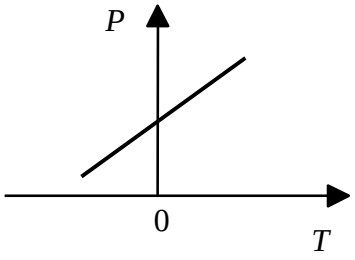
CHEMISTRY 534
EXAM #1
JUNE 2009

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

1 **Which of the following graphs represents the pressure of a gas as a function of temperature in Kelvin?**
The volume of the gas is constant.

A)


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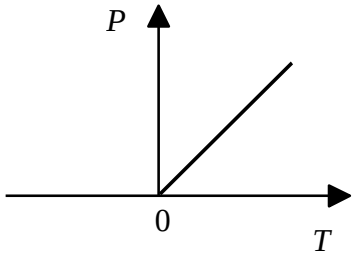

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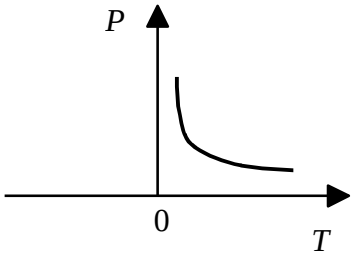

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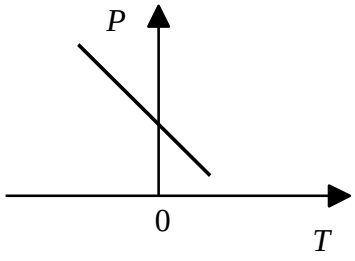


2 Consider the following statements about the properties of an ideal gas.

1. The molecules of an ideal gas have negligible volume.
2. There are no intermolecular attractions in an ideal gas.
3. The mass of an ideal gas is always less than the mass of a real gas.
4. An ideal gas will obey the gas laws at all pressures and temperatures.

Which of the statements about the properties of an ideal gas are TRUE?

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

3 A diver is sitting at the bottom of a pool. She opens her mouth and releases a bubble of air that rises up to the surface. The pressure at the bottom of the pool is 291 kPa. At the surface, the pressure is 101 kPa. Just as the bubble breaks the surface, it has a volume 145 mL.

What was the volume of the air bubble at the bottom of the pool?

A) 0.0199 mL
B) 50.3 mL
C) 195 mL
D) 418 mL

4 Peter has a purple balloon. On the ground, the balloon has a volume of exactly 2.0 L when it is filled to a pressure P_1. The air temperature is 23°C. Peter lets go of the balloon and it rises up into the air. Eventually it reaches an altitude where its volume has increased to 2.4 L, the air temperature is only 3.0°C, and the pressure in the balloon is P_2.

Which of the following shows the correct relationship between pressures P_2 and P_1?

A) $P_2 = 1.3\ P_1$

B) $P_2 = 1.1\ P_1$

C) $P_2 = 0.78\ P_1$

D) $P_2 = 0.11\ P_1$

5 The following are examples of changes that occur in nature:

- Dew forming on grass
- Icicles forming on trees
- Forest fires burning

Which statements below are TRUE concerning all of these changes?

1. The enthalpy of the reactants is greater than the enthalpy of the products.
2. The enthalpy of the reactants is less than the enthalpy of the products.
3. The changes require an overall addition of energy.
4. The changes require an overall release of energy.

A) 1 and 3

B) 1 and 4

C) 2 and 3

D) 2 and 4

6 The following two equations show the molar heats of formation of liquid carbon tetrachloride, $CCl_{4(l)}$, and gaseous carbon tetrachloride, $CCl_{4(g)}$.

$$C_{(s)} + 2\ Cl_{2(g)} \rightarrow CCl_{4(l)} \qquad \Delta H = -139.5\ kJ/mol$$
$$C_{(s)} + 2\ Cl_{2(g)} \rightarrow CCl_{4(g)} \qquad \Delta H = -103.2\ kJ/mol$$

Using these heats of formation, the molar heat of vaporization of carbon tetrachloride can be determined.

Which of the following is the correct molar heat of vaporization of CCl_4?

A) -242.7 kJ/mol

B) 242.7 kJ/mol

C) -36.3 kJ/mol

D) 36.3 kJ/mol

7 Platinum–gold alloys are often used in the production of fine jewellery. The alloys are 90% by mass platinum and 10% by mass gold. During the fabrication of the alloy, the two metals are heated separately to a temperature that exceeds their melting points by 100.0°C and are then mixed.

Consider the following information and assume that no heat is lost to the surroundings.

Property	Platinum	Gold
Melting point (°C)	1768	1064
Specific heat capacity (J/g•°C)	0.1300	0.1300

What is the final temperature of the mixture?

A) 1798°C
B) 1698°C
C) 1516°C
D) 1416°C

8 The chart below lists water temperatures and types of molecular motion.

Water temperature	Molecular Motion
1. 500 K	a. rotation
2. 358 K	b. vibration
3. 225 K	c. translation

Which combination below correctly matches each water temperature with the predominant type of molecular motion that characterizes water at that temperature?

A) 1a, 2c and 3b
B) 1b, 2a and 3c
C) 1c, 2b and 3a
D) 1c, 2a and 3b

9 A student performed an experiment on the decomposition of hydrogen peroxide, H_2O_2. She performed the experiment twice, once without a catalyst and once with a catalyst. After each trial, she recorded her observations in a table and then made a graph of her data using the same scale. Unfortunately, she dropped all of her tables and graphs and they were mixed up! Her papers are shown below.

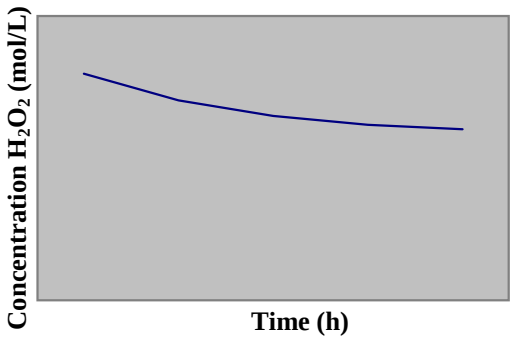
Table 1

Initial $[H_2O_{2(aq)}]$	Final $[H_2O_{2(aq)}]$	Elapsed time
0.20 mol/L	0.18 mol/L	6 hours

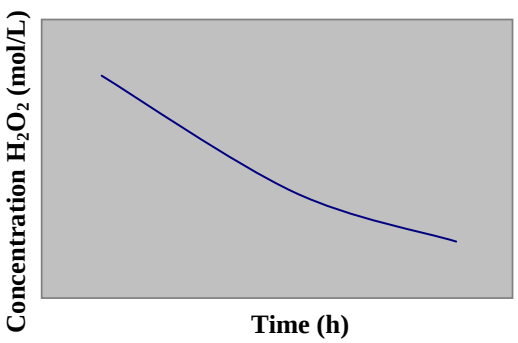
Table 2

Initial $[H_2O_{2(aq)}]$	Final $[H_2O_{2(aq)}]$	Elapsed time
0.20 mol/L	0.10 mol/L	6 hours

Graph 3



Graph 4



Which combination of table and graph represents the trial with a catalyst added?

A) Table 1 and graph 3

B) Table 1 and graph 4

C) Table 2 and graph 3

D) Table 2 and graph 4

10 You are producing aluminum bromide, $AlBr_3$, at an average rate of 0.67 mol/min based on the following balanced equation:

$$3\ CaBr_{2(aq)} + Al_2(SO_4)_{3(aq)} \rightarrow 3\ CaSO_{4(s)} + 2\ AlBr_{3(aq)}$$

What is the rate of consumption of calcium bromide, $CaBr_2$, in g/min?

A) 2.0×10^2 g/min

B) 8.9×10^1 g/min

C) 1.0 g/min

D) 4.5×10^{-1} g/min

11 The temperature in the following hypothetical equilibrium system is increased.

$$A_{(g)} + 2B_{(g)} \leftrightarrow C_{(g)} + D_{(g)} \quad \Delta H = -250 \text{ kJ/mol}$$

Which of the following statements are TRUE?

1. The increase in temperature favours the exothermic direction.
2. The increase in temperature favours the endothermic direction.
3. The increase in temperature will increase the concentration of A and B.
4. The increase in temperature will increase the concentration of C and D.

A) 1 and 3

B) 1 and 4

C) 2 and 3

D) 2 and 4

12 **What is the mathematical expression for the equilibrium constant for the following hypothetical reaction?**

$$2\ A_{(s)} + B_{(aq)} \leftrightarrow C_{(l)} + 3\ D_{(aq)} + 5\ E_{(g)}$$

A) $K_{eq} = \dfrac{[C_{(l)}][D_{(aq)}]^3[E_{(g)}]^5}{[A_{(s)}]^2[B_{(aq)}]}$

B) $K_{eq} = \dfrac{[A_{(s)}]^2[B_{(aq)}]}{[C_{(l)}][D_{(aq)}]^3[E_{(g)}]^5}$

C) $K_{eq} = \dfrac{[B_{(aq)}]}{[D_{(aq)}]^3[E_{(g)}]^5}$

D) $K_{eq} = \dfrac{[D_{(aq)}]^3[E_{(g)}]^5}{[B_{(aq)}]}$

13 The following chemical system is placed into a sealed container at a constant temperature and allowed to reach equilibrium.

$$UO_{2(s)} + 4HF_{(g)} \leftrightarrow UF_{4(g)} + 2\ H_2O_{(g)}$$

The equilibrium constant for the reaction at this temperature is 2.0. Once equilibrium is established, the concentrations of HF and UF_4 are both 0.20 mol/L.

What is the equilibrium concentration of $H_2O_{(g)}$ in the container?

A) 0.063 mol/L

B) 0.13 mol/L

C) 0.26 mol/L

D) 2.0 mol/L

14 The table below shows some of the results obtained after placing four solid metallic elements into four corresponding aqueous metal ion solutions.

	$A^+(aq)$	$B^+(aq)$	$C^+(aq)$	$D^+(aq)$
A(s)				No reaction
B(s)				
C(s)		Reaction		
D(s)		No reaction		

Which of the following sequences correctly lists the metallic solids in increasing order of their tendency to undergo oxidation?

A) A, C, D, B

B) A, D, B, C

C) B, D, C, A

D) C, B, D, A

Part B Questions 15, 16, 17, and 18 (Answer three questions only.)

If you answer all questions in this section, **draw a line through the question that you do not want to have corrected**. If you do not, questions 15, 16 and 17 will be corrected.

15 Xanthe, the laboratory technician, ordered two gas cylinders of equal volumes. One cylinder contains nitrogen gas, N_2, and the other cylinder contains carbon dioxide gas, CO_2.

Xanthe has the following information from the catalogue:

Cylinder of Nitrogen Gas

Mass of empty cylinder: 45.205 kg
Mass of filled cylinder: 45.317 kg

Cylinder of Carbon Dioxide Gas

Mass of empty cylinder: 48.112 kg

The delivery charge for the order is based on the total mass of the shipment. In order to budget for the delivery charge, Xanthe needs to calculate the mass of the filled cylinder of carbon dioxide gas.

Assuming that both gases are at equal temperature and pressure, what is the mass of the filled cylinder of carbon dioxide gas?

16 A number of different gases are used in the electrical industry as an insulating medium for high-voltage circuit breakers, switchgears, and other types of electrical equipment. These often replace oil-filled circuit breakers that can contain harmful toxic chemicals called polychlorinated biphenyls (PCBs).

A chemist was hired by a railway company to determine which gas was being used in a railway switchgear. The chemist collected the following data:

Volume of gas sample taken	97.3 mL
Temperature of gas sample	20.0°C
Pressure of gas sample	100.0 kPa

The chemist calculated the density of the gas sample to be 6.00 g/L.
According to the data, which of the following gases was present in the switchgear?

1. CO_2 2. SF_6 3. C_2H_6 4. CF_2Cl_2 5. SO_3 6. UF_6

Justify your choice.

17 You are conducting experiments to investigate the relationship between the pressure, the volume and the temperature of three unknown gases. You obtain the following results:

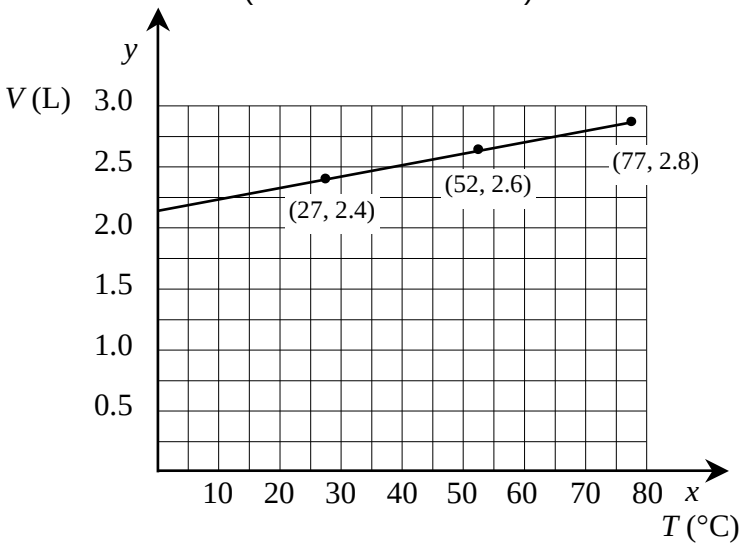
Gas A
Volume vs. Pressure
(*n* and *T* are constant)

Pressure (kPa)	Volume (L)
100	25.00
125	20.00
200	12.50
400	6.25
500	5.00

Gas B
Pressure vs. Temperature
(*n* and *V* are constant)

Temperature (°C)	Pressure (kPa)
21.0	100
42.0	200
63.0	300
84.0	400
105.0	500

Gas C
Volume vs. Temperature
(*n* and *P* are constant)



For each gas, identify the behaviour of the gas as ideal or non-ideal.
Justify your answer with calculations for each gas.

