Part A

Multiple-Choice Questions 1 to 10

Answer all questions in your ***Student Booklet***.

1. Gases have many uses in industry, medicine, and day-to-day applications. They vary in chemistry, properties and uses.

   Examples of various gases with their uses are provided in the tables below.

   Which of the following correctly matches the gases with their usage?

A)

Gas	Usage
Acetylene	Welding
Neon	Fertilizer
Ozone	Refrigeration

B)

Gas	Usage
Methane	Cooking
Nitrogen	Halogen lights
Oxygen	Patients with respiratory issues

C)

Gas	Usage
Hydrogen	Fuel
Nitrogen	Food packaging
Neon	Lights

D)

Gas	Usage
Oxygen	Food packaging
Nitrogen	Freezing warts
Fluorine	Toothpaste

2. The detection of odour molecules plays an important role in the survival of most animals. Odour is used to identify food, predators, and territory.

The table below lists three molecules and their odours.

Odour Molecules

Chemical Formula	Smell
$C_{10}H_{20}O_2$	Fruity
$C_{10}H_{13}O$	Minty
$C_7H_{12}O_2$	Nutty

Which of the following ranks these odour molecules from **fastest** to **slowest** rate of diffusion?
Assume that the temperature is the same for all gas molecules.

A) $C_7H_{12}O_2$ $C_{10}H_{13}O$ $C_{10}H_{20}O_2$

B) $C_7H_{12}O_2$ $C_{10}H_{20}O_2$ $C_{10}H_{13}O$

C) $C_{10}H_{13}O$ $C_{10}H_{20}O_2$ $C_7H_{12}O_2$

D) $C_{10}H_{20}O_2$ $C_{10}H_{13}O$ $C_7H_{12}O_2$

3. A high altitude weather balloon filled with helium, He, collects data as it rises through the atmosphere.

$T_1 = 290K$

At launch, the balloon recorded a temperature of 15.0 °C. At its maximum height of 37 km, the temperature recorded was -25.0 °C.

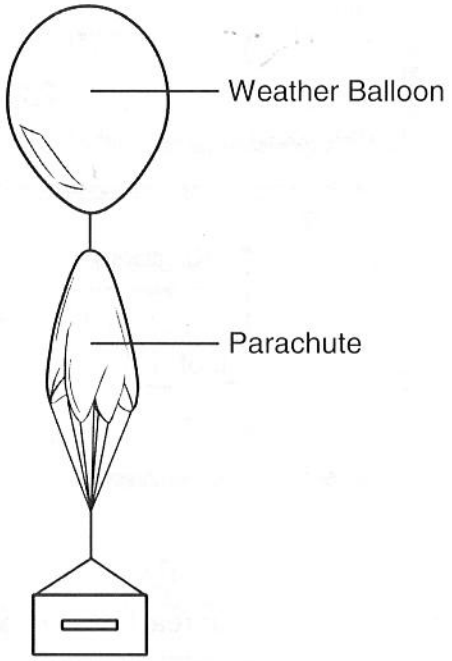
$T_2 = 250K$

The volume of the weather balloon during its ascent increased by a factor of 86.

$1L \rightarrow 86L$

$V_1 \quad V_2$

Weather Balloon



$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

$\frac{P_1}{P_2} = \frac{V_2T_1}{T_2V_1}$

$= \frac{(86)(290)}{(250)(1)}$

$= 100\times$

you can use whatever you want for V_1 & V_2 as long as $\frac{V_2}{V_1} = 86!$

Which statement describes the change to the pressure in the weather balloon as it rises from 0 km to 37 km? *Assume no gas leaves the weather balloon.*

A) The pressure will increase by a factor of 74.

B) The pressure will decrease by a factor of 74.

$\therefore P_1 = 100 \times P_2$

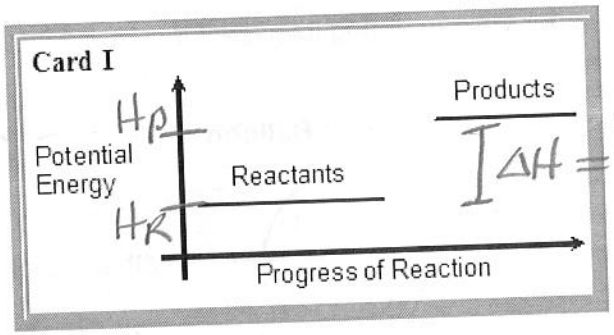
C) The pressure will increase by a factor of 100.

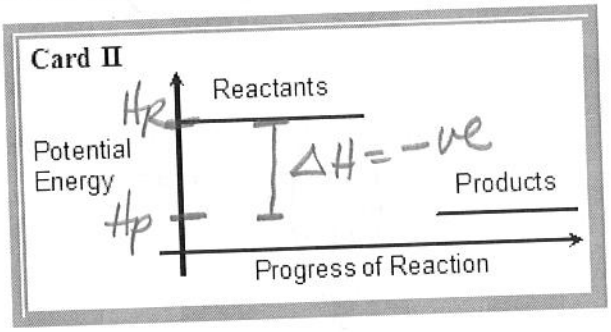
D) The pressure will decrease by a factor of 100.

$\frac{P_1}{P_2} = 100$

4. In order to study for a chemistry exam, a student made the following two flash cards:

Flash Cards
(Diagrams are not to scale.)





