Part A

Questions 1 to 14
Blacken the letter that corresponds to your answer in the answer booklet.

1 The pressure inside an aerosol spray can is approximately 118 kPa at 25.0°C. The can will rupture at an internal pressure of 202 kPa.

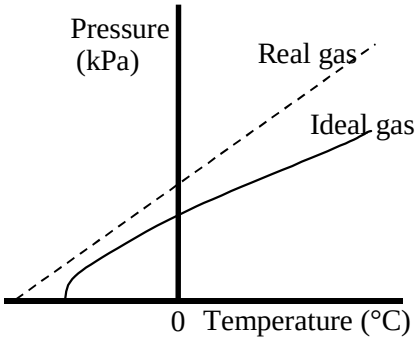
At what temperature will this occur?

A) 22°C
B) 45°C
C) 237°C
D) 510°C

2 The illustrator of a chemical textbook wants to create a graph showing gas behaviour. The graph must show the difference between the behaviour of an ideal gas (using a solid line) and the behaviour of a real gas (using a dotted line).

Which of the graphs below shows the correct representation of both an ideal gas and a real gas?

A)



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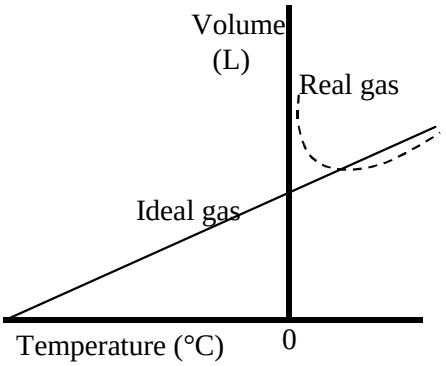

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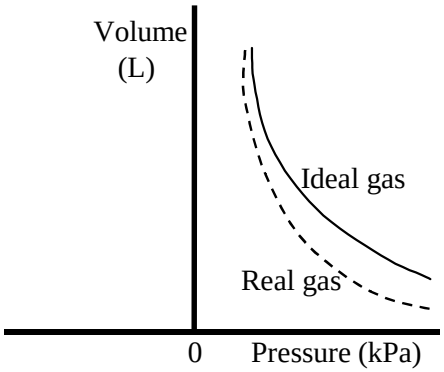

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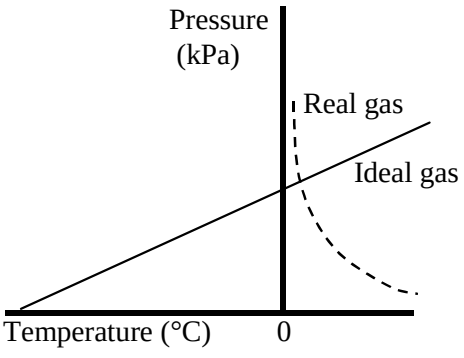


3 A student was asked to fill up 2 identical balloons to the same volume. Each balloon must be filled with a different gas from the cylinders below. The cylinders will be completely emptied after the balloons have been filled. (All balloons are inflated under the same conditions).

Which 2 cylinders when completely emptied will fill up the 2 balloons to the same volume?

1. 

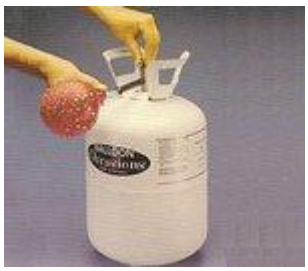
Carbon Dioxide Gas Cylinder

5.0 L
25.0°C
200 kPa

2. 

Oxygen Gas Cylinder

5.0 L
25.0°C
300 kPa

3. 

Helium Gas Cylinder

12.0 L
25.0°C
200 kPa

4. 

Neon Gas Cylinder

8.0 L
25.0°C
300 kPa

A) 1 and 2

B) 2 and 4

C) 1 and 3

D) 3 and 4

4 During respiration, gases diffuse from the alveoli in the lungs into the blood stream. When someone breathes in a smoke filled room, the following gases are present:

CO CO_2 O_2 H_2O

Which of the following combinations ranks these gases in their ability to diffuse from fastest to slowest?

A) CO, O_2, CO_2, H_2O

B) H_2O, CO, O_2, CO_2

C) CO_2, O_2, CO, H_2O

D) H_2O, O_2, CO, CO_2

5 **Which of the following activities represent an endothermic process?**

1. 

Ice cube melting

2. 

Dry ice subliming

3. 

Solvent evaporating in nail polish

4. 

Frost forming on windshield

5. 

Match burning

A) 1, 2 and 3

B) 1, 2 and 4

C) 2, 3 and 4

D) 3, 4 and 5

6 The specific heat capacity of $Fe_{(s)}$ is 0.45 J/g°C and that of $Al_{(s)}$ is 0.90 J/g°C.

Given the same mass of solid aluminum (Al) and iron (Fe), which of the following is true?

A) The amount of energy required to raise the temperature of Fe one degree Celsius is twice that of Al.

B) The amount of energy required to raise the temperature of Al one degree Celsius is twice that of Fe.

C) The amount of energy removed from Fe that has cooled one degree Celsius is twice that of Al.

D) The same amount of energy is required to raise the temperature of Fe and Al one degree Celsius.

7 In the petro-chemical industry it is often necessary to "crack" larger molecules into smaller molecules, as shown in the reaction below.

$$C_4H_9OH_{(l)} + 4\ H_{2(g)} \rightarrow 4\ CH_{4(g)} + H_2O_{(g)}$$

What is the ΔH of this reaction?

You may use any of the reactions in the table below in your work.