18 In 1784, Jacques Charles made the first ascent in a hydrogen-filled balloon. He produced the hydrogen for his balloon by reacting sulphuric acid, H_2SO_4, with iron filings, Fe, according to the following balanced chemical reaction.

$$Fe_{(s)} + H_2SO_{4(aq)} \rightarrow H_{2(g)} + FeSO_{4(aq)}$$

The reaction consumed 5.0×10^2 L of 18 mol/L sulphuric acid. Assume he collected the hydrogen gas at a pressure of 100.8 kPa and a temperature of 19°C.

What volume of hydrogen gas would Jacques Charles have produced?

Part C Questions 19, 20, 21, and 22 (Answer three questions only.)

If you answer all questions in this section, **draw a line through the question that you do not want to have corrected**. If you do not, questions 19, 20 and 21 will be corrected.

19 In many parts of the world, ethanol is now being used as an additive to reduce the amount of gasoline used for automobiles. Inside the engine, ethanol, C_2H_5OH, reacts with oxygen, O_2, to produce carbon dioxide, CO_2, water, H_2O, and heat in the following reaction:

$$C_2H_5OH + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(g)} + 1364\ kJ$$

A spark plug provides 368 kJ of energy per mole of ethanol, which is required to initiate the reaction.
Assume the enthalpy of the reactants is –235 kJ per mole of ethanol.
In your answer booklet, draw a potential energy graph for the combustion of 1 mole of ethanol.
Show the appropriate calculations to justify your answer.

20 Propane, C_3H_8, is used as an alternative to gasoline, C_8H_{18}, with claims that it contributes less to global warming. The following equations represent the combustion reactions for these two fuels:

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

$$C_8H_{18(g)} + 12.5\ O_{2(g)} \rightarrow 8\ CO_{2(g)} + 9\ H_2O_{(g)}$$

Given the following heat of formation reactions:

$$3C_{(s)} + 4\ H_{2(g)} \rightarrow C_3H_{8(g)} \qquad \Delta H = -103.7\ \frac{kJ}{mol}$$

$$8C_{(s)} + 9\ H_{2(g)} \rightarrow C_8H_{18(g)} \qquad \Delta H = -208.4\ \frac{kJ}{mol}$$

$$H_{2(g)} + \frac{1}{2}\ O_{2(g)} \rightarrow H_2O_{(g)} \qquad \Delta H = -242.0\ \frac{kJ}{mol}$$

$$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)} \qquad \Delta H = -393.5\ \frac{kJ}{mol}$$

How much more energy per mole of carbon dioxide produced is provided by the combustion of propane compared with the combustion of gasoline?

21 A biofuel is any fuel that can be derived from a living biological source. One advantage of a biofuel is that it is biodegradable, and thus relatively harmless to the environment, if spilled.

An example of a biofuel is ethanol, C_2H_5OH. It can be extracted from plants such as corn.

As an experiment, a chemistry student extracted a mixture containing ethanol from corn and decided to test its purity by measuring its heat of combustion.

The student burned the ethanol mixture in a calorimeter and recorded the following data.

Mass of extracted sample of ethanol	2.30 g
Mass of water heated by extracted ethanol	5.00×10^2 g
Initial temperature of the water	19.0°C
Final temperature of the water	49.0°C
$\Delta H_{combustion}$ of 100% pure ethanol	-1367 kJ/mol

A fuel that is at least 90% pure is an acceptable biofuel.

Assume that all the heat released is from the combustion of the ethanol.

Is the extracted ethanol mixture an acceptable biofuel?

22 In the laboratory, students are given an unknown crystalline solid and are asked to identify it. They are given a calorimeter filled with 250 mL of distilled water at 25°C and a table of known heats of solution for three substances.

Substance	Heat of solution (kJ/mol)
Lithium chlorate, $LiClO_3$	-26.59
Potassium hydroxide, KOH	-57.56
Sodium chloride, NaCl	-74.78

A student dissolved 4.67 g of the solid in the water in the calorimeter and noted that the resulting temperature was 30.7°C.

Assume no heat is lost to the surroundings.

Which solid was used in the experiment?

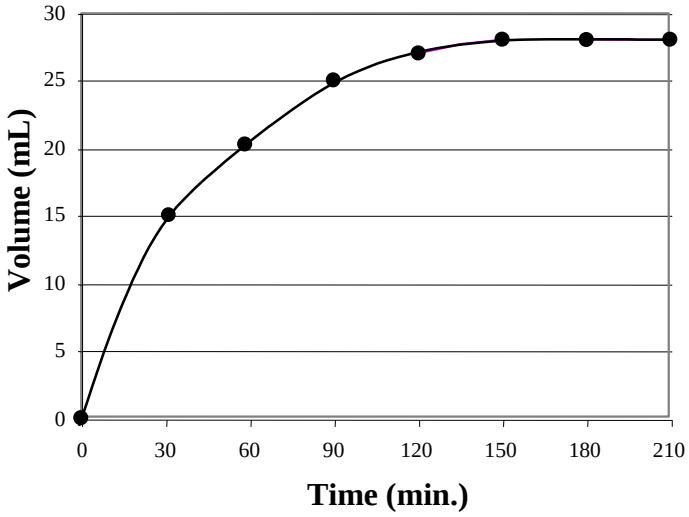
Part D	Questions 23, 24 and 25 (Answer two questions only.) If you answer all questions in this section, **draw a line through the question that you do not want to have corrected**. If you do not, questions 23 and 24 will be corrected.

23 In recent years, architects and builders have noticed that the longevity of copper roofs in some areas of the country has been greatly reduced because of the damaging effects of acid rain. In order to estimate the life of a copper roof, scientists in the laboratory reacted copper strips with dilute nitric acid according to the following chemical reaction:

$$Cu_{(s)} + 4\ HNO_{3(aq)} \rightarrow Cu(NO_3)_{2(aq)} + 2\ NO_{2(g)} + 2\ H_2O_{(l)}$$

To estimate the rate of decomposition of the copper, scientists collected the nitrogen dioxide, NO_2, produced by the reaction. The graph below shows the amount of nitrogen dioxide collected for various times of the reaction.

Volume of nitrogen dioxide produced (mL) vs. Time (min)



The atmospheric pressure was 101.9 kPa and the temperature was 20.5°C when the experiment was performed.

What is the average rate of consumption of copper, Cu, in g/min, during the first 90.0 minutes of this reaction?

24 A lab technician has to produce a large volume of hydrogen gas to use with a class. As she has very limited materials available to her, she is forced to produce the hydrogen gas by reacting magnesium metal ribbon, Mg, in hydrochloric acid, HCl.

$$Mg_{(s)} + 2\ HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$$

Since she is pressed for time, she wants to produce the hydrogen gas as quickly and as safely as possible.

What are two methods that the lab technician can use to speed up the rate of production of hydrogen gas?

Justify your answers, using the collision theory.

25 The Haber process is the reaction of nitrogen gas, N_2, and hydrogen gas H_2, to produce ammonia, NH_3. The Haber process is important because the ammonia is used to produce fertilizer, which helps produce food crops for one third of the world's population.

The balanced equation for the Haber process is:

$$N_{2(g)} + 3\ H_{2(g)} \rightarrow 2\ NH_{3(g)}$$

The following data chart records the change in concentration of hydrogen gas over time in an industrial preparation of ammonia using the Haber Process.

Time (s)	$[H_2]$ mol/L
0	10.0
30	7.0
60	5.0
90	4.0
120	3.4

What is the average rate of production of ammonia, in mol/L/s, between 30 seconds and 120 seconds?

Part E	Questions 26, 27, 28, and 29 (Answer three questions only.) If you answer all questions in this section, **draw a line through the question that you do not want to have corrected**. If you do not, questions 26, 27 and 28 will be corrected.

26 You are trying to determine the equilibrium constant for a given reaction. You inject 3.5 moles of sulphur dioxide gas, SO_2, and 2.5 moles of oxygen gas, O_2, into a closed 4.0 litre container.

Eventually, the following equilibrium is established:

$$2\ SO_{2(g)} + O_{2(g)} \leftrightarrow 2\ SO_{3(g)}$$

At equilibrium, 3.2 moles of sulphur trioxide gas, SO_3, is present.

What is the equilibrium constant, K_{eq}, for this reaction?

27 Hydrofluoric acid, HF, is so corrosive that it cannot be stored in glass or metal containers.

$$HF_{(aq)} \rightleftharpoons H^+_{(aq)} + F^-_{(aq)} \qquad K_a = 7.2 \times 10^{-4}$$

A 4.0 litre sample of acid is prepared using 40.0 g of hydrogen fluoride.

What is the pH of the hydrofluoric acid solution?

28 Given below is information for three hypothetical acids.

i)

$HA_{(aq)} \leftrightarrow H^+_{(aq)} + A^-_{(aq)}$		
Acid	**Initial acid concentration**	**pH**
$HA_{(aq)}$	0.10 mol/L	2.7

ii)

$HB_{(aq)} \leftrightarrow H^+_{(aq)} + B^-_{(aq)}$		
Acid	**Equilibrium concentration of HB**	**Equilibrium concentration of H^+ ion**
$HB_{(aq)}$	0.074 mol/L	1.3×10^{-4} mol/L

iii)

$HC_{(aq)} \leftrightarrow H^+_{(aq)} + C^-_{(aq)}$	
Acid	**K_a**
$HC_{(aq)}$	4.9×10^{-7}

Use the information above to rank the three acids in increasing order of strength.
Show the appropriate calculations to justify your answer.

29 A chemistry student wants to create an electrochemical cell with a minimum voltage of 3.0 volts. The student has a choice of the following electrodes and solutions.

Metal electrodes available	Aqueous solutions available
Silver (Ag)	1.0 mol/L $AgNO_3$
Magnesium (Mg)	1.0 mol/L $Mg(NO_3)_2$
Zinc (Zn)	1.0 mol/L $Zn(NO_3)_2$

a) What is the net balanced cell equation of the combination that would be successful in producing the desired voltage?

b) What is the standard cell potential, $E°$?

c) What is the reducing agent?

d) What is the name of the electrode indicated on the sketch of the electrochemical cell in the Answer Booklet?

CHEMISTRY 534
EXAM #2
JUNE 2008

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

1 **Which group correctly pairs three of the gases with their uses or hazards?**

A) Nitrogen gas - explosion
Chlorofluorocarbons - refrigeration
Carbon Dioxide - plant respiration

B) Chlorofluorocarbons - ozone depletion
Hydrogen gas - fuel
Carbon Dioxide - global warming

C) Sulphur Dioxide - acid rain
Carbon monoxide - poisoning
Methane Gas - refrigeration

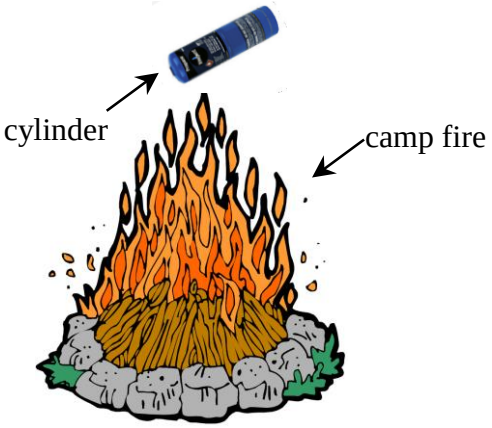
D) Neon Gas - lights
Propane gas - fuel
Nitrogen gas - global warming

2 A company sells gas in steel cylinders. All of the cylinders have the same volume but not the same mass. The mass of each evacuated cylinder is stamped on it. A worker takes the first cylinder, which is stamped 524.3 g and fills it with ammonia gas, NH_3, until its mass is 537.2 g. The worker then takes a second cylinder, stamped 487.6 g, and fills it with fluorine gas, F_2. The contents of both cylinders must be at the same temperature and pressure.

What is the total mass of the second cylinder after it has been filled?

A) 500.5 g
B) 502.0 g
C) 516.4 g
D) 553.1 g

3 A used propane cylinder, containing only air, is accidentally thrown onto a camp bonfire. The initial conditions inside the cylinder are 25°C and 101.3 kPa. The cylinder can withstand an internal pressure of 341 kPa.



Above what temperature will an explosion occur?

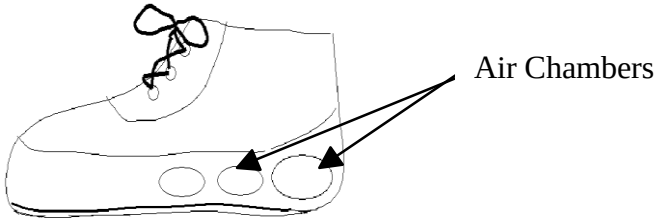
A) 8.42×10^{1} °C

B) 7.30×10^{2} °C

C) 1.00×10^{3} °C

D) 1.28×10^{3} °C

4 To help reduce the stress on the skeletal system, many brands of athletic footwear integrate air chambers into the soles of their shoes. During the hot temperatures of summer, some long distance runners notice that these air chambers enlarge.



Using the kinetic molecular theory of gases, which of the following statements explain why this phenomenon is observed?

