \frac{4\,mol}{2L} = 2M$

$[HI] = \frac{12\,mol}{2L} = 6M$

$K_c = \frac{[HI]^2}{[H_2][I_2]}$

$= \frac{(6)^2}{(5)(2)} = 3.6$

Answer

The value of the equilibrium constant is 3.6.

2	1	0

b) What will happen to the value of the equilibrium constant if the temperature of the reaction vessel is decreased? Explain your answer.

The equilibrium constant will:

☐ increase ☐ decrease ☐ remain unchanged.

(Check one box.)

Explanation:

$\uparrow H_2 + \uparrow I_2 + 53kJ \rightleftharpoons 2HI$

stress = ↓T

want = ↑T

shift = ← to produce

the Keq ↓ in value

$K_c = [HI]\downarrow = \downarrow K_c$

$\uparrow [H_2][I_2] \uparrow$

2	1	0