ΔH of Reactions
in kilojoules per mole of product
T = 25°C P = 101.0 kPa

					ΔH
$C_{(s)}$	+	$O_{2(g)}$	$\rightarrow$	$CO_{2(g)}$	-393 kJ
$C_{(s)}$	+	$2\ H_{2(g)}$	$\rightarrow$	$CH_{4(g)}$	-76 kJ
$4\ C_{(s)}$	+ $5\ H_{2(g)}$ +	$1/2\ O_{2(g)}$	$\rightarrow$	$C_4H_9OH_{(l)}$	-326 kJ
$H_{2(g)}$	+	$1/2\ O_{2(g)}$	$\rightarrow$	$H_2O_{(g)}$	-242 kJ
$H_{2(g)}$	+	$1/2\ O_{2(g)}$	$\rightarrow$	$H_2O_{(l)}$	-285 kJ

A) -263 kJ

B) -872 kJ

C) -318 kJ

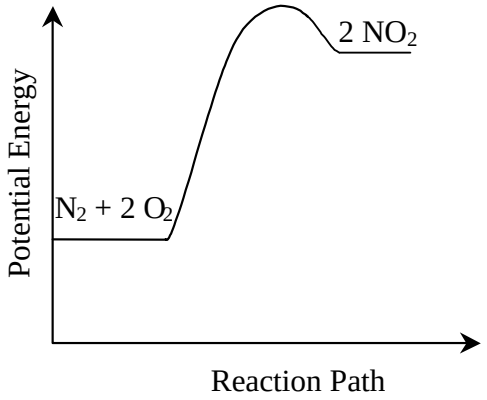
D) -220 kJ

8 Chemical reactions fall into two general categories. Some reactions are spontaneous while other reactions are non-spontaneous.

The graphs of four reactions all occurring at the same temperature, are shown below. The potential energy axes are drawn to the same scale.

Which reaction is most likely to be spontaneous?

A)



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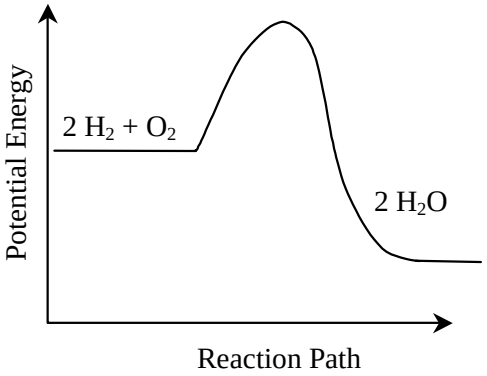

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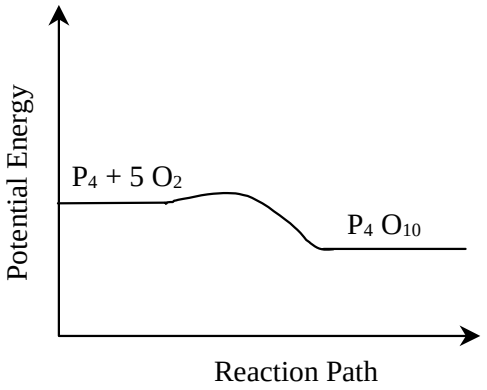
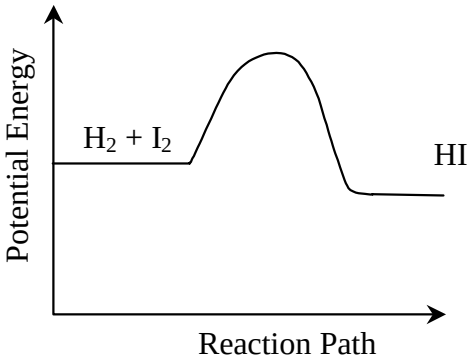
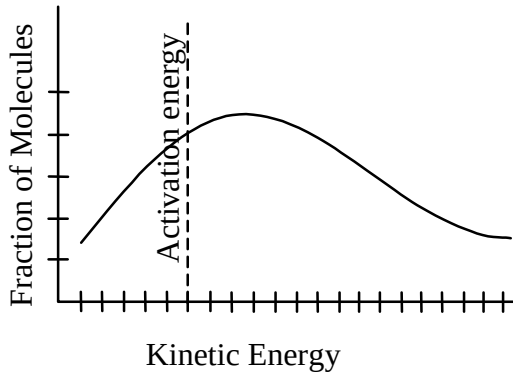


D)

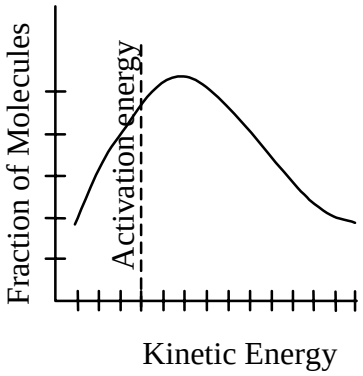


9 The graph below shows the distribution of energy for a sample of molecules. A catalyst is added and the temperature decreased.



Which of the following graphs represents the change that would occur?

A)



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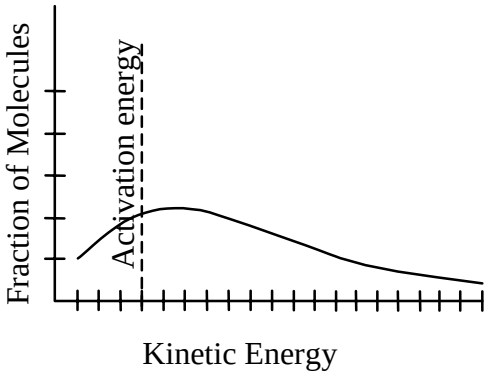