She wanted to use the following four reactions as examples on the back of the cards:

Reaction 1 $2\,Fe_{(s)} + \frac{3}{2}\,O_{2\,(g)} \rightarrow Fe_2O_{3\,(s)}$ $\Delta H = -824.2$ kJ

Reaction 2 $NH_4NO_{3\,(s)} \rightarrow NH_4^{+}{}_{(aq)} + NO_3^{-}{}_{(aq)}$ $\Delta H = +26.2$ kJ

Reaction 3 $2\,Al_2O_{3\,(s)} + 3\,352$ kJ $\rightarrow 4\,Al_{(s)} + 3\,O_{2\,(g)}$

Reaction 4 $C_2H_5OH_{(l)} + 3\,O_{2\,(g)} \rightarrow 2\,CO_{2\,(g)} + 3\,H_2O_{(g)} + 1370.7$ kJ

Which of the following correctly matches the reactions to the cards?

	Card I	Card II
A)	Reactions 1 and 3	Reactions 2 and 4
B)	Reactions 1 and 4	Reactions 2 and 3
C)	Reactions 2 and 3	Reactions 1 and 4
D)	Reactions 2 and 4	Reactions 1 and 3

* as soon as enthalpy is mentioned sketch the graph & mark off Hr + Hp

5. A student dissolves silver nitrate, $AgNO_3$, into a flask containing water. The reaction is represented by the following equation:

$$AgNO_{3(s)} \rightarrow Ag^{+}_{(aq)} + NO_3^{-}_{(aq)}$$

$T_1 \rightarrow T_2$ water T ↓ ENDO!

The temperature of the solution in the flask decreases from 18.2 °C to 14.7 °C.

Which of the following statements best describes the enthalpy change during the dissolution of the $AgNO_3$?

$\Delta H = +ve$

A) The dissolution of $AgNO_{3(s)}$ in water is an exothermic process.

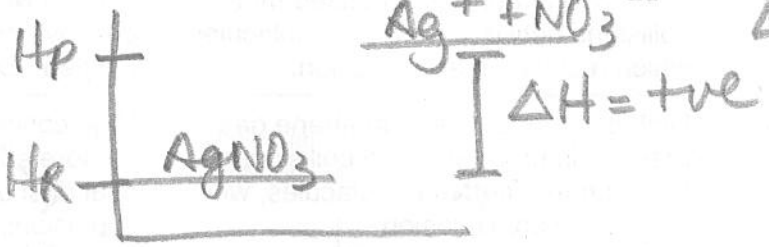
B) The potential energy of $Ag^{+}_{(aq)}$ and $NO_3^{-}_{(aq)}$ is greater than the potential energy of $AgNO_{3(s)}$.

see graph

C) The energy required to break the bonds is less than the energy released when bonds are formed.

($AgNO_3$) endo endo

D) The energy is transferred from the system to the surroundings during the dissolution of $AgNO_{3(s)}$ in water.



6. In 1992, there were two explosions in the Westray Coal Mine in Nova Scotia: a methane gas explosion and a coal dust explosion.

The methane gas in the mine reacted with oxygen, causing an explosion. Then, the coal dust on the floor of the mine also reacted with oxygen, causing another series of explosions.

The explosions could have been prevented with proper ventilation to prevent the methane explosion, and by spreading limestone powder over the coal dust.

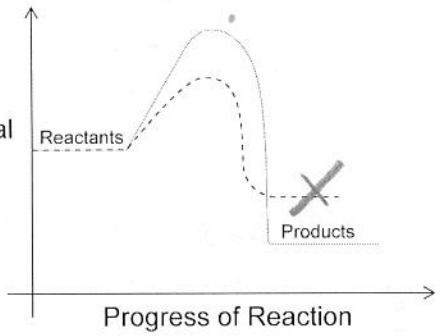
Which of the following uses the collision theory to correctly explain the most likely cause of the Westray coal mine explosions?

	Methane Gas	Coal Dust
A)	High concentrations of methane gas came into contact with the oxygen in the air. The effective collisions between the gases resulted in an explosion.	The large surface area of the coal dust meant that there was more coal in contact with the air. The result was more effective collisions between coal and oxygen. Explosions occurred.
B)	High concentrations of methane gas came into contact with heat. An increased temperature caused more collisions between methane molecules, which resulted in an explosion.	The small surface area of the coal dust meant that there was more coal in contact with the air. The result was more effective collisions between coal and oxygen. Explosions occurred.
C)	High concentrations of methane gas resulted in more effective collisions between the methane molecules, which resulted in an explosion.	High concentrations of coal dust resulted in more effective collisions between the coal dust particles, causing large explosions.
D)	The methane ignited because of high pressure which caused more effective collisions between the methane molecules.	The coal dust ignited because the heat in the mine caused more effective collisions between the coal dust particles.

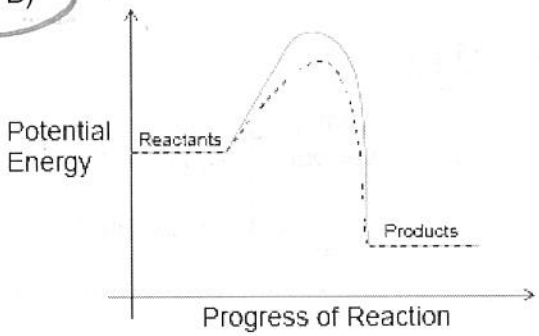
7. A catalytic converter is an emissions control device that decreases the toxicity of pollutants in exhaust gas. The catalyst is often a mix of precious metals, including platinum, the most widely used, as well as palladium and rhodium.

Which of the following graphs correctly identifies the effects of a catalyst in the catalytic convertor?