A) As the temperature increases, gas molecules increase their volume due to thermal expansion.

B) As the temperature increases, the volume of the gas increases as the pressure inside the air chamber decreases.

C) As the temperature increases, an increase in the collisions between the gas molecules generates heat, causing an increase in the volume of the chambers.

D) As the temperature increases, the gas molecules move faster, resulting in more and stronger collisions that push out the sides of the air chambers into a larger volume.

5 **Which of the following reactions has a reverse reaction that is endothermic?**

A) $2\ H_{2(g)} + O_{2(g)} \rightarrow 2\ H_2O_{(l)} + 572\ kJ$

B) $2\ C_{(s)} + 2\ H_{2(g)} + 52.3\ kJ \rightarrow C_2H_{4(g)}$

C) The decomposition of aluminum chloride absorbs 1408 kJ of energy.

D) $\frac{1}{2}\ H_{2(g)} + \frac{1}{2}\ I_{2(s)} \rightarrow HI_{(g)} \quad \Delta H = +26\ kJ/mol$

6 You have set up a lemonade stand on your street. After a few hours, a customer complained that his lemonade was too warm. You took the temperature of the remaining 250 mL and agreed that lemonade at 24.0°C was indeed unpleasant to drink. Instead of throwing the lemonade out, you simply added 2.0 L of fresh lemonade from the fridge at 4.0°C.

What was the final temperature of the lemonade?

(Assume the density and specific heat capacity of lemonade are the same as water.)

A) 6.2°C

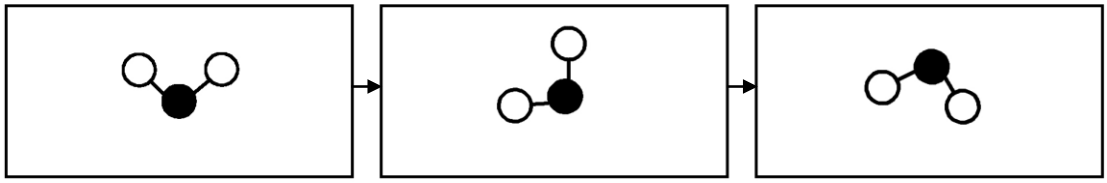
B) 7.0°C

C) 9.3°C

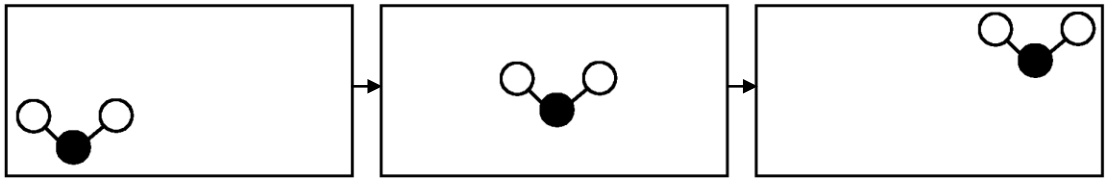
D) 14°C

7 The following diagrams demonstrate various behaviours that a water molecule can exhibit.

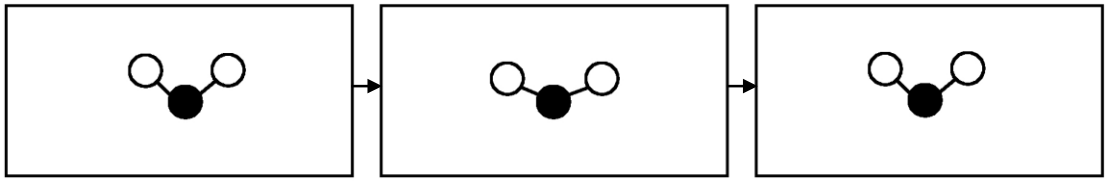
I



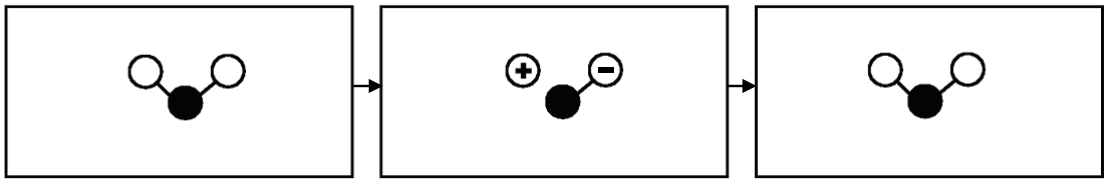
II



III



IV



According to the Kinetic Molecular Theory, which diagrams represent the types of kinetic energy that are predominantly displayed by water molecules in the liquid state?

A) I and II only

B) I and III only

C) II and IV only

D) III and IV only

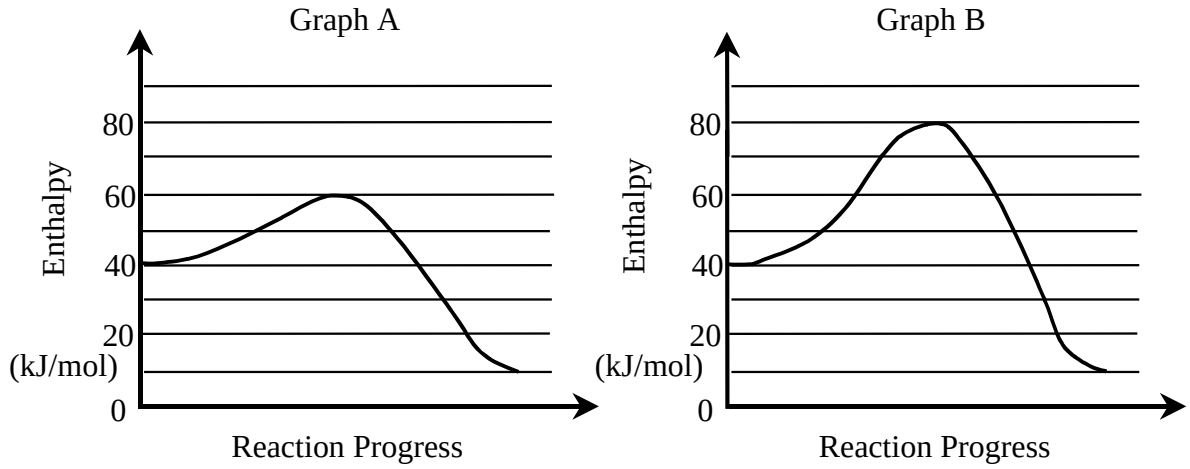
8 Four processes are shown below.

1. Sunlight + 6 $CO_{2(g)}$ + 6 $H_2O_{(l)}$ → $C_6H_{12}O_{6(aq)}$ + 6 $O_{2(g)}$
2. $NaOH_{(s)}$ → $Na^+_{(aq)}$ + $OH^-_{(aq)}$
3. $CH_{4(g)}$ + 2 $O_{2(g)}$ → $CO_{2(g)}$ + 2 $H_2O_{(g)}$
4. $H_2O_{(l)}$ → $H_2O_{(g)}$

Which of these processes are endothermic?

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

9 The following graphs show the enthalpy vs. reaction progress for the same reaction.



Which of the following statements is true?

A) Graph A represents the uncatalyzed reaction and the ΔH is 20 kJ/mol.
B) Graph A represents the uncatalyzed reaction and the ΔH is -30 kJ/mol.
C) Graph B represents the uncatalyzed reaction and the ΔH is 40 kJ/mol.
D) Graph B represents the uncatalyzed reaction and the ΔH is -30 kJ/mol.

10 There are three general categories of forest fires: ground fires, surface fires, and crown fires.

- Ground fires spread across the grass, low-lying vegetation, and through roots. They are fought by digging trenches in the path of the fire.
- Surface fires burn the trunks of trees as well as grass and low-lying vegetation. They are fought by spraying the area with water.
- Crown fires spread across the tops of trees. They are fought by using thick fire retardant foam, usually sprayed from planes.

Which of the following statements is true?

A) Fighting ground fires by digging trenches is effective because it reduces the amount of fuel available to the combustion reaction.

B) Fighting ground fires by digging trenches is effective because it reduces the amount of oxygen available to the combustion reaction.

C) Fighting surface fires by spraying with water is effective because it reduces the amount of oxygen available for the combustion reaction.

D) Fighting crown fires using foam is effective because it reduces the amount of heat available to the combustion reaction.

11 A student wrote the equilibrium constant expressions, K_c, for each of the four reactions below, but only one is correct.

For which equation did the student write the correct K_c expression?

A) $2\ C_2H_{2(g)} + 5\ O_{2(g)} \leftrightarrow 4\ CO_{2(g)} + 2\ H_2O_{(l)}$ $K_c = \dfrac{[CO_2]^4\,[H_2O]^2}{[C_2H_2]^2\,[O_2]^5}$

B) $N_{2(g)} + 2\ O_{2(g)} \leftrightarrow 2\ NO_{2(g)}$ $K_c = \dfrac{[NO_2]}{[N_2][O_2]}$

C) $4\ HCl_{(aq)} + O_{2(g)} \leftrightarrow 2\ H_2O_{(l)} + 2\ Cl_{2(g)}$ $K_c = \dfrac{[HCl]^4\,[O_2]}{[Cl_2]^2}$

D) $2\ KClO_{3(s)} \leftrightarrow 2\ KCl_{(s)} + 3\ O_{2(g)}$ $K_c = [O_2]^3$

12 The ionization equation for water can be written as:

$$H_2O_{(l)} \leftrightarrow H^+_{(aq)} + OH^-_{(aq)}$$

The value for K_w at 25°C is 1.00×10^{-14}. This reaction is endothermic. The temperature is increased to 70°C.

Using Le Chatelier's principle, which of the following could be the pH value of water at 70°C?

A) 6.4
B) 7.0
C) 7.5
D) 14

13 The acidity constants (K_a values) for two different reactions are given below.

I) $H_3PO_{4(aq)} + H_2O_{(l)} \leftrightarrow H_3O^+_{(aq)} + H_2PO_4^-{}_{(aq)}$ $\quad K_a = 7.1 \times 10^{-3}$

II) $H_2CO_{3(aq)} + H_2O_{(l)} \leftrightarrow H_3O^+_{(aq)} + HCO_3^-{}_{(aq)}$ $\quad K_a = 4.4 \times 10^{-7}$

Which of the following statements is true?

A) $H_2PO_4^-$ is a stronger acid than $H_3PO_{4(aq)}$.
B) H_3PO_4 is a stronger acid than $H_2CO_{3(aq)}$.
C) In reaction II, equilibrium favours the formation of HCO_3^- ions.
D) If additional water is added to the H_2CO_3 solution, the K_a will decrease.

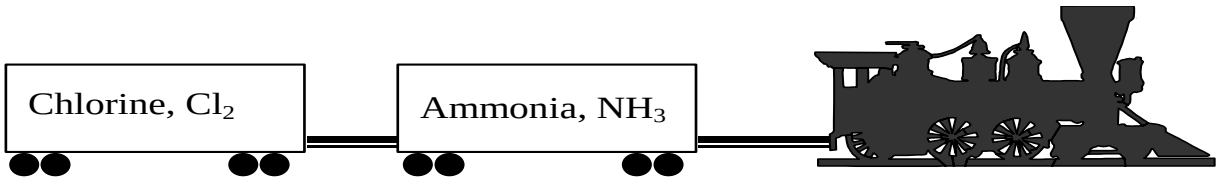
14 A lab technician had an unidentified solution. He poured small amounts of it into three different containers (aluminum, iron, and copper) to determine the most appropriate storage vessel. He observed reactions in the aluminum and iron containers but not in the copper container.

What could the unidentified solution have been?

A) Silver nitrate
B) Magnesium nitrate
C) Lead nitrate
D) Aluminum nitrate

Part B	Questions 15, 16, 17, and 18 (Answer three questions only.) If you answer all questions in this section, **draw a line through the question that you do not want to have corrected**. If you do not, questions 15, 16 and 17 will be corrected.

15 A train is carrying two large tanks of industrial chemicals. During a derailment, the tanks are damaged and two different poisonous gases are released into the atmosphere. Chlorine gas is yellow-green in colour and smells like a mixture of pineapple and pepper. Ammonia gas is colourless and is easily identified by many people because it is commonly used in household cleaners.



Which gas will the students at the nearby high school smell first?

Justify your answer, showing appropriate calculations.

16 A tire store fills its tires with nitrogen gas, N_2. At two o'clock when the temperature is 23°C, the store fills a tire to 315 kPa of pressure and finds that it requires 84.0 g of nitrogen gas. Unfortunately, the tire valve is leaking. At eight o'clock, when the temperature is 15°C, a worker checks the pressure and finds that it has decreased to 235 kPa.

What mass of nitrogen remained in the tire?
(Assume that the capacity of the tire did not change.)

17 A student wants to determine the value of the universal gas constant, R, by studying the following chemical reaction:

$$2\ NaClO_{3(s)} \rightarrow 2\ NaCl_{(s)} + 3\ O_{2(g)}$$

She measures 3.42 g of solid sodium chlorate, $NaClO_3$, into an Erlenmeyer flask and inserts a one-hole rubber stopper fitted with a glass tube. She seals the glass tube with an empty plastic bag. She then slowly heats the Erlenmeyer flask and the plastic bag inflates. When no more gas is being produced, she removes the bag and finds that the volume of gas produced is 1240 mL. The temperature of the gas is 74°C and the pressure is 102.5 kPa.

Calculate the experimental value of the universal gas constant using this data.