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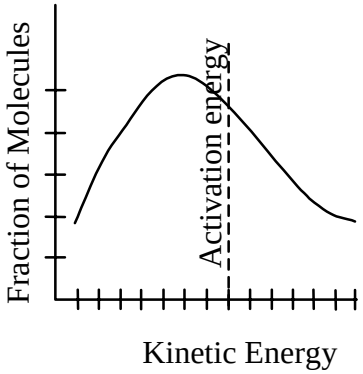
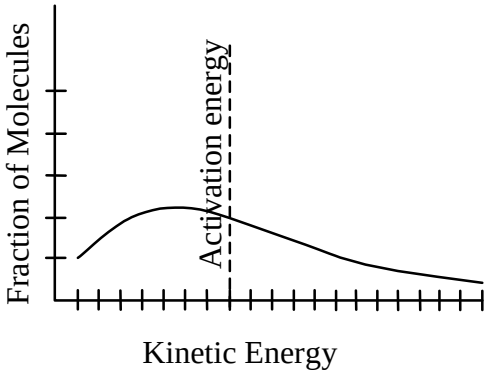


D)



10 When nitrogen and oxygen are mixed, the following reaction can occur:

$$N_2 + O_2 \rightarrow 2\ NO$$

When these two gases (N_2 and O_2) are mixed at 25°C and 101.3 kPa, the amount of NO gas produced is negligible.

Why is so little NO gas produced in this reaction at 25°C and 101.3 kPa?

A) The attractive forces between the molecules are negligible and so very few collisions can take place.

B) The collisions between molecules are perfectly elastic and so no new molecules can be produced.

C) The molecules are too far apart to provide enough collisions to give a significant reaction rate.

D) The collisions between molecules are not energetic enough to break the bonds of the reactant molecules.

11 Copper ions react with chloride ions to form equilibrium with $CuCl_4^{2-}$ ions. One such example is the following:

$$Cu^{2+}_{(aq)} + 4\ Cl^-_{(aq)} \leftrightarrow CuCl_4^{2-}{}_{(aq)}$$

Which of the following actions will decrease the concentration of Cl^- ions when added to this system?

1) Add a 0.5 M $CuCl_2$ solution, producing Cu^{2+} + and Cl^-
2) Add 3 g of NaCl, producing Na^+ and Cl^-
3) Add 3 g $Cu(NO_3)_2$, producing Cu^{2+} and NO_{3-}
4) Add 3 g $CuSO_4$, producing Cu^{2+} and SO_4^{2-}

A) 1 and 2
B) 1 and 4
C) 2 and 3
D) 3 and 4

12 The following system is at equilibrium:

$$N_2O_{4(g)} \leftrightarrow 2\ NO_{2(g)}$$

How is the system affected when its volume is decreased?

A) The amount of N_2O_4 and NO_2 remains constant.

B) The amount of N_2O_4 increases due to a pressure increase.

C) The amount of NO_2 increases due to a pressure increase.

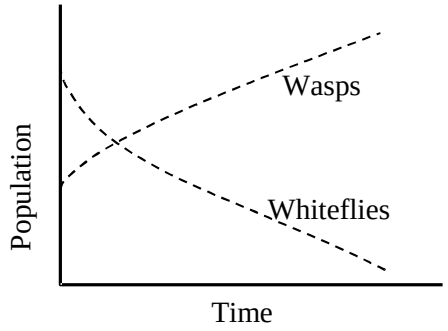
D) The amount of N_2O_4 increases due to a pressure decrease.

13 Operators of greenhouses must contend with a great variety of insect pests. Biological controls are available, which avoid the environmental contamination resulting from toxic chemicals. The Whitefly is a greenhouse pest that can be controlled by introducing the wasp, "Encarsia formosa".

The graphs below show the results of four tests done in greenhouses with typical Whitefly infestations.

In which of these tests have the investigators succeeded in establishing equilibrium between the Whitefly and the wasp populations?

A)



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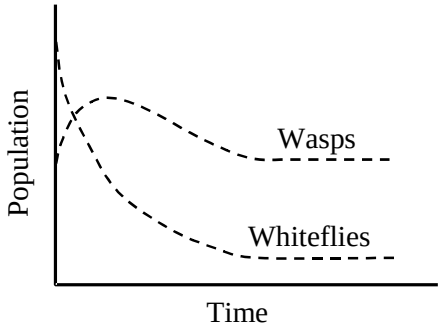

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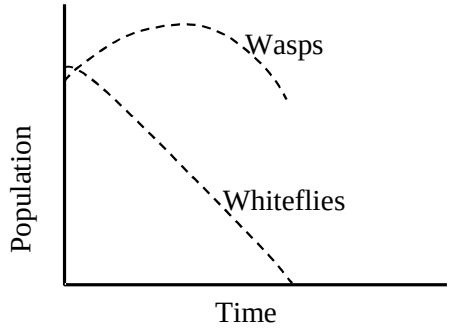
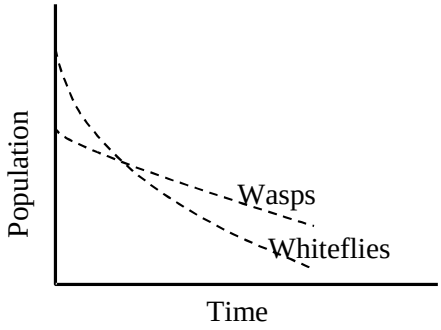


D)



14 The ionization constant (K_w) of water is 1×10^{-14} at 25°C.

$$H_2O + \text{energy} \leftrightarrow H^+ + OH^-$$

If the temperature of the water is increased to 50°C, which of the following will occur?

A) The K_w is unaffected by temperature and remains 1×10^{-14}.

B) K_w is a constant that does not change.

C) There will be a shift to re-establish equilibrium and K_w will decrease.