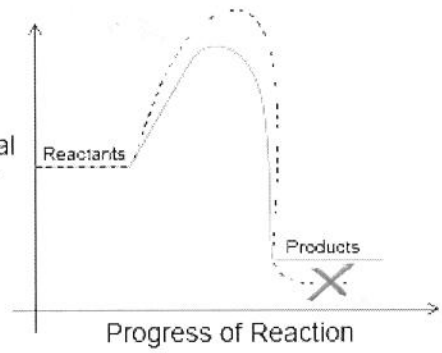
A)



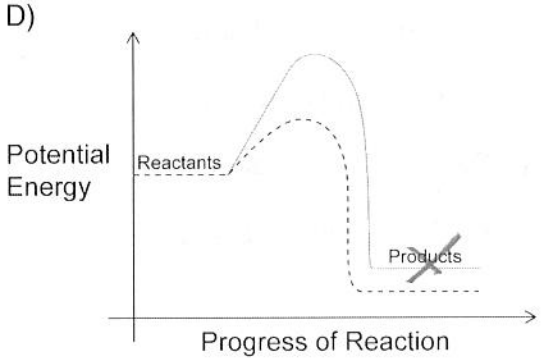
B)



C)



D)



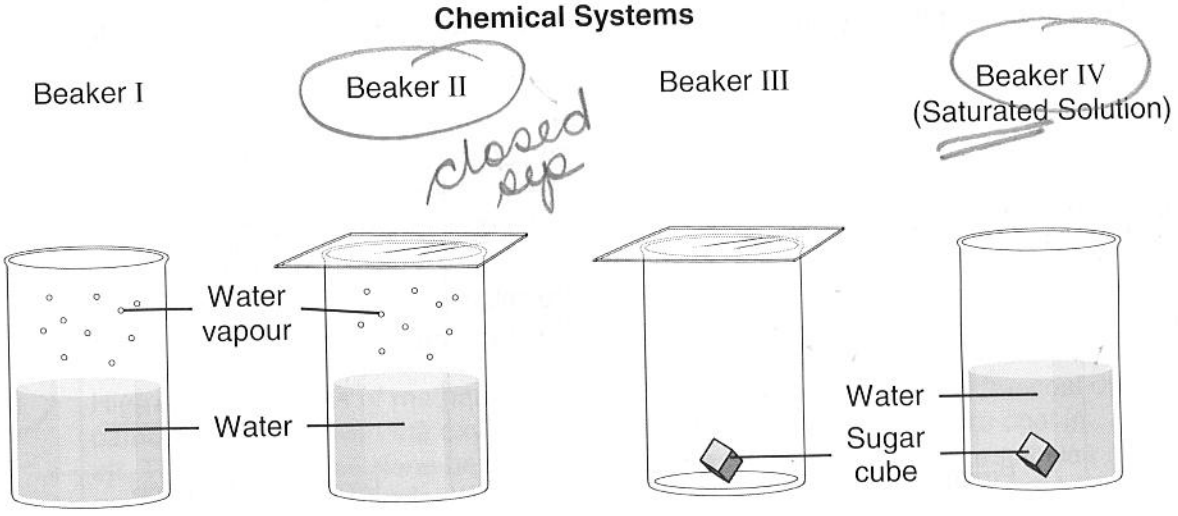
LEGEND		
Solid line	_____	Reaction without catalyst
Dotted line	----------	Reaction with catalyst

a catalyst speeds up a rxn

- ↓ E_A
- diff mechanisms
- not used up by the rxn
- does not change H_R or H_P ∴ no change to ΔH

8. Heather and Sue performed an experiment in the laboratory to investigate dynamic equilibrium in chemical systems. They prepared beakers with four chemical systems as illustrated below.

Chemical Systems



Which beakers are in dynamic equilibrium?

A) Beaker I and Beaker III

B) Beaker I and Beaker IV

C) Beaker II and Beaker III

D) Beaker II and Beaker IV

9. The dissociation of dinitrogen tetroxide, N_2O_4, into nitrogen dioxide, NO_2, is a reversible reaction that may be represented by the following equation:

1 mol gas 2 mol gas

$$N_2O_{4\,(g)} + \text{heat} \rightleftharpoons 2\,NO_{2\,(g)}$$

At a given temperature and pressure, a 5.0 L mixture of the two gases is at equilibrium.

When the volume occupied by the mixture is doubled, a shift in equilibrium will occur.

Which statement best describes the direction of the shift in equilibrium following an increase in volume?

A) The pressure decreases causing the equilibrium to shift towards the reactants.

B) The pressure decreases causing the equilibrium to shift towards the products.

C) The pressure increases causing the equilibrium to shift towards the reactants.

D) The pressure increases causing the equilibrium to shift towards the products.

stress = ↑V = ↓P

want = ↑P = need more particles of gas to hit the sides of the container

= only moles of gas involved

shift → favours products

10. Benzoic acid, C_6H_5COOH, is a weak acid that is used in medicine for the treatment of fungal skin diseases such as tinea, ringworm, and athlete's foot.

At chemical equilibrium, the ionization of this weak acid is as follows:

$$C_6H_5COOH_{(aq)} + H_2O_{(l)} \rightleftharpoons C_6H_5COO^-{}_{(aq)} + H_3O^+{}_{(aq)}$$

Which of the following algebraic expressions can be used to find the equilibrium constant for C_6H_5COOH?

A) $\dfrac{[C_6H_5COOH]}{[C_6H_5COO^-][H_3O^+]}$

B) $\dfrac{[C_6H_5COOH][H_2O]}{[C_6H_5COO^-][H_3O^+]}$

C) $\dfrac{[C_6H_5COO^-]}{[C_6H_5COOH][H_2O]}$

D) $\dfrac{[C_6H_5COO^-][H_3O^+]}{[C_6H_5COOH]}$

$K_A = \dfrac{[C_6H_5COO^-][H_3O^+]}{[C_6H_5COOH]}$

Part B

Constructed-Response Questions 11 to 25

Answer questions 11 to 25 in your ***Student Booklet***, showing all work.

Part A

Multiple-Choice Questions 1 to 10

Shade the letter that corresponds to your answer.

Each question is worth 4 marks.