18 Ammonia gas, NH_3, is reacted with sulfuric acid, H_2SO_4, to form the important fertilizer ammonium sulphate, $(NH_4)_2SO_4$.

$$2\ NH_{3(g)} + H_2SO_{4(aq)} \rightarrow (NH_4)_2SO_{4(s)}$$

What mass of ammonium sulfate can be produced from 85.0 kL of ammonia gas at STP?

Part C	Questions 19, 20, 21, and 22 (Answer three questions only.) If you answer all questions in this section, **draw a line through the question that you do not want to have corrected**. If you do not, questions 19, 20 and 21 will be corrected.

19 During two experiments, students determine the heats of reaction for the following thermochemical equations:

$NaOH_{(s)} \rightarrow NaOH_{(aq)}$ □□ + 44.2 kJ
$NaOH_{(s)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)} + 100.1$ kJ

In a third experiment, 150.0 mL of aqueous sodium hydroxide, $NaOH_{(aq)}$, is mixed with 150.0 mL of hydrochloric acid, $HCl_{(aq)}$ and the temperature of the solution rises from 25.0°C to 38.0°C.

This reaction is represented by the following equation:

$$NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$$

How many moles of NaOH reacted in the third experiment?

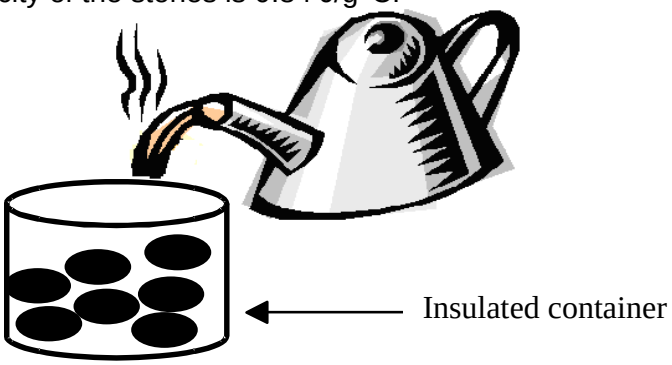
(Assume $NaOH_{(aq)}$ and $HCl_{(aq)}$ have the same specific heat capacity and density as water.)

20 Salicylic acid ($C_7H_6O_3$) is a key ingredient in many skin-care products for the treatment of acne, psoriasis, calluses, and corns. Salicylic acid is also used as an active ingredient in gels that remove warts. To make the gel, chemists must first dissolve tablets containing salicylic acid in water. The heat of solution (ΔH) of salicylic acid is -3.02 kJ/mol.

One tablet containing 3.84 g of salicylic acid is placed in 0.100 L of water.

What is the change in the temperature (ΔT) of the water?

21 During a hot stone massage, smooth pieces of black volcanic rock that absorb and retain heat well are used to relax and prepare muscles for deep tissue treatments. The stones, stored at a room temperature of 21.0°C, must be sanitized and brought to the ideal temperature of 63.0°C by pouring boiling water at 100.0°C over them. Each treatment requires 3.0 kg of stones. The specific heat capacity of the stones is 0.84 J/g°C.



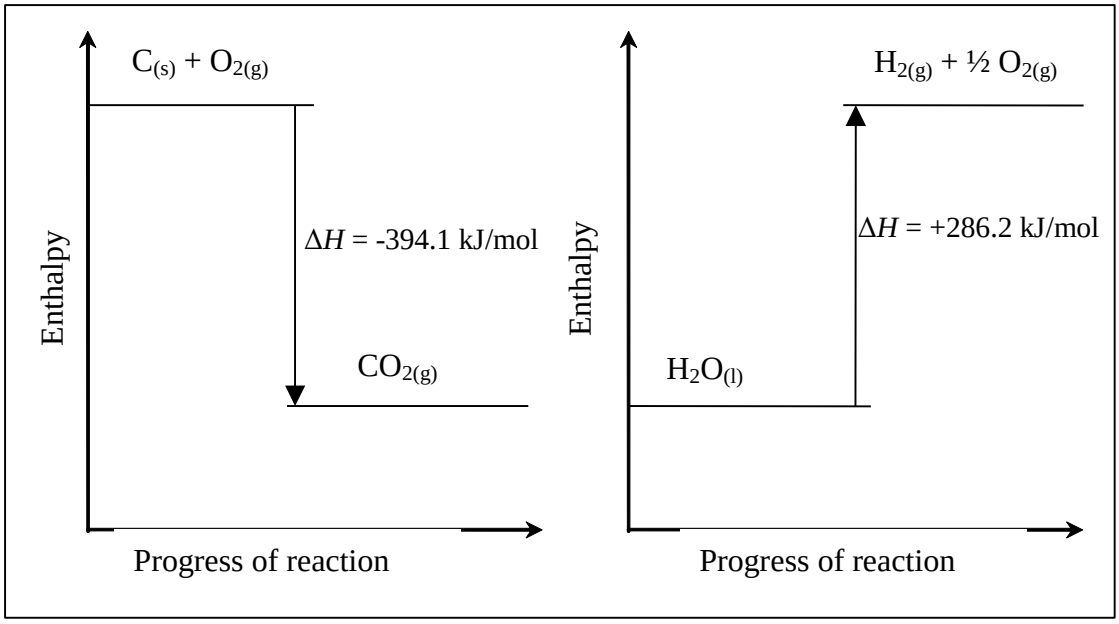
What volume of boiling water must be prepared?
(Assume complete heat transfer between the water and the stones.)

22 Glucose, $C_6H_{12}O_6$, is the fundamental energy source for humans.

$$C_6H_{12}O_{6(s)} + 6O_{2(g)} \rightarrow 6\,CO_{2(g)} + 6\,H_2O_{(l)}$$

Determine the amount of heat produced by the combustion of 90.0 g of glucose using the information below.

$$6\,C_{(s)} + 6\,H_{2(g)} + 3\,O_{2(g)} \rightarrow C_6H_{12}O_{6(s)} \qquad \Delta H = -1274.5\ \text{kJ/mol}$$



Part D	Questions 23, 24 and 25 (Answer two questions only.) If you answer all questions in this section, **draw a line through the question that you do not want to have corrected**. If you do not, questions 23 and 24 will be corrected.

23 The following reaction takes place very slowly under room temperature conditions.

$$4\ HCl_{(aq)} + O_{2(g)} \rightarrow 2\ H_2O_{(l)} + 2\ Cl_{2(g)}$$

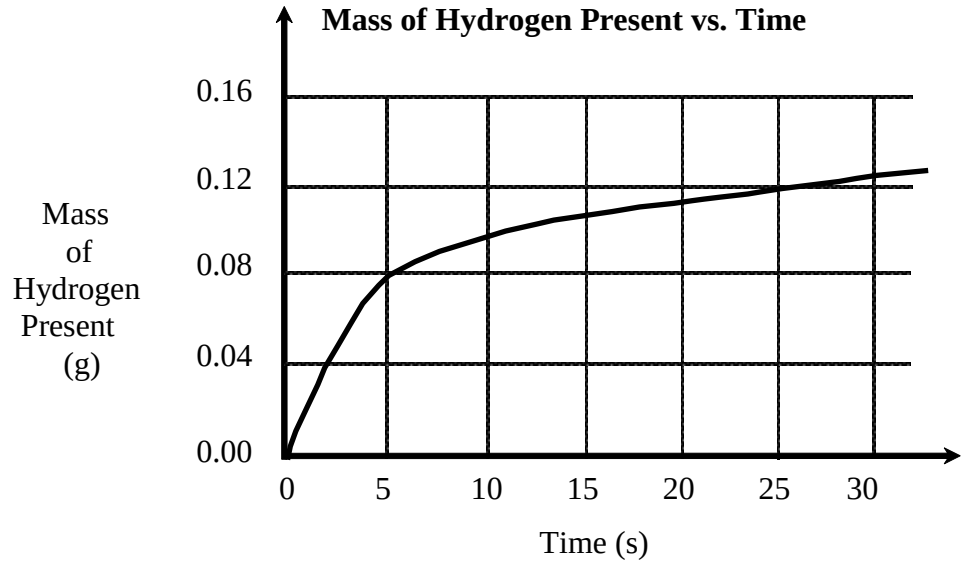
State four modifications that would increase the rate of this reaction.

For each modification, use the collision theory to explain why the modification would increase the rate.

24 A scientist is studying the rate of the following reaction:

$$2\ Ag_{(s)} + 2\ HNO_{3(aq)} \rightarrow H_{2(g)} + 2\ AgNO_{3(aq)}$$

He produces the following graph for this reaction.



Based on this graph, what is the average rate of consumption (g/s) of silver, Ag, between 5 s and 25 s?

Express your answer in grams per second.

25 A student neutralizes 1.00 L of hydrochloric acid, HCl, by adding calcium carbonate, $CaCO_3$.

The following reaction takes place:

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

The student uses a pH meter to check the progress of the reaction. It takes 25 seconds for the pH of the solution to change from 1.00 to 2.00.

What was the average rate of formation of carbon dioxide gas, CO_2, during this time?

Part E Questions 26, 27, 28, and 29 (Answer three questions only.)

If you answer all questions in this section, **draw a line through the question that you do not want to have corrected**. If you do not, questions 26, 27 and 28 will be corrected.

26 During the decomposition of hydrogen peroxide, $H_2O_{2(aq)}$, water, $H_2O_{(l)}$ and oxygen gas, $O_{2(g)}$ are produced in the following exothermic reaction:

$$2\ H_2O_{2(aq)} \leftrightarrow 2\ H_2O_{(l)} + O_{2(g)}$$

Using the terminology of Le Chatelier's principle, state four stresses that can be placed on the system to shift the equilibrium in order to increase the production of oxygen gas. Justify each of your proposed changes to the system.

27 The following reaction takes place in a closed 4.0 L container.

$$2\ SO_{2(g)} + O_{2(g)} \leftrightarrow 2\ SO_{3(g)}$$

Initially, only 1.20 moles of SO_2 and 1.00 mole of O_2 are present in the container. At equilibrium, 0.40 moles of SO_2 remain unreacted.
What is the value of the equilibrium constant, K_c, for this reaction?

28 A solution of acetic acid, CH_3COOH, has a concentration of 0.30 mol/L and a K_a of 1.8×10^{-5}.

$$CH_3COOH_{(aq)} \leftrightarrow H^+_{(aq)} + CH_3COO^-_{(aq)}$$

What is the pH of this solution of acetic acid?

29 Zinc, Zn, can be used to reduce iron (III) ions, Fe^{3+}, to iron (II) ions, Fe^{2+}.

1. **Give the balanced net oxidation-reduction reaction.**
2. **Determine the E^o value of this reaction.**
3. **Identify the oxidizing agent.**
4. **Would increasing the concentration of $Zn^{2+}_{(aq)}$ favour the reduction of iron (III) ions, Fe^{3+}, to iron (II) ions, Fe^{2+}? Justify your answer using Le Chatelier's principle.**

CHEMISTRY 534
EXAM #3
JUNE 2007

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

1 On a cold winter morning, the tires on a car appear flat.
(Assume that no air has leaked out of the tires.)

Which of the following statements explains this phenomenon?

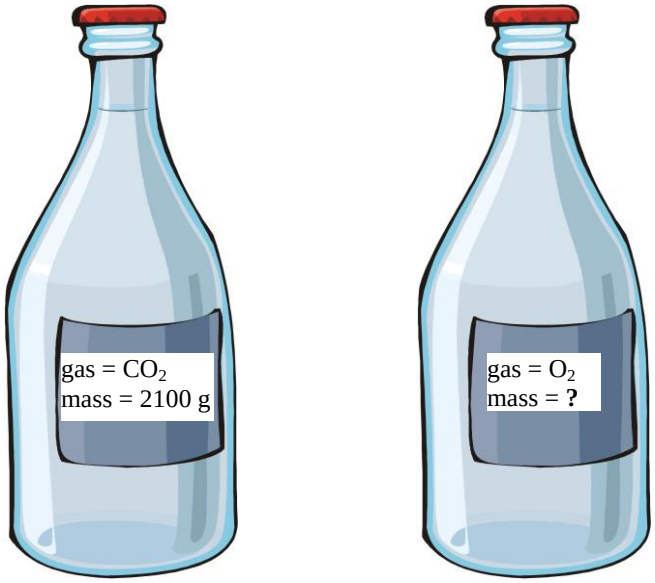
A) As the outside temperature increases, the pressure inside de tire decreases.

B) As the outside temperature decreases, the pressure inside de tire decreases.

C) As the outside pressure decreases, the volume inside de tire increases.

D) As the outside pressure increases, the volume inside de tire increases.

2 Two identical tanks contain different gases at the same temperature and pressure. One tank contains $CO_{2(g)}$, the other contains $O_{2(g)}$. The tank containing $CO_{2(g)}$ has a label indicating the mass of its contents.



What is the mass of $O_{2(g)}$ indicated on the other label?

A) 4.8×10^1 g

B) 7.6×10^2 g

C) 1.5×10^3 g

D) 2.1×10^3 g

3 A 300-mL container holds 5.00 g of oxygen gas at a temperature of -25.0°C.

What pressure is exerted by the oxygen gas?

A) 1.10×10^0 kPa

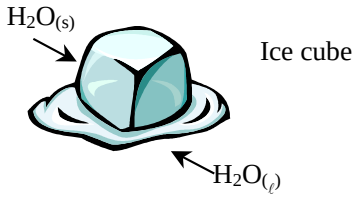
B) 1.29×10^2 kPa

C) 2.15×10^2 kPa

D) 1.07×10^3 kPa

4 Heat energy is always transferred from objects of higher temperature to objects of lower temperature.

With regard to molecular motion, which of the following statements best describes the differences in the two states of matter in the diagram?