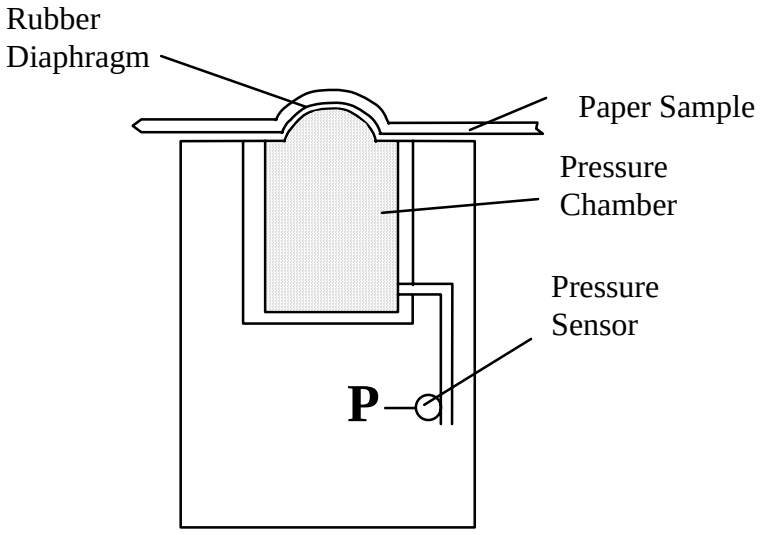
D) There will be a shift to re-establish equilibrium and K_w will increase.

Parts B, C, D and E of the examination comprise questions for which you must show all your work. Answer these questions in the answer booklet. Show all the work needed to solve the problem: **data given, explanations, formulas** and **calculations**. Then write your answer 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. Where necessary, corrections will take into account the units of measurement; however, significant figures will not be considered.

Part B

Questions 15, 16, 17 and 18
Choose any **three** of these questions and answer them in the answer booklet.

15 Pulp and paper mills must test the physical properties of the paper they produce. One of the properties is burst pressure. This is the pressure at which the paper will tear. Technicians change the pressure inside a chamber to which the paper is attached. The gas particles in the chamber push up on a rubber diaphragm, which in turn pushes up on a sheet of paper until it bursts.



A technician burst a piece of newspaper at 156 kPa. Fine stationery requires double the bursting pressure. To test a stationery sample, the technician tripled the moles of gas and halved the volume.

Show mathematically how the temperature must be adjusted under the new conditions in order to double the bursting pressure.

16 The standard value for R is 8.31 $\frac{\text{kPa} \bullet \text{L}}{\text{mol} \bullet \text{K}}$. Over time atmospheric pressure has been measured using many different units, including:

101.3 kPa
1 atmosphere (atm)
760 mm Hg
407 inches H_2O

What would be the ideal gas constant, *R*, if the pressure were measured in inches H_2O? (Use standard units for *V*, *n*, *T*.)

17 Research scientists investigating the chemistry of the element fluorine have produced a compound of sulphur and fluorine. An analysis shows that these two atoms are present in a ratio of one to five (1:5). The simplest formula for this compound would then be SF_5. It is possible, however, that the formula of this compound might be S_2F_{10} or S_3F_{15}.

In order to decide the molecular formula of this compound, a technician empties a flask and proceeds to fill the flask with oxygen (O_2) gas. The flask is then emptied again and filled with the gaseous compound of sulphur and fluorine. The data from this experiment is shown below:

Mass of empty flask	=	76.411 g	
Mass of flask and oxygen (O_2)	=	79.078 g	*Both gases measured at the same pressure and temperature.*
Mass of flask and compound	=	97.578 g	

Determine the molecular formula of this compound.

18 Liquid vegetable oil can be converted into solids (like margarine) by a process called hydrogenation. Such a reaction can be seen below:

$$(C_{17}H_{33}COO)_3C_3H_{5(l)} + 3H_{2(g)} \rightarrow (C_{17}H_{35}COO)_3C_3H_{5(s)}$$

Olein Stearin

Assume that 3.00×10^3 L of hydrogen gas at 25.0°C and 101.3 kPa is entered into the reaction.

What mass of Olein is hydrogenated?

Part C

Questions 19, 20, 21 and 22
Choose any **three** of these questions and answer them in the answer booklet.

19 A chemistry student found five unmarked oily liquids in a refrigerated cabinet in a lab. Using the concept of characteristic properties, the student decided to identify the liquid using calorimetry.

The student took 100 mL of water at 27.1°C and then added 20.0 g of the oily substance, which was at 4.2°C. The final temperature of the mixture was 24.7°C.

Using the table of specific heat capacities, identify the unknown liquid.

Liquid	**Specific Heat Capacity J/g°C**
Anilin	2.18
Castor Oil	1.8
Citron Oil	1.84
Ethylene glycol	2.22
Glycerine	2.43

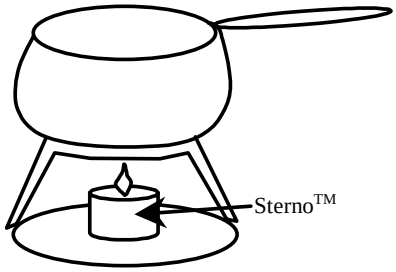
20 You were asked to mix 20.0 mL of a 1.0 M HCl solution with 100.0 mL of a 1.0 M NaOH solution. The initial temperature of both solutions was 18.9°C. The temperature of the final solution was 21.1°C.
Assume HCl and NaOH have the same specific heat capacity and density as water.

What is the ΔH/mol for the neutralization of HCl?

21 Sterno™, a solid, portable fuel also known as Canned Heat®, is burned in camp stoves or fondue pots. Its composition is mainly gelled ethanol, C_2H_5OH.

Cooking oil used in fondue pots has a specific heat capacity of 2.01 J/g°C and a density of 0.92 g/cm^3.

At a dinner party, the temperature of 500.0 mL of cooking oil in a fondue pot was increased from 25.0°C to 300.0°C.