1.	[A]	[B]	[C]	[D]	4	0
2.	[A]	[B]	[C]	[D]	4	0
3.	[A]	[B]	[C]	[D]	4	0
4.	[A]	[B]	[C]	[D]	4	0
5.	[A]	[B]	[C]	[D]	4	0
6.	[A]	[B]	[C]	[D]	4	0
7.	[A]	[B]	[C]	[D]	4	0
8.	[A]	[B]	[C]	[D]	4	0
9.	[A]	[B]	[C]	[D]	4	0
10.	[A]	[B]	[C]	[D]	4	0

/40

Part B

Constructed-Response Questions 11 to 25

Show all the work and units needed to solve the problem.

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 be evaluated in question 25 only.

11. An anesthetic is a type of medicine used to control pain during surgery.

laughing gas

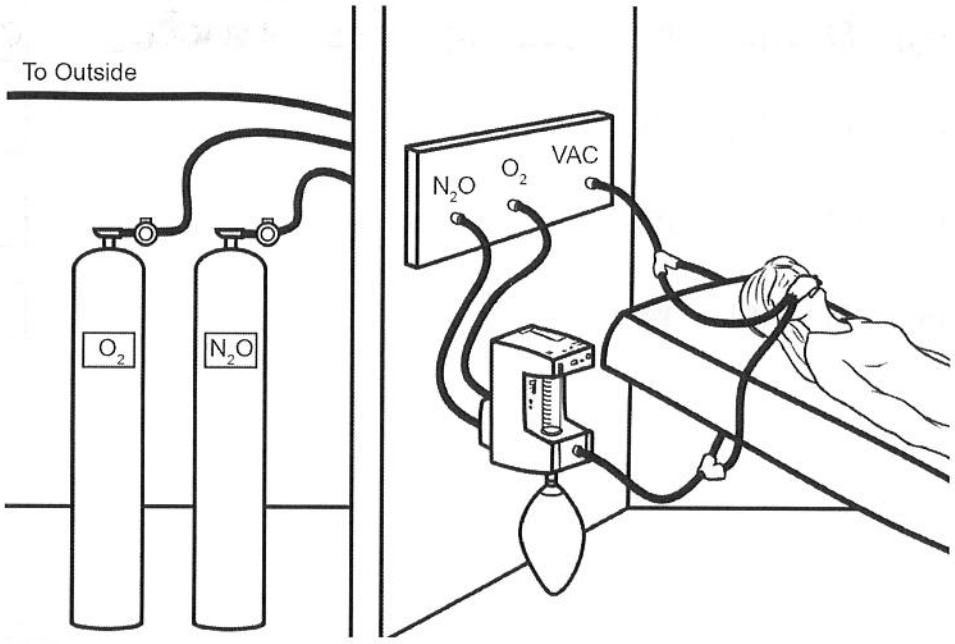
Nitrous oxide, N_2O, has been used since the 1840's as a mild anesthetic in dental surgery. Side effects of N_2O includes nausea, headaches and vomiting.

= made me ralph at 8!

Today a mixture of 30 % N_2O and 70 % oxygen gas, O_2, is used on patients. The N_2O and O_2 gases are stored in tanks and administered in exact doses by a machine.

The patient wears a mask with two tubes. One tube administers the gaseous mixture, while the vacuum tube removes the exhaled gas. The exhaled gas mixture includes N_2O.

Anesthesia Apparatus



11. *(Cont'd)*

a) Using the kinetic molecular theory explain why large quantities of gas can be stored in these tanks.

(1)
• gas particles have huge distances btw them so they can be compressed!
(2)

OR

2	1	0

b) Using the kinetic molecular theory explain why, for the safety of the dentist, the exhaled gas mixture is removed through a tube.

• gas are in constant random motion
OR • the particles move in straight line motion
• the gas would diffuse through the air & knock the dentist out

2	1	0

12. A science teacher mixes five different gases as described in the table below:

Gases in Mixture

Name of gas	Symbol	Pressure (Pa)
Nitrogen	N_2	78 000
Oxygen	O_2	21 000
Water vapour	H_2O	300
Carbon dioxide	CO_2	200
Methane	CH_4	???

× 1 kPa / 1000 Pa

V of all gases!

At the end of the demonstration, the 24.18 L gas mixture has a pressure of 1.03×10^2 kPa, and a temperature of 26.7 °C. (2)

$T = 26.7°C + 273 = 299.3\,K$

P_T

What quantity of methane gas is in this gas mixture?
Show all your work.

(1) $P_T = P_1 + P_2 + \ldots$

$= (78\,kPa + 21\,kPa + 0.3\,kPa + 0.2\,kPa) + ?$

$103\,kPa - 99.5\,kPa = 3.5\,kPa$ Methane partial P

(3) $\frac{PV}{RT} = \frac{nRT}{RT} = \frac{(3.5\,kPa)(24.18\,L)}{\left(8.314\,\frac{kPa\,L}{mol\,K}\right)(299.3\,K)}$

$= 0.034\,mol\,CH_4$ OR $\times \frac{16\,g}{1\,mol} =$

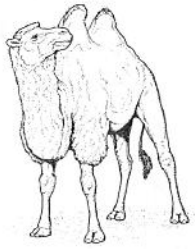
$= 0.54\,g$

The quantity of methane gas in this gas mixture is 0.034 mol CH_4 or 0.54 g.

4	3	2	1	0

13. Camels store tristearin, $C_{57}H_{110}O_6$, in their humps. Tristearin is a fat which serves as a source of energy allowing a camel to survive for long periods of time without food.

Camel



1) stoich bec solid fat
2) PV=nRT = ideal gas law bec now dealing w O_2 gas

The tristearin is metabolized according to the following reaction.