A) $H_2O_{(s)}$ has vibrational and rotational motion, while $H_2O_{(\ell)}$ has vibrational motion.

B) $H_2O_{(s)}$ has vibrational motion, while $H_2O_{(\ell)}$ has vibrational and rotational motion.

C) $H_2O_{(s)}$ has rotational motion, while $H_2O_{(\ell)}$ has vibrational motion.

D) $H_2O_{(s)}$ has translational motion, while $H_2O_{(\ell)}$ has vibrational and translational motion.

5 **Which of the following may be identified as an endothermic process?**

1. The baking of bread
2. Formation of snow in the clouds
3. Sublimation of iodine crystals to purple gas
4. Dissolving sodium hydroxide in water
5. The breakdown of a water molecule by electrolysis to form hydrogen and oxygen gas

A) 1, 2 and 4

B) 1, 3 and 5

C) 2, 3 and 5

D) 2, 4 and 5

6 A student placed 3.50 g of $Mg(OH)_2$ in a bomb calorimeter containing 250.0 mL of water. When the substance was completely dissolved he noted a temperature increase of 22.8°C.

What is the molar heat of solution?

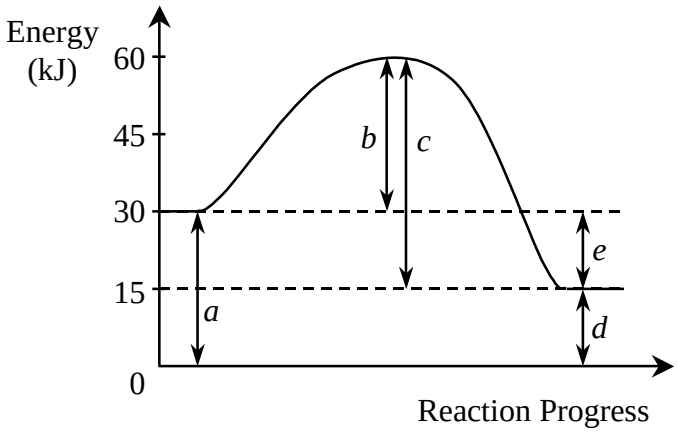
A) 1.40×10^0 kJ/mol

C) 3.98×10^2 kJ/mol

B) 2.39×10^1 kJ/mol

D) 1.43×10^3 kJ/mol

7 Below is a graph representing the enthalpy change of a thermochemical reaction as a function of reaction progress.



In the graph, which letters refer to the following concepts?

I. ΔH of the reaction
II. Activation energy of the forward reaction
III. Energy of the products

A) I- e II- b III- d

B) I- e II- c III- a

C) I- c II- a III- d

D) I- b II- e III- c

8 Scientists such as Helmholtz, Hess, Kelvin, and Nobel have contributed to expanding our knowledge of thermochemistry.

Which of the concepts below is associated with Hess's contribution to the field of thermochemistry?

A) Nitroglycerine and dynamite

B) The absolute temperature scale

C) The heat of summation

D) The law of conservation of mechanical energy

9 The combustion of magnesium, Mg, produces magnesium oxide, MgO, according to the following equation:

$$Mg_{(s)} + \frac{1}{2} O_{2(g)} \rightarrow MgO_{(s)}$$

Which of the following would produce the fastest reaction rate?

1. The combustion of a magnesium ribbon
2. The combustion of magnesium powder
3. The combustion of magnesium in air
4. The combustion of magnesium in a pure oxygen environment

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

10 During the science fair, Tammy wanted to simulate a volcanic eruption by mixing together baking soda, $NaHCO_3$, and vinegar, HCH_3COO.

Which of the following combinations should she use in order to produce the slowest rate of reaction?

A) 0.5 M HCH_3COO and a 4.0 g block of $NaHCO_3$
B) 0.5 M HCH_3COO and 4.0 g of powdered $NaHCO_3$
C) 1.0 M HCH_3COO and a 4.0 g block of $NaHCO_3$
D) 1.0 M HCH_3COO and 4.0 g of powdered $NaHCO_3$

11 Consider the following systems:

1. A can of soda pop fizzes after being opened.
2. An alcohol thermometer reads 27°C.
3. A cup of coffee cools on the top of a desk.
4. A stoppered test-tube contains distilled water.

Which of the above are examples of a closed system?

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

12 Consider the following system at equilibrium:

$$2\ SO_{2(g)} + O_{2(g)} \leftrightarrow 2\ SO_{3(g)} + \text{Energy}$$

Which of the following changes would result in an increase of products?

A) Increase the pressure and decrease the temperature.

B) Increase the pressure and increase the temperature.

C) Decrease the pressure and increase the temperature.

D) Decrease the pressure and decrease the temperature.

13 Anthony wants to know which of five acids is the strongest. He refers to a table of Acid Dissociation Constants (K_a).

After consulting the table below, which acid did he decide was the strongest?

Name	Formula	Ka
Arsenic acid	H_3AsO_4	5.0×10^{-3}
Carbonic acid	H_2CO_3	4.3×10^{-7}
Oxalic acid	$H_2C_2O_4$	6.5×10^{-2}
Phosphoric acid	H_3PO_4	7.5×10^{-3}
Sulfurous acid	H_2SO_3	1.5×10^{-2}

A) Arsenic acid

B) Carbonic acid

C) Oxalic acid

D) Sulfurous acid

14 Four strips of different metals are placed in solutions containing different metallic ions. The results are recorded in the table below. An X indicates that a reaction has occurred.

	$Pd^{2+}_{(aq)}$	$Pt^{2+}_{(aq)}$	$Ir^{3+}_{(aq)}$	$Au^{+}_{(aq)}$
$Pd_{(s)}$		X	X	X
$Pt_{(s)}$				X
$Ir_{(s)}$		X		X
$Au_{(s)}$				

Which of the following combinations correctly arranges these metals in decreasing order of oxidation?

A) Pd, Ir, Pt, Au

B) Pd, Au, Pt, Ir

C) Au, Pt, Ir, Pd

D) Ir, Pt, Au, Pd

Part B	Questions 15, 16, 17 and 18 (Answer three questions only.) If you answer all questions in this section, **draw a line through the question that you do not want to have corrected**. If you do not, questions 15, 16 and 17 will be corrected.

15 A student performs an experiment to find the relationship between the volume of a gas and its pressure.

He places books on a syringe plunger and measures the volume of air in the syringe as a function of pressure. He obtains the following data:

Pressure (in number of books)	Volume (mL)
1	90.0
2	45.0
3	30.0
4	22.5

What will be the volume when 12 books are placed on the syringe?

16 In a laboratory experiment, a student decomposed 1.27 g of potassium chlorate, $KClO_3$, producing potassium chloride, KCl, and oxygen gas, O_2. The decomposition reaction can be summarized as follows:

$$2\ KClO_{3(s)} + \text{Heat} \rightarrow 2\ KCl_{(s)} + 3\ O_{2(g)}$$

A volume of 468 mL of the gas was collected at a pressure of 94.7 kPa and a temperature of 20.0°C.

Can the gas be considered an ideal gas?

17 Greenhouse gases are a natural part of the atmosphere. They trap the sun's warmth, and maintain the earth's surface temperature at a level necessary to support life. The problem we now face is that human activity - particularly the burning of fossil fuels (coal, oil and natural gas), the use of refrigerants, farming, industrial processes and land clearing - are increasing the concentrations of these gases, creating the prospect of global climate change. This is called the enhanced greenhouse effect.

A sample of gas that was collected at an industrial site must be identified. The data below was recorded:

Volume of evacuated flask	334 mL
Mass of evacuated flask	51.02 g
Mass of flask and unknown gas	51.96 g
Pressure	98.0 kPa
Temperature	20.0°C

Which of the following greenhouse gases is most likely the unknown gas?

CH_4 CO_2 O_3 CHF_3 CF_4

Show all your calculations and justify your choice.

18 In an experiment, a student places magnesium metal in aqueous sulfuric acid, H_2SO_4, according to the following equation:

$$Mg_{(s)} + H_2SO_{4(aq)} \rightarrow MgSO_{4(aq)} + H_{2(g)}$$

The student must produce 174.1 mL of hydrogen gas by reacting magnesium with an excess of $H_2SO_{4(aq)}$, at a temperature of 30.0°C and a pressure of 100 kPa.

What mass of magnesium is needed?

Part C Questions 19, 20, 21 and 22 (Answer three questions only.)

19 After completing an experiment, a researcher was left with an excess of 225 mL of a 1.00 M HNO_3 solution. In order to safely dispose of this solution, she mixed it with 375 mL of a 1.00 M LiOH solution. The temperature of the new solution increased by 30.0°C.

What is the molar heat, ΔH, of neutralization of the nitric acid, HNO_3?
(Assume that the specific heat capacity and density of the solution are the same as that of water.)

20 With so much instability in the current world oil market, many are seeking out alternative fuels to power cars. Ethanol is a possible alternative fuel.

The combustion of ethanol is the following equation:

$$C_2H_5OH_{(\ell)} + 3\ O_{2(g)} \rightarrow 2\ CO_{2(g)} + 3\ H_2O_{(\ell)}$$

The combustion of octane (C_8H_{18}) provides 5509 kJ/mol of energy.

How many grams of ethanol would be required to produce the same amount of energy as 1 mole of octane?

	Equations	**ΔH_f (kJ/mol)**
1	$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$	-394
2	$H_{2(g)} + ½\ O_{2(g)} \rightarrow H_2O_{(\ell)}$	-285
3	$2\ C_{(s)} + 3\ H_{2(g)} + ½\ O_{2(g)} \rightarrow C_2H_5OH_{(\ell)}$	-278
4	$H_{2(g)} + ½\ O_{2(g)} \rightarrow H_2O_{(g)}$	-242

21 Because zinc oxide can absorb U.V. light, it can be used in ointments, creams, and lotions to protect against sunburn.

You need to find the molar heat of formation for zinc oxide according to the following equation:

$$Zn_{(s)} + \frac{1}{2} O_{2(g)} \rightarrow ZnO_{(s)}$$

Given that this is difficult to do in a lab, you perform a series of experiments to find the molar heat of formation indirectly.

First Experiment:
The reaction of 0.200 g of granular zinc with 50.0 mL of 1 mol/L of HCl according to the following equation:

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

Results:

Zinc	HCl	Initial temperature	Final temperature
0.200 g	50.0 mL	20.0°C	22.7°C

Second Experiment:
The reaction of 0.390 g of zinc oxide with 50.0 mL of 1 mol/L HCl according to the following equation:

$$ZnO_{(s)} + 2\ HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_2O_{(\ell)}$$

Results:

Zinc oxide	HCl	Initial temperature	Final temperature
0.390 g	50.0 mL	19.0°C	21.1°C

Consulting your chemistry text, you find that the molar heat of formation for water is:

$$H_{2(g)} + \frac{1}{2} O_{2(g)} \rightarrow H_2O_{(l)} \qquad \Delta H = -286\ \text{kJ/mol}$$

Based on the results obtained, what is the molar heat of formation for zinc oxide?
(Assume the density and specific heat for all solutions to be equal to that of water.)

22 An 80.5-g piece of brass is heated to a temperature of 95.7°C in a hot water bath. The brass is transferred to a calorimeter containing 105 g of water at a temperature 15.6°C.

The final temperature of the water bath is 23.8°C.

What is the specific heat capacity of the piece of brass?

Part D Questions 23, 24 and 25 (Answer two questions only.)

23 The rate of a chemical reaction is influenced by many factors. Two of these factors are the nature of the reactants and the state of the reactants.

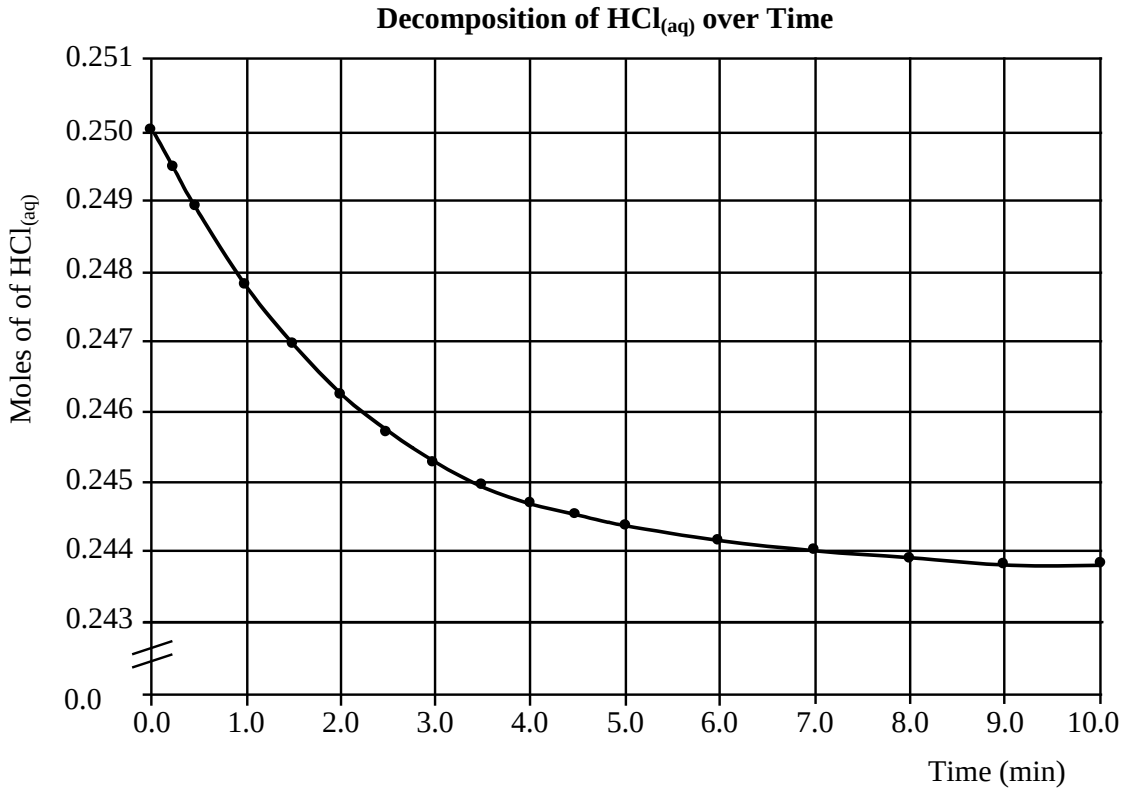
Below are two groups of reactants. For each group, choose the fastest reacting substance and justify your answer.