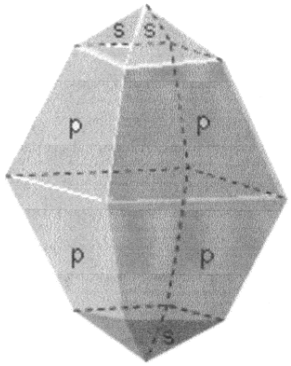


Given that ethanol burns as follow:

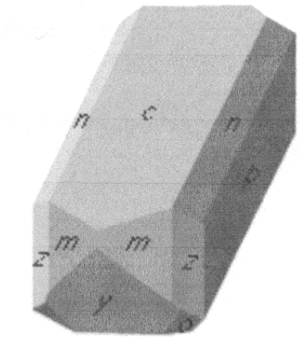
$C_2H_5OH_{(s)} + 3\ O_{2(g)} \rightarrow 2\ CO_{2(g)} + 3\ H_2O_{(g)}$ ΔH = -278 kJ/mol

How many grams of ethanol were burned in order to heat the oil to 300°C?

22 Pure sulphur is found in more than one crystalline form. Two of these forms can be represented by the symbols S_σ and S_β (shown below).



S_σ



S_β

Each of these can be burned in oxygen as shown below.

$S_\sigma + O_{2(g)} \rightarrow SO_{2(g)}$ ΔH = -294 kJ
$S_\beta + O_{2(g)} \rightarrow SO_{2(g)}$ ΔH = -299 kJ

Which form of sulphur has the higher enthalpy?
Explain your work.

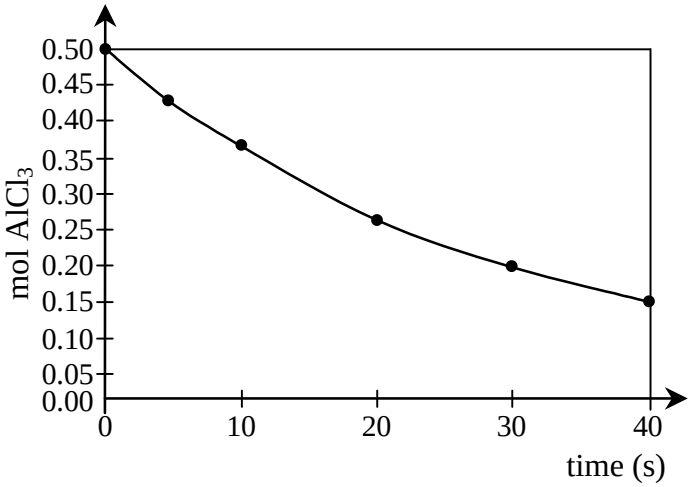
Part D

Questions 23, 24 and 25
Choose any **two** of these questions and answer them in the answer booklet.

23 A student was studying the electrolysis of 1 L of aqueous aluminum chloride ($AlCl_{3(aq)}$) according to the following equation:

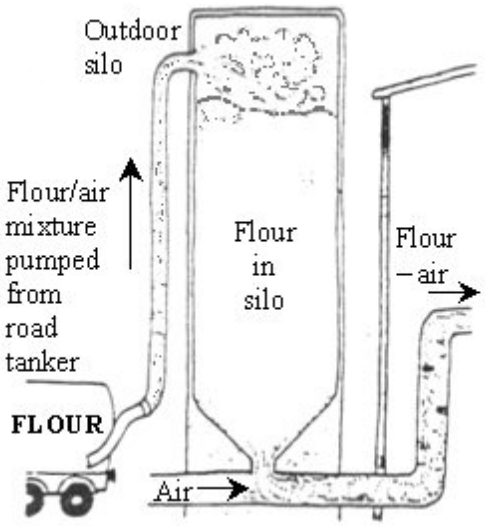
$$2\ AlCl_{3(aq)} \xrightarrow{\text{Electrical Energy}} 2Al_{(s)} + 3\ Cl_{2(g)}$$

Moles of $AlCl_3$ versus time



Using the graph above, calculate the average rate of formation of chlorine gas from 10 s to 20 s.

24 A small explosion and fire recently occurred when the flour inside a silo combusted.



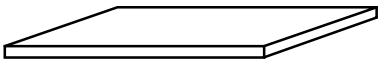
Explain what might have caused the fire.

Your explanation must take into account the factors affecting the rate of combustion and make reference to the collision theory.

25 A student conducted an experiment to measure the rate of the following reaction between calcium carbonate and hydrochloric acid:

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

The experiment was done with a very thin rectangular slab of marble, ($CaCO_3$). The time required for the evolution of CO_2 gas is noted in the table below.

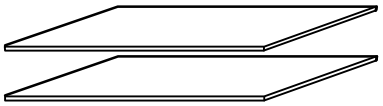


marble slab

Volume of gas	5 mL	10 mL	15 mL	20 mL	25 mL	30 mL
Elapsed time	8 s	15 s	22 s	30 s	37 s	45 s

At the end of 30 seconds, the marble slab was not significantly smaller than it was at the start.

The slab was then cut into two layers along its length, as shown on the right, and the experiment was repeated. All other factors remained constant



marble slab

Fill in reasonable values for the times required for the evolution of CO_2 gas in this second experiment in the table below.

Volume of gas	5 mL	10 mL	15 mL	20 mL	25 mL	30 mL
Elapsed time						

What was the average rate of reaction in the second experiment? Include units.

Part E

Questions 26, 27, 28 and 29
Choose any **three** of these questions and answer them in the answer booklet.

26 Sulfur dioxide gas ($SO_{2(g)}$), an air pollutant responsible for acid rain, is produced at coal-burning electrical power plants. Sulfur impurities in the coal result in sulphur dioxide.

A solid metal catalyst might be used to reverse this process before $SO_{2(g)}$ can be released into the atmosphere.

$$SO_{2(g)} \xleftrightarrow{\text{metal catalyst}} S_{(s)} + O_{2(g)}$$

Scientists studying this problem placed 0.50 moles of sulphur dioxide in a 10.0 L reaction vessel. They followed the reaction at a temperature for which the equilibrium constant, K_{eq}, was 2.4×10^{-2}.