310 K

$$2\,C_{57}H_{110}O_{6\,(s)} + 163\,O_{2\,(g)} \rightarrow 114\,CO_{2\,(g)} + 110\,H_2O_{(l)}$$

What volume of oxygen is consumed by the camel when 1.00 kg of tristearin is burned at 37.0 °C and 101.3 kPa ?

Show all your work.

$57\times12 = 680$
$1\times110 = 110$
$16\times6 = 96$
} 890 g / 1 mol fat

stoich

$$2\,C_{57}H_{110}O_{6\,(s)} + 163\,O_{2\,(g)} \rightarrow 114\,CO_{2\,(g)} + 110\,H_2O_{(l)}$$

(1) $1.00\,\text{kg fat} \times \frac{1000\,\text{g}}{1\,\text{kg}} \times \frac{1\,\text{mol fat}}{890\,\text{g}} \times \frac{163\,\text{mol}\,O_2}{2\,\text{mol fat}} = 92.0\,\text{mol}\,O_2$

(2) $PV = nRT$ $\quad \frac{PV}{P} = \frac{nRT}{P}$

$$= \frac{(92.0\,\text{mol})\left(8.314\,\frac{\text{kPa L}}{\text{mol K}}\right)(310\,\text{K})}{(101.3\,\text{kPa})}$$

$$= 2.30\times10^{3}\,\text{L}$$

The volume of oxygen consumed by the camel is 2300 L.

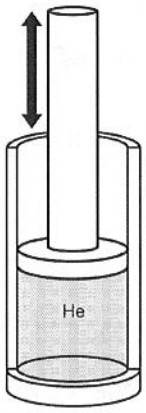
4	3	2	1	0

0.4000L V_1 can Δ to L but don't have to V_2 0.3400L

14. A 400.0 mL cylinder with a movable piston is filled with 20.0 g of helium, He.

Some of the helium escaped and the volume was adjusted to 340.0 mL so that the pressure and temperature inside the piston remains constant.

Cylinder with Movable Piston no ΔP!



What mass of helium remains in the cylinder?
Show all your work.

$20.0\text{ g He} \times \frac{1\text{ mol He}}{4\text{ g}} = 5.00\text{ mol He} = n_1$

$\frac{V_1}{n_1} = \frac{V_2}{n_2}$ $\quad n_2 = \frac{V_2 n_1}{V_1}$

$= \frac{(340.0\text{ mL})(5.00\text{ mol})}{(400.0\text{ mL})}$

$= 4.30\text{ mol He left}$

$4.30\text{ mol He} \times \frac{4\text{ g}}{1\text{ mol}} = 17.0\text{ g He}$

The mass of helium that remains in the cylinder is 17.0 g He.

4	3	2	1	0

15. When steam, H_2O, is passed over very hot iron, Fe, a natural magnet called lodestone, Fe_3O_4, is produced. The reaction is represented by the following equation:

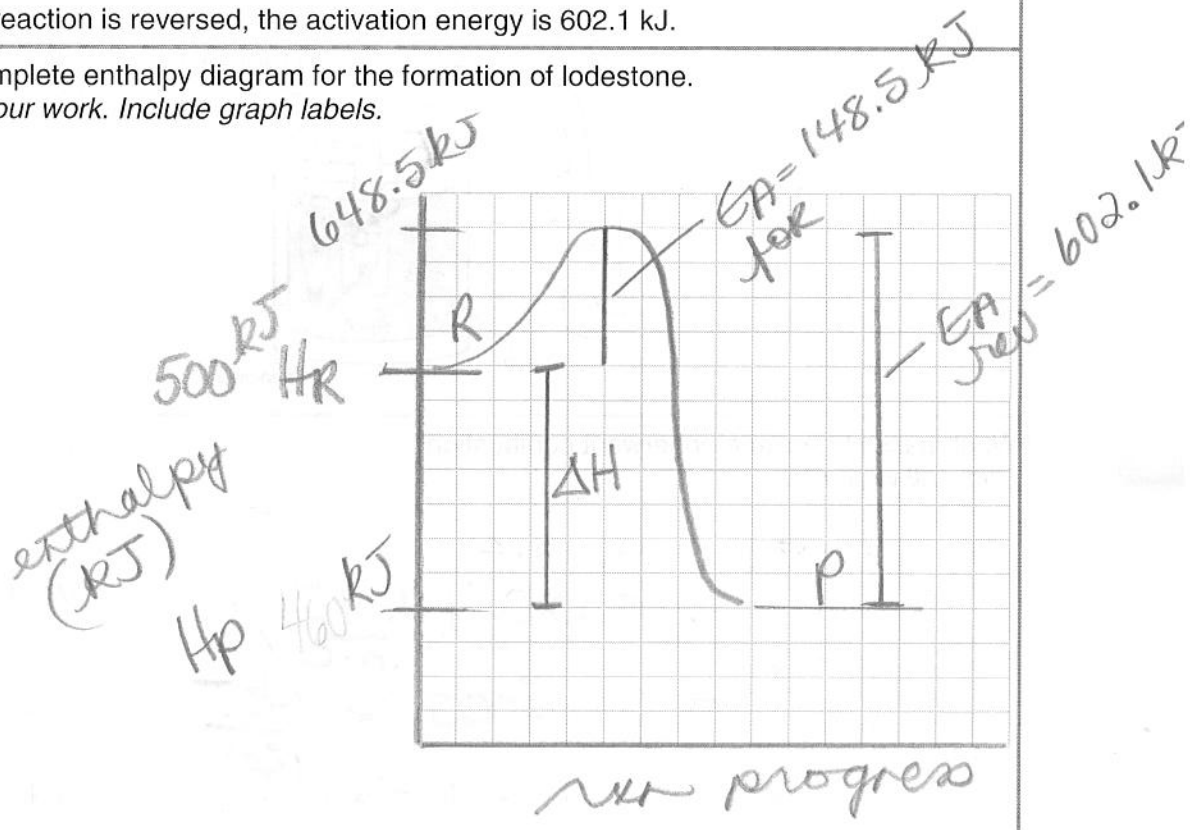
$$3\,Fe_{(s)} + 4\,H_2O_{(g)} \rightarrow Fe_3O_{4\,(s)} + 4\,H_{2\,(g)}$$

The potential energy of the reactants is 500.0 kJ.