Group A	**Group B**
$CH_{4(g)}$	$CH_3OH_{(g)}$
$C_2H_{6(g)}$	$CH_3OH_{(l)}$
$C_3H_{8(g)}$	$CH_3OH_{(s)}$

24 Stomach acid acts upon $CaCO_3$ in antacid tablets according to the following equation:

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

The following graph reveals the decomposition of $HCl_{(aq)}$ as a function of time.



What is the average rate of formation of CO_2 gas in the first seven minutes of this reaction?

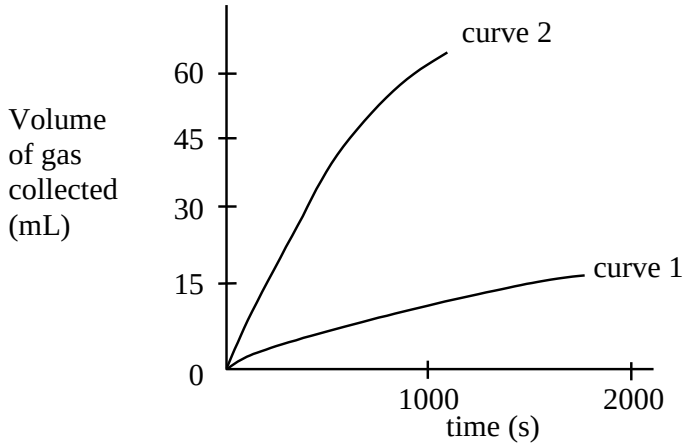
25 Hydrogen peroxide, $H_2O_{2(aq)}$ decomposes to produce water, $H_2O_{(\ell)}$, and oxygen, $O_{2(g)}$ according to the following equation.

$$H_2O_{2(aq)} \rightarrow H_2O_{(\ell)} + \frac{1}{2} O_{2(g)}$$

Scientists often use a potassium iodide catalyst to control the rate of the reaction.

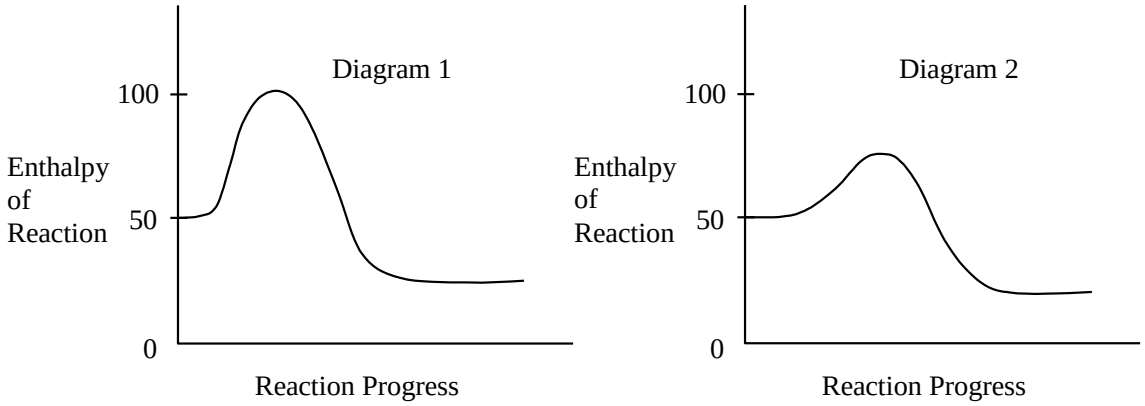
Question A

On the graph below, which curve represents the reaction without a catalyst? Justify your answer.



Question B

Which enthalpy diagram represents the reaction with a catalyst? Justify your answer.



Part E Questions 26, 27, 28 and 29 (Answer three questions only.)

26 The pollutant nitrogen monoxide, $NO_{(g)}$, can be partially eliminated by reacting it with hydrogen gas, H_2.

The equilibrium equation for the reaction is:

$$2\,H_{2(g)} + 2\,NO_{(g)} \leftrightarrow N_{2(g)} + 2\,H_2O_{(l)}$$

A technician initially mixes 4.0 moles of H_2 gas with 4.0 moles of NO gas in a 2.0-L flask.

At equilibrium he measures 0.8 moles of N_2 gas.

What is the equilibrium constant, K_c, for this reaction?

27 A 0.1 mol/L solution of formic acid, HCOOH, ionizes in water according to the following equation:

$$HCOOH_{(aq)} + H_2O_{(\ell)} \leftrightarrow H_3O^+_{(aq)} + HCOO^-_{(aq)}$$

The acid dissociation constant, K_a, of formic acid is 1.77×10^{-4}.

What is the pH of the formic acid solution?

28 A voltaic cell is constructed using electrodes with the following half-reactions:

$$Cu^{2+}_{(aq)} + 2\,e^- \rightarrow Cu_{(s)}$$

$$Al^{3+}_{(aq)} + 3\,e^- \rightarrow Al_{(s)}$$

A) **Which electrode is oxidized?**

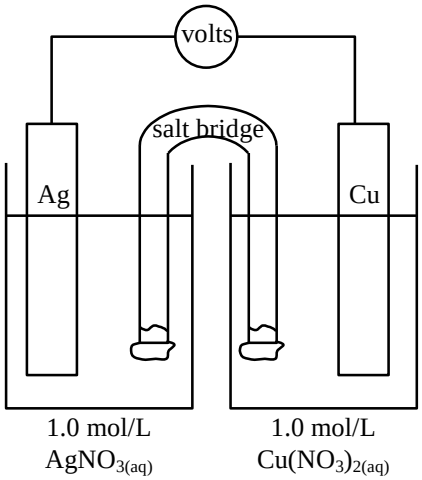
B) **What is the overall cell reaction?**

C) **What is the standard (net) cell potential of the voltaic cell? (Include units)**

D) **Which half-cell reaction occurs as a reduction?**

29 A copper, $Cu_{(s)}$, rod is placed into a beaker of 1.0 mol/L of copper (II) nitrate, $Cu(NO_3)_{2(aq)}$, and a silver, $Ag_{(s)}$, rod is placed into a beaker of 1.0 mol/L silver nitrate, $AgNO_{3(aq)}$.

An electrochemical cell is then constructed, as illustrated below.



A) **What is the overall cell reaction?**

B) **What is the standard (net) cell voltage? (Include units)**

C) **Based on Le Chatelier's Principle, explain what can be done to increase the standard (net) cell voltage.**

D) **Based on Le Chatelier's Principle, explain what would happen to the standard (net) cell voltage if a solution of sodium chloride, NaCl, (forms a precipitate with $AgNO_{3(aq)}$) were added to the system.**

EXAM #4
JUNE 2006

Part A

Questions 1 to 14
Blacken the letter that corresponds to your answer in the *Answer Booklet*.

1 A balloon has a volume of 22.4 L at 273 K and 101.3 kPa. The pressure is doubled to 202.6 kPa and the temperature is unchanged.

What is the volume of the balloon under these conditions?

A) 11.2 L
B) 22.4 L
C) 44.8 L
D) 50.6 L

2 In 1902, the French chemist, Georges Claude, was the first to apply an electrical discharge to a sealed tube of neon gas to create a lamp. Currently 150 colors can be created using gases such as carbon dioxide (CO_2), mercury (Hg), argon (Ar), and of course neon (Ne).

A 4.5 L tube is filled with 0.540 g of a certain gas with an internal pressure of 1.5 kPa and a temperature of 25°C.

Which gas is in the tube?

A) Argon
B) Carbon dioxide
C) Mercury
D) Neon

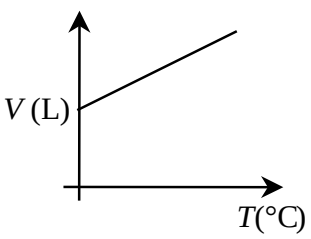
3 A balloon is filled with a gas and the initial pressure is recorded. The Kelvin temperature is doubled, the volume is halved, and the number of molecules is doubled.

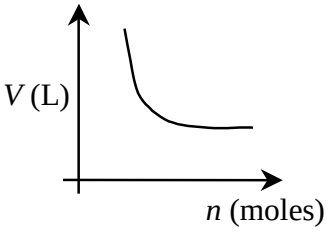
Which of the following best describes the final pressure of the gas?
(Assume the gas behaves as an ideal gas.)

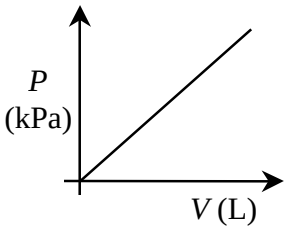
A) The final pressure is the same as the initial pressure.
B) The final pressure is 2 times higher than the initial pressure.
C) The final pressure is 4 times higher than the initial pressure.
D) The final pressure is 8 times higher than the initial pressure.

4 **According to the Ideal Gas Law, in which set of graphs below are all the axes labelled correctly?**

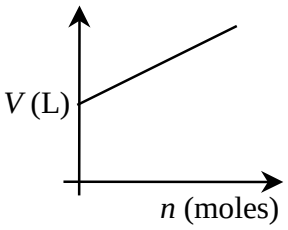
A)

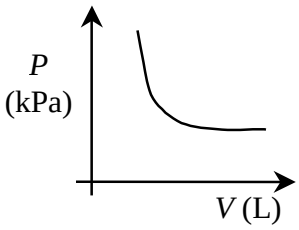


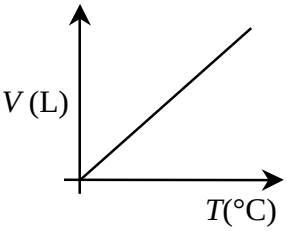




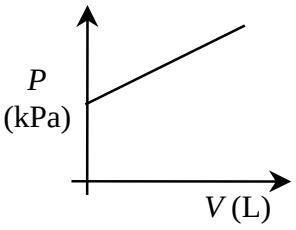
B)

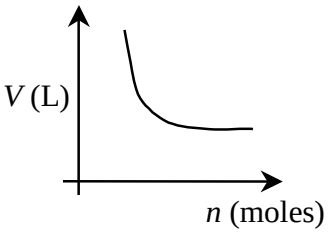


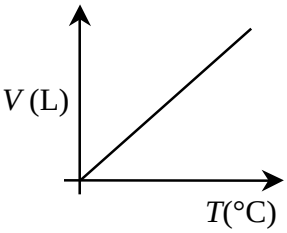




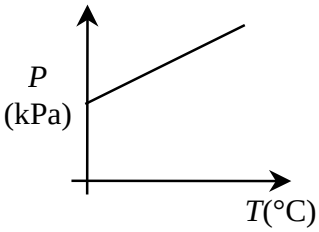
C)

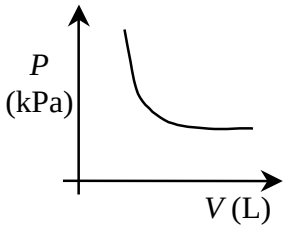


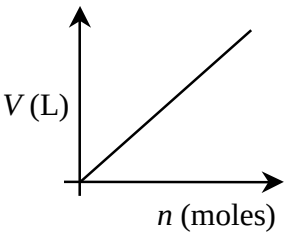




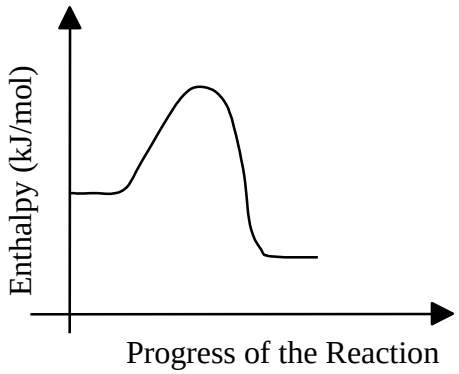
D)







5 Examine the enthalpy diagram below.



Which of the following changes could be represented by this diagram?

1) $H_{2(g)} + 1/2\ O_{2(g)} \rightarrow H_2O_{(l)}$ ΔH = -285.9 kJ/mol
2) $H_2O_{(g)} + C_{(s)} \rightarrow H_{2(g)} + CO_{(g)}$ ΔH = +131.8 kJ/mol
3) $CO_{(g)} + NO_{2(g)} \rightarrow CO_{2(g)} + NO_{(g)} + 226\ kJ$
4) $C_{12}H_{22}O_{11(s)} + 5.4\ kJ \rightarrow C_{12}H_{22}O_{11(aq)}$

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

6 A student dissolves 4.0 g of ammonium nitrate, NH_4NO_3, into 150 mL of distilled water at 23°C. After the NH_4NO_3 has completely dissolved, the temperature is 18°C.