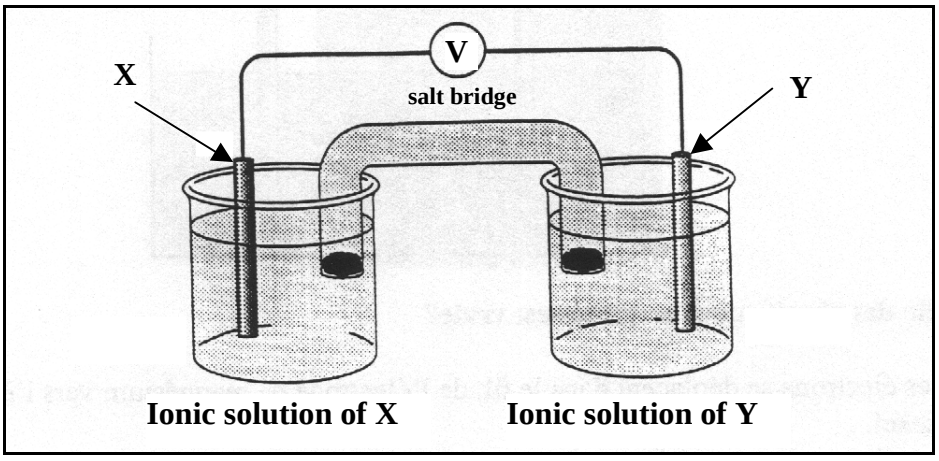
What will be the concentrations of the components at equilibrium?

27 Good quality vinegar usually has about 60 grams of acetic acid (CH_3COOH) per litre of solution. Sometimes unscrupulous suppliers water down the vinegar before bottling it. You have tested a recent batch of vinegar and found it to have a pH of 2.4.

$$CH_3COOH_{(aq)} \leftrightarrow CH_3COO^-_{(aq)} + H^+_{(aq)} \quad K_a = 1.8 \times 10^{-5}$$

Determine whether or not this vinegar has been watered down.

28 As part of a lab exam, a student was asked to set up an electrochemical cell in order to obtain a maximum voltage.



The student has a choice of the following electrodes:

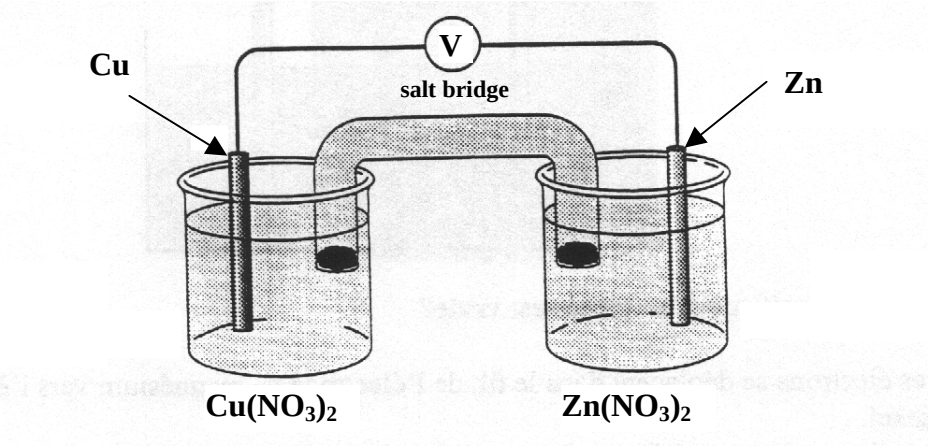
Silver(Ag)
Cobalt (Co)
Lead (Pb)
Magnesium (Mg)

1. **Write the balanced redox equation for the cell that will produce the maximum voltage.**

2. **Determine the cell potential, $E°$.**

3. **What would be the reducing agent?**

29 In order to study the effect of Le Chatelier's principle on electrochemical cells, a student decided to set up the following electrochemical cell:



The student had a 0.1 mol/L solution of copper nitrate, $Cu(NO_3)_2$, as well as three concentrations of zinc nitrate, $Zn(NO_3)_2$:

0.1 mol/L
0.5 mol/L
1.5 mol/L

1. **What is the net ionic equation for this reaction?**

2. **In terms of Le Chatelier's principle, explain which concentration of $Zn(NO_3)_2$ will best favour the rate of the reverse net ionic reaction.**

3- CORRECTION KEY

Part A

4 marks or 0 marks

1 C

2 B

3 D

4 B

5 A

6 B

7 D

8 B

9 A

10 D

11 D

12 B

13 C

14 D

Part B

15 **Example of an appropriate and complete solution**

1. $\dfrac{P_1V_1}{n_1T_1} = \dfrac{P_2V_2}{n_2T_2}$ $\quad\therefore\ T_2 = \dfrac{P_2V_2n_1T_1}{P_1V_1n_2}$

2. Set P_1, V_1, n_1 and $T_1 = 1$

$$T_2 = \frac{(2\cancel{P_1})\left(\frac{1}{2}\cancel{V_1}\right)(\cancel{n_1})(T_1)}{(\cancel{P_1})(\cancel{V_1})(3\cancel{n_1})} = \frac{1}{3}T_1$$

Answer: The temperature must change by a factor of $\mathbf{\frac{1}{3}}$.

16 **Example of an appropriate and complete solution**

$PV = nRT$

P = 407 inches H_2O
V = 22.4 L
n = 1 mol
$R = x$
T = 273 K

(407 inches H_2O) (22.4 L) = (1.00 mol) (x) (273 K)

$$x = \frac{33.4\ \text{inches}\ H_2O \bullet L}{\text{mol} \bullet K}$$

Answer: The ideal gas constant is $\mathbf{\dfrac{33.4\ inches\ H_2O \bullet L}{mol \bullet K}}$.