The activation energy for this reaction is 148.5 kJ.

When the reaction is reversed, the activation energy is 602.1 kJ.

a) Draw a complete enthalpy diagram for the formation of lodestone.
Show all your work. Include graph labels.



3	2	1	0

b) What is the ΔH for the formation of lodestone?
Show all your work.

$\Delta H = Hp - HR$
$= \quad kJ - 500\,kJ =$ kJ

The ΔH for the formation of lodestone is _____ kJ/1 mole Fe_3O_4.

1	0

16. A sample of benzene, C_6H_6, undergoes combustion in a calorimeter as shown below:

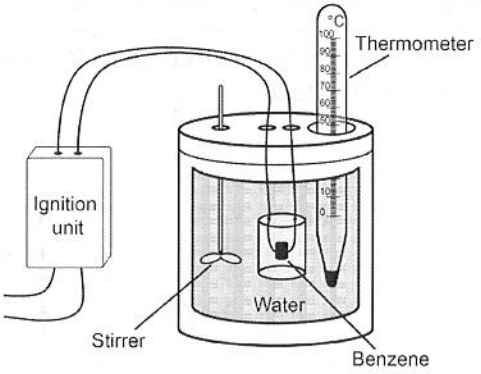
$$2\,C_6H_{6\,(g)} + 15\,O_{2(g)} \rightarrow 12\,CO_{2(g)} + 6\,H_2O_{(g)} + 6.6\times10^3\ kJ$$

$\Delta H = -6.6\times10^3\ kJ$ / 2 mol C_6H_6

During the reaction, the temperature of the 500.0 mL of water inside the calorimeter increased by 38.0 °C.

T = = ∴ exo

Calorimeter



What mass of benzene underwent combustion?
Show all your work.

1) $Q_{water} = mc\Delta T$
$= (500.0g)\left(4.19\frac{J}{g\cdot°C}\right)(38.0°C)$
$= 80\,000J \times \frac{1kJ}{1000J} = 80.0kJ$

2) $Q_{sub} = -80.0kJ$

3) n_{sub}

4) $\Delta H_{sub} = \frac{Q_{sub}}{n_{sub}}$

$-80.0kJ \times \frac{2mol\ C_6H_6}{-6.6\times10^3kJ} \times \frac{78g}{1mol} =$

$6\times12 = 72$
$6\times1 = 6$
78 g/mol

The mass of benzene that underwent combustion is 1.90 g C_6H_6.

4	3	2	1	0

neutralization = sketch!

17. During a high school chemistry laboratory, a student neutralized 50.0 mL of a sodium hydroxide, NaOH, solution with 25.0 mL hydrochloric acid, HCl solution.

The reaction was observed and the following temperatures were recorded:

$T_i = 20.5\ °C$ $T_f = 29.5\ °C$

The chemical equation for this neutralization reaction is the following:

$$NaOH_{(aq)} + HCl_{(aq)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)} + H_2O_{(l)}$$

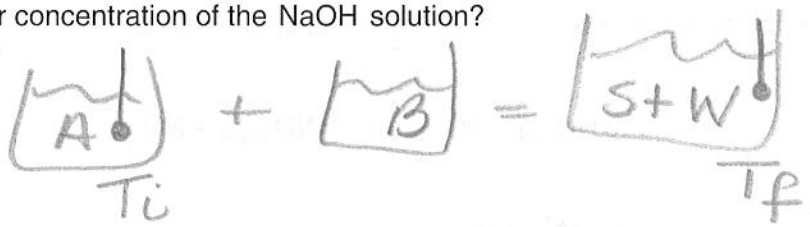
Unfortunately, the student neglected to record the concentration of the NaOH solution.

After research on the internet, the molar heat of neutralization for NaOH was found to be –56.6 kJ/mol. = ΔH

The student then decided to calculate the molar concentration of the NaOH solution. [NaOH] = ? Base

Assume that the specific heat capacity and density of the solutions are the same as those of water.

What was the molar concentration of the NaOH solution?
Show all your work.



1) $Q_{water} = mc\Delta T$

$= (50.0g + 25.0g)\left(4.19\frac{J}{g\cdot°C}\right)(29.5°C - 20.5°$

$= 2.80 \times 10^3\ J$

2) $Q_{sub} = -2.80 \times 10^3\ J = -2.80\ kJ$

3) $n = CV$ (soln!) BASE! 50.0mL = 0.0500L

4) $\Delta H = \frac{Q}{n}$ $\frac{-56.6\ kJ}{1\ mol\ Base}$ NEED [ ] = $\frac{mol}{1L}$!

The molar concentration of NaOH was 1.00 mol/L NaOH.

4	3	2	1	0

$\frac{1\ mol}{-56.6\ kJ} \times \frac{-2.80\ kJ}{1} \times \frac{1}{0.0500L} = 0.99\frac{mol}{L} = 1.00\frac{mol}{L}$

18. Air pollution from the burning of fossil fuels is a major cause of acid rain.

One chemical in air pollution that creates acid rain is nitrogen dioxide, NO_2. Acid rain usually forms high in the clouds where NO_2 reacts with water. This mixture forms a solution of nitric acid, HNO_3.

The equation for this reaction is shown below:

$$3\,NO_{2\,(g)} + H_2O_{(l)} \rightarrow 2\,HNO_{3\,(aq)} + NO_{(g)} \qquad \Delta H = ?$$

first write the ΔHs!