Which of the following statements is true?

A) The kinetic energy of the particles in the solution decreases as the NH_4NO_3 dissolves.

B) The sum of the potential and kinetic energies of the particles in the solution decreases as the NH_4NO_3 dissolves.

C) The process of dissolving NH_4NO_3 absorbs energy from the surroundings.

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

7 You have 250 mL of coffee, whose temperature is 25°C. You add 50.0 mL of water, whose temperature is 95°C.

What will be the final temperature of the coffee?
(Assume that coffee has the same density and specific heat capacity as water.)

A) 33°C
B) 37°C
C) 44°C
D) 60°C

8 **Which of the following processes involves an endothermic change?**

A) Your eyeglasses fog up when you breathe on them.

B) Rain freezes as it lands on hydro wires.

C) Sodium hydroxide pellets are dissolved in distilled water and the temperature of the solution increases.

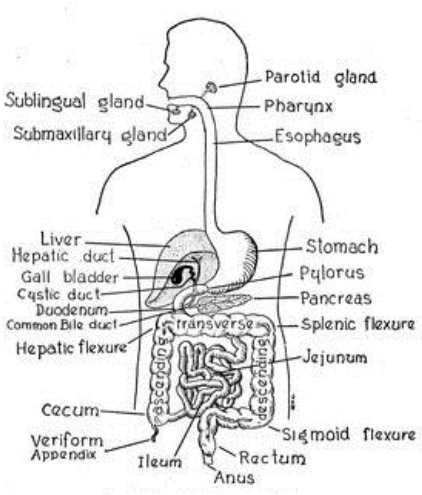
D) A solid air freshener sublimes after it has been opened.

9 Consider the chemical reactions illustrated below.

1) Combustion of Hydrogen

2) Composting

3) Digestion



4) Magnesium and Hydrochloric Acid

$$Mg + 2\,HCl \rightarrow MgCl_2 + H_2$$

In which of the following combinations are these chemical reactions arranged in order, from slowest to fastest?

A) 1, 4, 3, 2

B) 2, 3, 4, 1

C) 2, 4, 3, 1

D) 3, 2, 4, 1

10 **Which of the following describes how an inhibitor influences the rate of a chemical reaction?**

A) It decreases the activation energy of both the forward and reverse reactions.

B) It decreases the activation energy of the forward reaction.

C) It decreases the temperature of the system, while leaving the activation energy unchanged.

D) It increases the activation energy of both the forward and reverse reactions.

11 Consider the following system at equilibrium.

$$MgCl_{2(s)} \leftrightarrow Mg^{2+}_{(aq)} + 2\ Cl^{-}_{(aq)} \qquad \Delta H = +\ 12.5\ kJ$$

Which of the changes below would result in an equilibrium shift?

A) The addition of a catalyst to the system

B) An increase in the temperature

C) The addition of magnesium chloride, $MgCl_{2(s)}$, to the container

D) A decrease in the pressure on the system

12 Given the following equation:

$$2\ NaHCO_{3(s)} \leftrightarrow Na_2CO_{3(s)} + H_2O_{(g)} + CO_{2(g)}$$

What is the mathematical expression for the equilibrium constant, K_c?

A) $K_c = [H_2O_{(g)}]\ [CO_{2(g)}]$

B) $K_c = \dfrac{[Na_2CO_{3(s)}]\ [H_2O_{(g)}]\ [CO_{2(g)}]}{[NaHCO_{3(s)}]^2}$

C) $K_c = \dfrac{[NaHCO_{3(s)}]^2}{[Na_2CO_{3(s)}]\ [H_2O_{(g)}]\ [CO_{2(g)}]}$

D) $K_c = \dfrac{[Na_2CO_{3(s)}]\ [H_2O_{(g)}]\ [CO_{2(g)}]}{[NaHCO_{3(s)}]}$

13 The table below gives the K_a of six acids.

Selected Values of Aqueous Acid Ionization Constants at 25°C

Acid	Formula	K_a
acetic acid	CH_3COOH	1.75×10^{-5}
ammonium ion	NH_4^+	5.60×10^{-10}
chloroacetic acid	$CH_2ClCOOH$	1.36×10^{-3}
hydroxylammonium ion	$HONH_3^+$	1.12×10^{-6}
hydrogen sulphide	H_2S	1.02×10^{-7}

Which of the following combinations correctly pairs the strongest acid and the weakest acid?

	Strongest acid	Weakest acid
A)	H_2S	NH_4^+
B)	$CH_2ClCOOH$	NH_4^+
C)	CH_3COOH	$HONH_3^+$
D)	CH_3COOH	H_2S

14 A scientist, who must store a 1 mol/L solution of $Co(NO_3)_{2(aq)}$ at room temperature, needs a container that will not cause a chemical reaction with the solution it will hold.

From which of the following substances should the container be made?

Part B

Questions 15, 16, 17 and 18 (Answer three questions only.)
If you answer all questions in this section, **draw a line through the question that you do not want to have corrected**. If you do not, questions 15, 16 and 17 will be corrected.

15 A balloon, inflated with hydrogen gas, will be ignited outside a school to start its Terry Fox Run.

Inside the school, the gas in the balloon occupies a volume of 1.50×10^3 mL at 22.0°C and 101.8 kPa.

The balloon is taken outside, where the temperature is 33.0°C and the pressure is 102.3 kPa.

What is the volume of the balloon when it is outside?

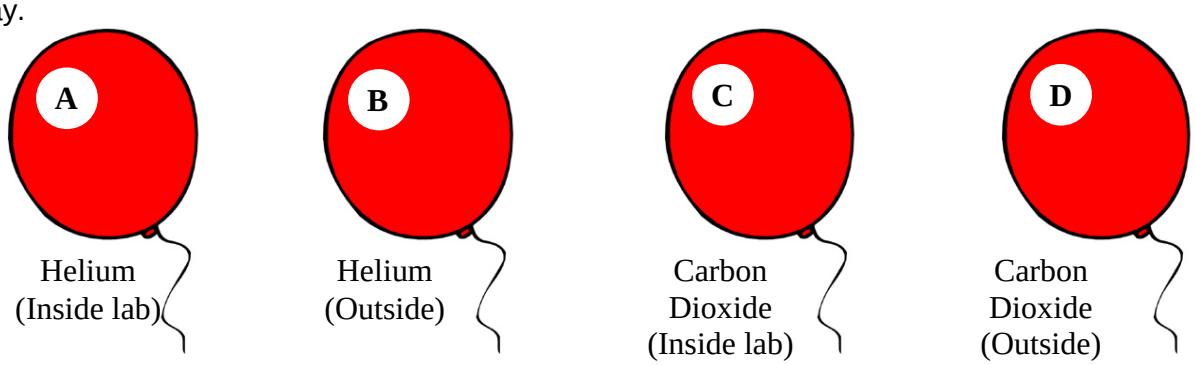
Show all your work.

16 Over time, the gas inside a rubber balloon can escape through pores in the rubber.

A student performs an experiment with four identical balloons filled to equal volumes.

Balloons A and B are filled with helium and balloons C and D are filled with carbon dioxide.

Balloons A and C are left in the lab, while balloons B and D are stored outside on a cold winter day.



Which balloon will deflate the fastest?

Justify your answer.

17 An evacuated metal tank with a fixed volume has a mass of 8275 g. When this tank is filled with ammonia gas, NH_3, the total mass of the tank and the ammonia is 8421 g. When a customer has used all of the ammonia, the tank is returned to the supplier who evacuates it and fills it with carbon dioxide gas, CO_2. The gas supply company always fills its tanks to the same conditions of pressure and temperature.

What is the total mass of the tank and carbon dioxide?

Show all your work.

18 Hydrogen sulphide, H_2S, a colourless gas with a stench similar to rotten eggs, occurs naturally from bacterial decay of organic matter. It can react to produce sulphur, according to the following chemical reaction:

$$2\ H_2S_{(g)} + SO_{2(g)} \rightarrow 2\ H_2O_{(l)} + 3\ S_{(s)}$$

A sample of $H_2S_{(g)}$ is present in a container at a temperature of 21.0°C and a pressure of 67.5 kPa. A sufficient amount of $SO_{2(g)}$ is added to the container to ensure the complete reaction of the $H_2S_{(g)}$. After the $H_2S_{(g)}$ has reacted completely, 6.40 g of sulphur was produced.

What was the original volume of the container?

Show all your work.

Part C
Questions 19, 20, 21 and 22 (Answer three questions only.)

19 When a calorimeter was filled with 20.0 mL of 3.00 mol/L hydrochloric acid, $HCl_{(aq)}$, and 50.0 mL of 1.20 mol/L sodium hydroxide, $NaOH_{(aq)}$, the temperature rose from 22.4°C to 29.8°C.

What was the molar heat of neutralization of $HCl_{(aq)}$?
(Assume the density and specific heat for all solutions to be equal to that of water.)

Show all your work.

20 A student finds three metal cubes and wants to determine the specific heat capacity of each cube. First, he finds the mass of each metal cube. He pours 125 mL of distilled water at 21°C into each of three identical Styrofoam cups. Then he heats the three metal cubes to 98°C. He places each metal cube into a different Styrofoam cup and records the resulting temperature of the water and the metal. His results are listed in the table below:

	Mass	Resulting Temperature
Cube A	115 g	32°C
Cube B	132 g	35°C
Cube C	175 g	37°C

Which metal cube has the largest specific heat capacity?
(Assume that all of the heat lost by each metal cube was gained by the water.)

Show all your work.

21 A student performs a simple experiment to obtain an approximate value for the molar heat of combustion of methanol (CH_3OH). He adds methanol to a methanol burner and finds its mass. He ignites the methanol and uses the burner to heat a sample of water. After heating the water and allowing the burner to cool, he measures the mass of the burner again. His observations are recorded in the table below:

Mass of water heated	275 g
Mass of the burner and methanol before heating the water	642.53 g
Mass of the burner and methanol after heating the water	635.68 g
Temperature of the water before heating	16.4°C
Temperature of the water after heating	94.7°C

The student assumes that all of the heat released by the burning of the methanol was absorbed by the water.

What is the molar heat of combustion (ΔH) of methanol?

Show all your work.

22 Nitric acid is produced when dinitrogen pentoxide gas reacts with water as indicated in the following equation:

$$N_2O_{5(g)} + H_2O_{(l)} \rightarrow 2\ HNO_{3(aq)}$$

Find the heat of reaction (ΔH) for this reaction using the information below.

$2\ H_{2(g)} + O_{2(g)} \rightarrow 2\ H_2O_{(l)}$ ΔH = -572 kJ

$N_{2(g)} + 3\ O_{2(g)} + H_{2(g)} \rightarrow 2\ HNO_{3(aq)}$ ΔH = -348 kJ

$2\ N_{2(g)} + 5\ O_{2(g)} \rightarrow 2\ N_2O_{5(g)}$ ΔH = +28 kJ

Show all your work.

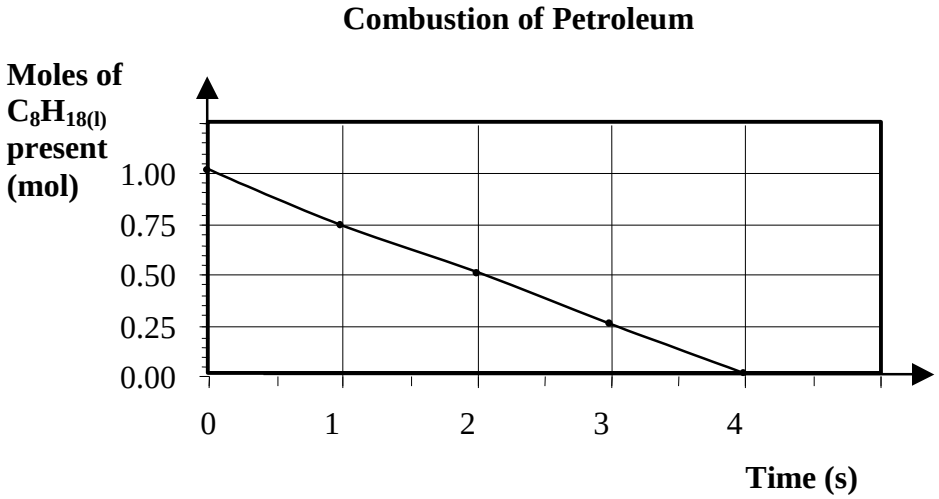
Part D

Questions 23, 24 and 25 (Answer two questions only.)

23 Cars need oxygen in order to burn petroleum, $C_8H_{18(l)}$, according to the following equation:

$$C_8H_{18(l)} + \frac{25}{2}\ O_{2(g)} \rightarrow 8\ CO_{2(g)} + 9\ H_2O_{(g)} + \text{energy}$$

Consider the graph below.