17 **Example of an appropriate and complete solution**

Mass of O_2 = 79.078 g – 76.411 g = **2.667 g** of O_2

Mass of other gas = 97.578 g – 76.411 g = **21.167 g** of other gas

Since these masses represent equal volume and therefore equal moles of gases:

$$\frac{\text{molar mass of } O_2}{\text{molar mass of unknown gas}} = \frac{32\text{ g}}{x} = \frac{2.667\text{ g}}{21.167\text{ g}}$$

x = molar mass of unknown gas = 254 g

Since the molar mass of S_2F_{10} is 254 g, the unknown gas is S_2F_{10}.

Answer: The unknown gas is **S_2F_{10}**.

18 **Example of an appropriate and complete solution**

1. $PV = nRT$
   $(101.3)(3.00 \times 10^3) = n(8.31)(298)$
   $123 = n$

2. $$\frac{1(C_{17}H_{33}COO)_3C_3H_5}{x} = \frac{3\,H_2}{123}$$
   x = 41.0 mols

3. $n = \frac{m}{mm}$ mm = 884 g/mol
   $41.0 = \frac{m}{884}$
   m = 36 200 g or 36.2 kg

Answer: The mass of hydrogenated Olein is **36 200 g or 36.2 kg**.

Part C

19 **Example of an appropriate and complete solution**

$Q_{oil} = -Q_{water}$

$m_{oil} \times c_{oil} \times \Delta T_{oil} = m_{water} \times c_{water} \times \Delta T_{water}$

20.0 g × c_{oil} × 20.5°C = 100 mL × 4.19 J/g°C × 2.40°C

c_{oil} = 2.45 J/g°C

Answer: The unknown liquid is **glycerine**.

20 **Example of an appropriate and complete solution**

Mass

$120.0 \text{ mL} \times 1.0 \text{ g/mL} = 120.0 \text{ g}$

Specific heat

4.19 J/g°C

$\Delta q = m \times c \times \Delta T$
$= (120)(4.19)(2.2)$
$= 1100 \text{ J}$
$= -1100 \text{ J (or } -1.1 \text{ kJ)}$

$0.02 \text{ L HCl} \times 1.0 \dfrac{\text{mol}}{\text{L}} \text{ HCl} = 0.02 \text{ moles HCl}$

$\Delta H = \dfrac{\Delta q}{n}$
$= \dfrac{-1.1 \text{ kJ}}{0.02 \text{ mols}}$
$= -55 \text{ kJ/mol}$

Answer: The ΔH for the reaction is **-55 kJ/mol**.

21 **Example of an appropriate and complete solution**

$Q = mc\Delta T$ for the oil

$0.92 \dfrac{\text{g}}{\cancel{\text{cm}}^3} \times 500.0 \cancel{\text{mL}} = 460 \text{ g}$

$Q = 460 \text{ g} \times 2.01 \dfrac{\text{J}}{\text{g°C}} \times (300.0\text{°C} - 25.0\text{°C})$

$= 250\,000 \text{ J or } 2.5 \times 10^2 \text{ kJ}$ of heat energy to increase the temperature of the oil

$\dfrac{1 \text{ mol ethanol}}{-278 \text{ kJ}} \times 2.5 \times 10^2 \text{ kJ} \times \dfrac{46.0 \text{ g}}{1 \text{ mol ethanol}}$

$= 42 \text{ g}$ ethanol required

Answer: **42 g** of ethanol was burned to heat the oil.

22 **Examples of an appropriate and complete solution**

Approach #1

$$\begin{array}{lll} S_\beta + \cancel{O_{2(g)}} & \rightarrow \cancel{SO_{2(g)}} & \Delta H = -299 \text{ kJ} \\ \underline{\cancel{SO_{2(g)}} \quad\quad\quad\quad} & \underline{\rightarrow S_\sigma + \cancel{O_{2(g)}} \quad\quad\quad\quad} & \underline{\Delta H = +294 \text{ kJ}} \\ S_\beta & \rightarrow S_\sigma & \Delta H = -5 \text{ kJ} \end{array}$$

Because the net reaction above is exothermic, the energy released must have been stored as potential energy in S_β. Therefore S_β has 5 kJ more enthalpy than S_σ.

Approach #2

$$\begin{array}{lll} S_\sigma + \cancel{O_{2(g)}} & \rightarrow \cancel{SO_{2(g)}} & \Delta H = -294 \text{ kJ} \\ \underline{\cancel{SO_{2(g)}} \quad\quad\quad\quad} & \underline{\rightarrow S_\beta + \cancel{O_{2(g)}} \quad\quad\quad\quad} & \underline{\Delta H = +299 \text{ kJ}} \\ S_\sigma & \rightarrow S_\beta & \Delta H = +5 \text{ kJ} \end{array}$$

Because the net reaction above is endothermic, the energy absorbed is being stored in the product (S_β) as a potential energy. Therefore S_β has 5 kJ more enthalpy than S_σ.

Approach #3

Burning S_β produces 5 kJ more energy than burning S_σ. Since the burning reactions are identical except for the sulphur, the "extra" 5 kJ in the second reaction must have been stored in the S_β. Therefore the S_β has 5 kJ more energy than the S_σ.

Answer: S_β has the higher enthalpy.

Part D

23 **Example of an appropriate and complete answer**

1. At 20 s, $[AlCl_3] = 0.28$ mol
   At 10 s, $[AlCl_3] = 0.37$ mol **(moles $AlCl_3$ ±0.02 mol)**

   $0.37 \text{ mol} - 0.28 \text{ mol} = 0.09 \text{ mol } AlCl_3$

2. $$0.09 \text{ mol } AlCl_3 \times \frac{3 \text{ mol } Cl_2}{2 \text{ mol } AlCl_3} = 0.14 \text{ mol } Cl_2$$

3. $$\frac{0.14 \text{ mol } Cl_2}{20 \text{ s} - 10 \text{ s}} = 0.014 \frac{\text{mol}}{\text{s}} Cl_{2(g)}$$

Answer: The average rate of formation of $Cl_{2(g)}$ between 10 s and 20 s was **0.014** $\frac{\textbf{mol}}{\textbf{s}}$

24 **Example of an appropriate and complete solution**

The surface area of the flour has been greatly increased and is mixing with the oxygen in the air.