The following equations can be used to determine the ΔH for the formation of acid rain:

$2\,NO_{(g)} + O_{2\,(g)} \rightarrow 2\,NO_{2\,(g)} + 116\ kJ$ ΔH = −116

$2\,N_{2\,(g)} + 5\,O_{2\,(g)} + 2\,H_2O_{(l)} \rightarrow 4\,HNO_{3\,(aq)} + 256\ kJ$ ΔH = −256

$N_{2\,(g)} + O_{2\,(g)} + 183\ kJ \rightarrow 2\,NO_{(g)}$ ΔH = +183

What is the ΔH for the formation of acid rain in the equation below?
Show all your work.

$$3\,NO_{2\,(g)} + H_2O_{(l)} \rightarrow 2\,HNO_{3\,(aq)} + NO_{(g)}$$

$\frac{3}{2} \times 2NO_2 \rightarrow \frac{3}{2} \times 2NO + \frac{3}{2}O_2$ $\frac{3}{2}(+116) = 170$

$\frac{2N_2}{2} + \frac{5O_2}{2} + \frac{2H_2O}{2} \rightarrow \frac{4HNO_3}{2}$ $\frac{(-256)}{2} = -127.5$

$2NO \rightarrow N_2 + O_2$ -183

The ΔH for the formation of acid rain is ~130 kJ/1 mol NO.

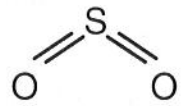
4	3	2	1	0

19. Humans have had a negative impact on the sulphur cycle.

Coal and natural gas contain large amounts of hydrogen sulphide, H_2S. Hydrogen sulphide is burned in the presence of oxygen, O_2, producing water, H_2O, and sulphur dioxide, SO_2, as shown in the following equation:

$$2\,H_2S_{(g)} + 3\,O_{2\,(g)} \rightarrow 2\,H_2O_{(l)} + 2\,SO_{2\,(g)}$$

The structural formula for SO_2 is shown below:



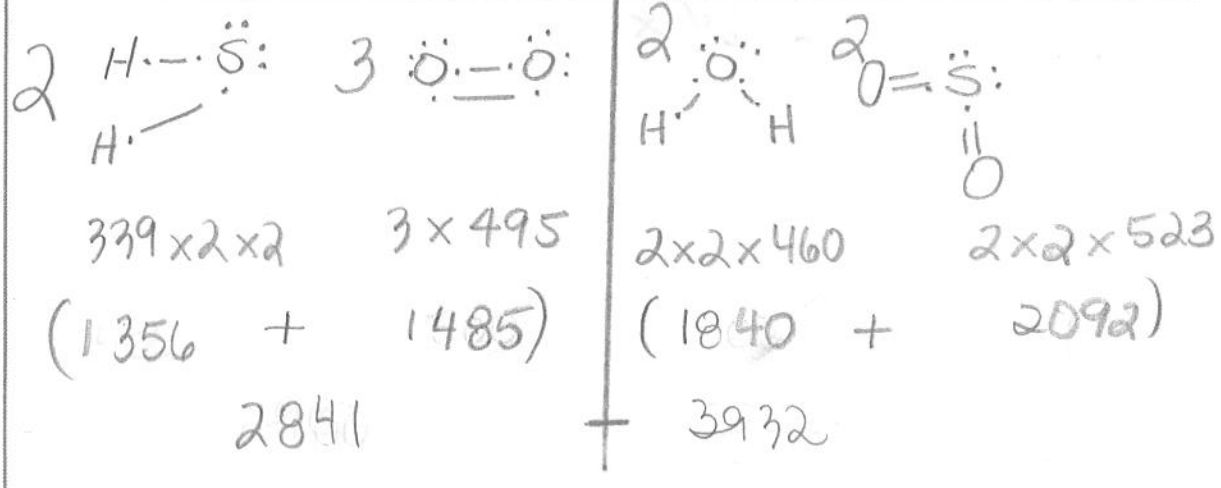
The table of bond energies is shown below.

Average enthalpy associated with breaking of certain bonds in kJ

C – H	413	C – O	358	O = O	495
O – H	460	O – O	146	S = O	523
S – H	339	S – O	347		

What is the ΔH of this reaction?
Use the table of bond energies above. Show all your work.

$$2\,H_2S_{(g)} + 3\,O_{2\,(g)} \rightarrow 2\,H_2O_{(l)} + 2\,SO_{2\,(g)}$$



The ΔH of this reaction is -1091 kJ.

4	3	2	1	0

20. Hydrochloric acid, HCl, is used in steel pickling.

Steel pickling is the process by which iron oxide, Fe_2O_3, is removed from the surface of steel by converting the oxide to soluble compounds. The reaction is illustrated below.

$$Fe_2O_{3\,(s)} + 6\,HCl_{(aq)} \rightarrow 2\,FeCl_{3\,(aq)} + 3\,H_2O_{(l)}$$

An industrial chemist wishes to change the rate of this reaction by doubling the concentration of HCl and decreasing the mass of the Fe_2O_3 by half.

What is the effect of these changes on the reaction rate?
Show all your work. Include the algebraic expression.

$$Fe_2O_{3\,(s)} + 6\,HCl_{(aq)} \rightarrow 2\,FeCl_{3\,(aq)} + 3\,H_2O_{(l)}$$

rate = $k[HCl]^6$

$= k(2)^6$

rate =

∴ if rate = 1 when [HCl] = 1
then rate = 64 x

(1) cannot change the conc of a S so not included in the rate expression

(2) rate depends on [R] = has ∅ to do with the P

The reaction rate will increase ☒ **OR** decrease ☐ by a factor of 64.
(Check one box.)

4	2	1	0

there is a Chemistry God!

yes!

$[O_2] = \frac{0.500\ mol}{1L} = 0.500$

21. A 1.00 L flask is filled with 2.00 mol of carbon, C, and 0.500 mol of oxygen, O_2. The reaction reaches equilibrium. At equilibrium, the concentration of carbon dioxide, CO_2, is determined to be 0.250 mol/L. The equation is shown below.

$$2\,C_{(s)} + O_{2\,(g)} + \text{energy} \rightleftharpoons 2\,CO_{2\,(g)}$$

What is the equilibrium constant, K_c, of this reaction?
Show all your work.

	$2C$	$+ O_2 \rightleftharpoons$	$2CO_2$
R		0.500M	Ø
I			
C		−0.125	+0.250
E		0.375 M	0.250 mol/L

solid get rid of bec can't change [ ]!

$0.250\ \frac{mol}{L} \times \frac{1\ mol\ O_2}{2\ mol\ CO_2} = 0.125\ \frac{mol}{L}\ O_2$ lost

$$K_{eq} = \frac{[CO_2]^2}{[O_2]} = \frac{(0.250)^2}{(0.375)} = 0.167$$

The equilibrium constant, K_c, of this reaction is 0.167.

4	3	2	1	0

22. A student examines the equilibrium of a system at a temperature of 20.0 °C.

The two different coloured cobalt (II) complex ions, $Co(H_2O)_6^{2+}$ and $CoCl_4^{2-}$, exist together in solution in the presence of chloride ions. The reaction is shown below.

$$Co(H_2O)_6^{2+}{}_{(aq)} + 4\,Cl^-{}_{(aq)} + \text{energy} \rightleftharpoons CoCl_4^{2-}{}_{(aq)} + 6\,H_2O_{(l)}$$

pink *blue*

The temperature of the system is decreased to 10.0 °C and the student observes a colour change.

Using *Le Châtelier's Principle*, discuss what colour changes will be observed by the student as a result of the temperature change on the system.

stress = ↓T

want = ↑T

shift = ← colour = more pink

4	2	1	0

23. Chromium hydroxide green, $Cr(OH)_3$, is a colourant used in hair dye. The $Cr(OH)_3$ dissolves in water according to the following equation:

$$\underset{x}{Cr(OH)_{3\,(s)}} \rightleftharpoons \underset{x}{Cr^{3+}_{\ (aq)}} + \underset{3x}{3\,OH^-_{\ (aq)}} \qquad K_{sp} = 6.3\times10^{-31}$$

Determine the molar concentration of Cr^{3+} ions and the molar concentration of OH^- ions in a saturated solution of chromium oxide.
Show all your work.

$Ksp = [Cr^{3+}][OH^-]^3$

$= (x)(3x)^3$

$6.3\times10^{-31} = 27x^4$

$x = 1.2\times10^{-8}\ \frac{mol}{L} = [Cr^{3+}]$

$\times 3$

$3.6\times10^{-8}\ M = [OH^-]$

The molar concentration of Cr^{3+} is $1.2\times10^{-8}\ M$.

The molar concentration OH^- is $3.6\times10^{-8}\ M$.

4	3	2	1	0

24. A student compares two weak bases, ammonia, NH_3, and urea, NH_2CONH_2 at 25° C.

The results are listed below.

Ammonia, NH_3	**Urea,** NH_2CONH_2
Ionization: $NH_{3\,(aq)} + H_2O_{(l)} \rightleftharpoons NH_4^{+}{}_{(aq)} + OH^-{}_{(aq)}$	Ionization: $NH_2CONH_{2\,(aq)} + H_2O_{(l)} \rightleftharpoons NH_2CONH_3^{+}{}_{(aq)} + OH^-{}_{(aq)}$
pH = 11.6 pOH = 2.4	$K_b = 1.3 \times 10^{-14}$
Equilibrium concentration = 0.93 M	Equilibrium concentration = 1.0 M

Which of the two bases has the greater relative strength? Explain your answer.
Show all your work.

NH_3

pOH 2.4 $\therefore$ $[OH^-] = 4.0 \times 10^{-3}$ M

$$\% \text{ ion} = \frac{4.0 \times 10^{-3} \text{ M}}{0.93 \text{ M}} \times 100 = 0.43\% = 4.3 \times 10^{-1}\%$$

OR $K_b = \frac{(4.0 \times 10^{-3})^2}{0.93} = 1.7 \times 10^{-5}$

UREA

$$K_b = \frac{[B^-][OH^-]}{[BOH]} = 1.3 \times 10^{-14} = \frac{x^2}{1.0\text{M}} \Rightarrow x = 1.1 \times 10^{-7} \text{ M}$$

$$\% \text{ ion} = \frac{1.1 \times 10^{-7} \text{ M}}{1.0 \text{ M}} \times 100$$

$$= 1.1 \times 10^{-5}\%$$

The base with the greater relative strength is NH_3.

Explanation:

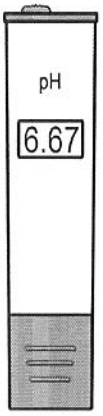
- higher % ionization
- higher K_A

4	3	2	1	0

25. A student measured the pH of water at 47 °C with a pH meter.

The following measurement was recorded on the pH meter below:

pH Meter



⇒ [H+]

Water dissociates as follows:

$$2\,H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$$

What is the K_w of water at this temperature?
Show all your work. Significant figures will be evaluated in this question.

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

$[H^+] = \log^{-pH} = \log^{-6.67}$

$[H^+] = 2.14 \times 10^{-7}\ M$ = the new neutral

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

$K_w = [H^+][OH^-] = (2.14 \times 10^{-7})^2$

new $K_w = 4.58 \times 10^{-14}$

The K_w of water is 4.58×10^{-14}.

4	3	2	1	0