By increasing the surface area, more effective collisions will occur between the flour and the oxygen, thereby increasing the rate of the reaction.

25 **=Example of an appropriate and complete solution**

In the second experiment, the marble slab is sliced into two parts. As a consequence, the surface area of the marble will be doubled and the rate will double.

Since this is experimental data, some variation (± 1 sec) in the data and in the answers must be allowed. The final time must be close to 23 sec ($\approx \frac{45}{2}$).

Answer:

Volume of gas	5 mL	10 mL	15 mL	20 mL	25 mL	30 mL
Elapsed time	**4 s**	**8 s**	**11 s**	**15 s**	**19 s**	**22 s**

The surface area of the four edges of the slab is not doubled when the slab is cut but this will be a very minor factor given that the slab of marble is said to be “very thin”.

Calculate the rate:

$$\text{Average rate} = \frac{30 \text{ mL of } CO_2}{22 \text{ s}}$$

$$= \frac{1.4 \text{ mL of } CO_2}{\text{s}}$$

Answer: The average rate of reaction in the second experiment is $\mathbf{\frac{1.4 \text{ mL of } CO_2}{s}}$.

Part E

26 **Example of an appropriate and complete answer**

	$SO_{2(g)}$	$\longleftrightarrow$	$S_{(s)}$	$+ O_{2(g)}$
R				
I	$\frac{0.5\ \text{mol}}{10\ \text{L}}$		—	—
C	$-x$		—	$+x$
E	$0.05 - x$		—	x

$$K_{eq} = \frac{[O_2]}{[SO_2]} = 2.4 \times 10^{-2}$$

$$\frac{x}{0.05\ \frac{\text{mol}}{\text{L}} - x} = 2.4 \times 10^{-2}$$

$$x = 1.2 \times 10^{-3} - 2.4 \times 10^{-2}\, x$$

$$x = 1.2 \times 10^{-3}$$

$[O_2] = 0.0012$ mol/L $\qquad$ $[SO_2] = 0.049$ mol/L

If student states that the change in concentration is negligible, we calculate by:

$$[SO_2] = \frac{0.5\ \text{mol}}{10\ \text{L}} = 0.05\ \text{mol/L}$$

$$K_{eq} = \frac{[O_2]}{[SO_2]} = 2.4 \times 10^{-2}$$

$$\frac{[O_2]}{0.05\ \frac{\text{mol}}{\text{L}}} = 2.4 \times 10^{-2}$$

O_2 at equilibrium $= 1.2 \times 10^{-3}$ mol/L

	$SO_{2(g)}$	$\longleftrightarrow$	$S_{(s)}$	$+ O_{2(g)}$
R				
I	0.05 mol/L		—	—
C	-0.0012 mol/L		—	+ 0.0012 mol/L
E	0.045 mol/L		—	0.0012 mol/L

$[O_2] = 0.0012$ mol/L $\qquad$ $[SO_2] = 0.049$ mol/L

Answer: The equilibrium concentration of **SO_2 is 0.049 mol/L and of O_2 is 0.0012 mol/L**.
Note: If student states x is negligible, accept procedure as correct.

27 **Example of an appropriate and complete solution**

Approach #1

Find the pH of good quality vinegar

Molarity of Acetic Acid

$$\frac{60\text{ g } CH_3COOH}{1\text{ litre of solution}} = 1.0\text{ M } CH_3COOH \text{ solution}$$

$$\frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = \frac{x \bullet x}{1.0\text{ M}}$$

$$x^2 = 1.8 \times 10^{-5}$$

$$x = 4.24 \times 10^{-3}\text{ M}$$

$$\text{pH} = 2.37 = 2.4$$

This pH matches that of the sample, therefore this vinegar is good.

Approach #2

Find the "K_a" of the acid in the sample assuming the solution is 1.0 M CH_3COOH.

Since the pH is 2.4, the $[H^+] = 4.24 \times 10^{-3}$ M

$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]}$$

$$= \frac{(4.24 \times 10^{-3}\text{ M})^2}{1.0\text{ M}}$$

$$= \mathbf{1.8 \times 10^{-5}}$$

This K_a matches that of acetic acid so clearly the solution of the sample was 1.0 M in CH_3COOH (i.e. Good quality).

Answer: The vinegar **has not** been watered down.

28 **Example of an appropriate and complete answer**

1. $2\ Ag^{+} + \cancel{2e^{-}} \rightarrow 2\ Ag_{(s)}$ +0.80 V

   $\underline{Mg_{(s)} \rightarrow Mg^{2+} + \cancel{2e^{-}}}$ +2.37 V

   $2\ Ag^{+} + Mg_{(s)} \rightarrow 2\ Ag_{(s)} + Mg^{2+}$

   2 marks

2. E° = **3.17 V**

   1 mark

3. **Mg** is the reducing agent.

   1 mark

29 **Example of an appropriate and complete answer**

1. $Zn_{(s)} + Cu^{2+}_{(aq)} \rightarrow Zn^{2+}_{(aq)} + Cu_{(s)}$

   Note: Accept $\leftrightarrow$ in the equation also.

2. Adding Zn ions to the system causes a stress on the system. The higher the concentration of zinc ions the more the system will shift to rid this stress by shifting to the reactants. The result is an increase in copper ions. The highest concentration (1.5 M) of $Zn(NO_3)_2$ will be the most favourable to increase the rate of the reverse reaction.