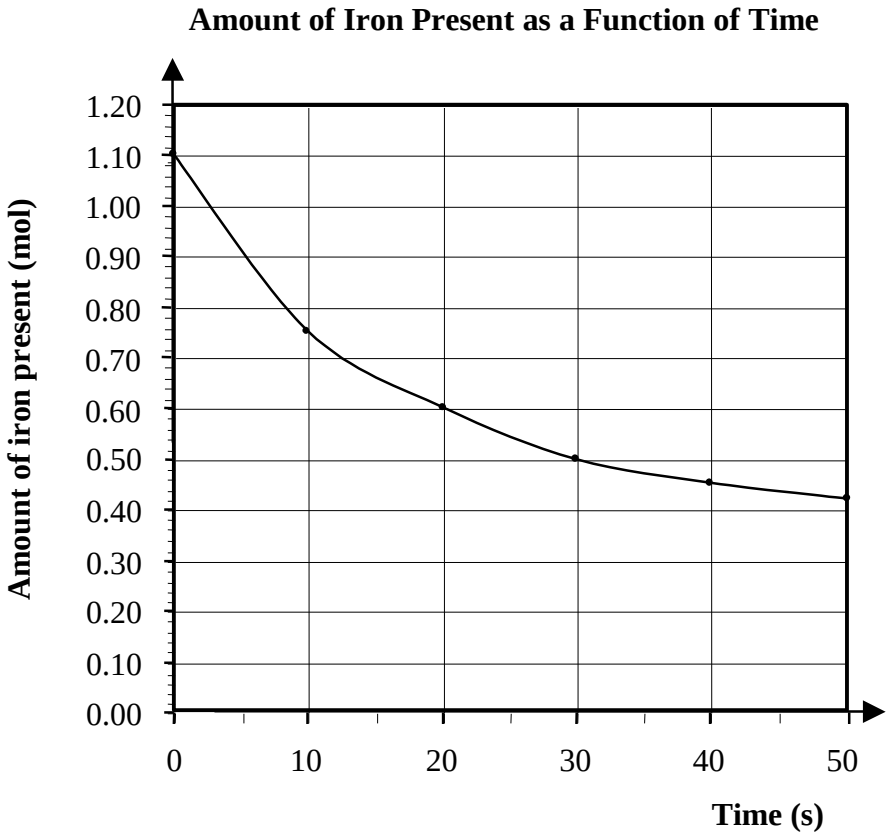
What is the average rate of consumption of oxygen gas in mol/s?

Show all your work.

24 Consider the following chemical reaction:

$$2\ Fe_{(s)} + 3\ CO_{2(g)} \rightarrow Fe_2O_{3(s)} + 3\ CO_{(g)}$$

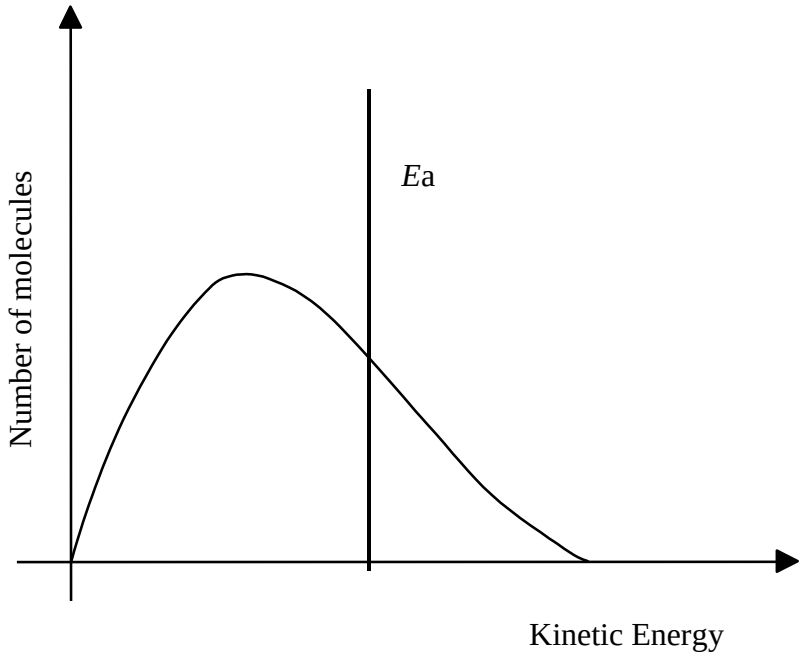
The graph below illustrates the moles of iron present as a function of time in seconds for the reaction.



Plot a graph of the moles of $CO_{(g)}$ present, as a function of time.

Show all your work.

25 An energy distribution curve is shown below.



A catalyst is added and the gas sample is cooled.

In your *Answer Booklet*, modify the graph to indicate the changes that would occur.

Justify the changes you made to the graph.

Part E
Questions 26, 27, 28 and 29 (Answer three questions only.)

26 Ethanol, $C_2H_5OH_{(g)}$, is manufactured by reacting ethylene, $C_2H_{4(g)}$, with steam, $H_2O_{(g)}$.

$$C_2H_{4(g)} + H_2O_{(g)} \leftrightarrow C_2H_5OH_{(g)} + 45 \text{ kJ/mol}$$

Phosphoric acid is used as a catalyst.
The objective of the manufacturing process is to produce as much ethanol as possible.

State whether each of the following changes would achieve this objective.

1. Raise the temperature.
2. Increase the pressure.
3. Add more catalyst.
4. Add more ethylene.

Justify your answers.

27 A scientist is studying the following reaction:

$$4\ NH_{3(g)} + 5\ O_{2(g)} \leftrightarrow 4\ NO_{(g)} + 6\ H_2O_{(g)}$$

She puts 6.0 moles of ammonia gas, $NH_{3(g)}$, and 8.0 moles of oxygen gas, $O_{2(g)}$, into an evacuated 4.0 L container. Once the reaction has reached equilibrium, she finds that 4.8 moles of water, $H_2O_{(g)}$, are present in the 4.0 L container.

What is the equilibrium constant, K_c, for this reaction?

Show all your work.

28 Hypobromous acid ionizes in water according to the following equation:

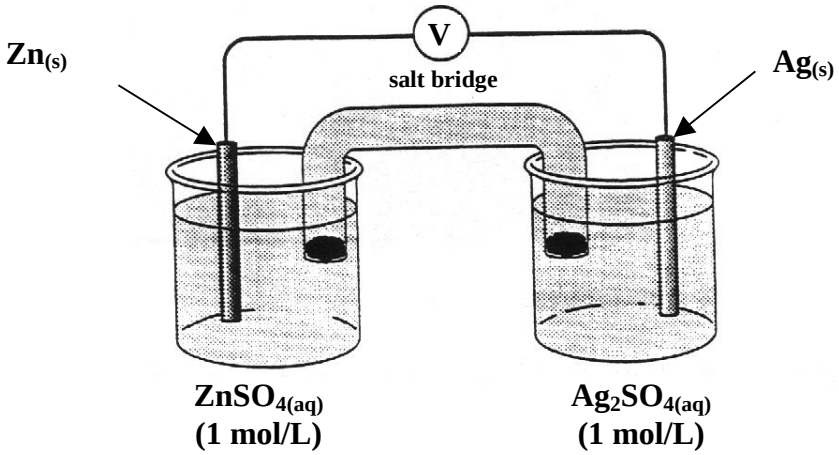
$$HOBr_{(aq)} + H_2O_{(l)} \leftrightarrow H_3O^+_{(aq)} + OBr^-_{(aq)}$$

A student prepares a 0.085 mol/L solution of hypobromous acid and finds that the pH of this solution is 4.6.

What is the acid ionization constant, K_a, for this acid?

Show all your work.

29 Consider the electrochemical cell illustrated below.



Determine each of the following:

a) The $E°$ of the cell
b) The direction of electron flow, specifying the metals
c) The balanced redox reaction, including the state of each substance
d) The metal that acts as the anode

EXAM #5
JUNE 2005

Part A

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

1 **Which of the following statement is TRUE?**

A) Gas molecules are strongly attracted to each other.

B) At a given temperature, the number of degrees Celsius is always larger than the number of Kelvins.

C) For a fixed amount of gas at a constant pressure, if temperature increases, volume decreases.

D) For a fixed amount of gas at a constant volume, if temperature increases, pressure increases.

2 The Kinetic Molecular Theory describes an ideal gas model. Among the main features of this model are:

(I) Gases consist of molecular particles moving at any given instant in straight lines.
(II) Molecules collide with each other and with the container walls without loss of kinetic energy.
(III) The average kinetic energy of gas molecules is directly proportional to the Kelvin temperature.
(IV) Gas molecules are very widely spaced, relative to the size of the molecules.

Which two of these Kinetic Molecular Theory features can be used to explain why gas bubbles always rise through a liquid and become larger as they move upward?

A) (I) and (III)
B) (I) and (IV)
C) (II) and (III)
D) (II) and (IV)

3 There are *n* molecules in 250 cm^3 of hydrogen gas (H_2), at a certain temperature and pressure.

How many molecules are in 1.0 L of oxygen gas (O_2) under the same conditions of temperature and pressure?

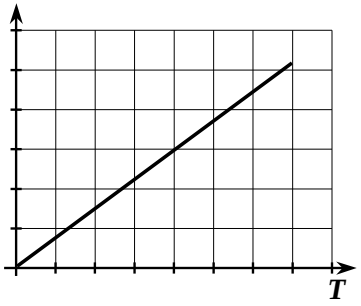
A) *n*
B) 2*n*
C) 4*n*
D) 8*n*

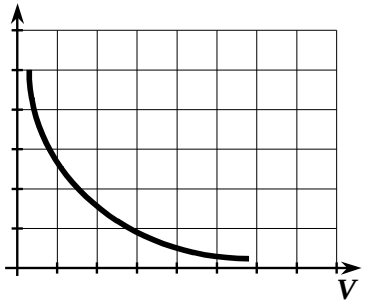
4 Consider the following two situations concerning gases.

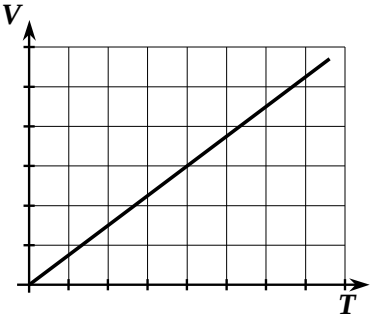
(I) Included on all spray cans is a warning to not incinerate the can even if it is empty, and to always store it below 40°C.

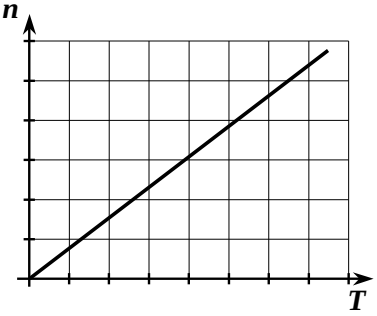
(II) When you examine the tires on your bicycle before you start out in the morning, you note that they appear slightly soft. However, after riding for several hours, they get harder.

Which of the following graphs can be used to explain these two situations?

A) 

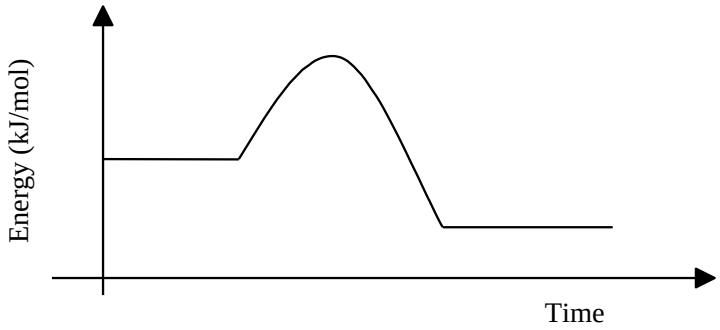
C) 

B) 

D) 

5 The enthalpy diagram below shows the energy involved in the formation of $CO_{2(g)}$.

$$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$$



Once the reaction above has been initiated, which of the following statements is true?

A) The formation of $CO_{2(g)}$ constitutes an endothermic reaction.

B) The formation of $CO_{2(g)}$ does not result in energy from the system being transferred into the surroundings.

C) The formation of $CO_{2(g)}$ results in energy from the system being transferred into the surroundings.

D) In the formation of $CO_{2(g)}$ the enthalpy of the products will be greater than the enthalpy of the reactants.

6 Everyday, phenomena take place all around us.

Which of the following may be identified as exothermic processes?

1. Dew forming on blades of grass
2. Melting snow and ice on a driveway by adding salt
3. Drying a wet T-shirt on a clothesline
4. Freezing meat to preserve it
5. Burning propane gas in a stove

A) 2 and 3
B) 4 and 5
C) 1, 2 and 3
D) 1, 4 and 5

7 Ethane, C_2H_6, can be decomposed into ethene, C_2H_4, and hydrogen gas:

$$C_2H_{6(g)} \rightarrow C_2H_{4(g)} + H_{2(g)}$$

Using the following equations, determine the enthalpy change for the decomposition of ethane.

1. $2\ H_{2(g)} + O_{2(g)} \rightarrow 2\ H_2O_{(l)}$ $\Delta H = -572$ kJ
2. $C_2H_{4(g)} + 3\ O_{2(g)} \rightarrow 2\ H_2O_{(l)} + 2\ CO_{2(g)}$ $\Delta H = -1401$ kJ
3. $2\ C_2H_{6(g)} + 7\ O_{2(g)} \rightarrow 6\ H_2O_{(l)} + 4\ CO_{2(g)}$ $\Delta H = -3100$ kJ

A) -5073 kJ
B) -3237 kJ
C) 137 kJ
D) 3237 kJ

8 Barbeque propane gas, C_3H_8, burns according to the following equation:

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

How many grams of propane are needed to provide the 980 kJ required to cook a salmon steak?

	ΔH_f (kJ/mol)
$3\ C_{(s)} + 4\ H_{2(g)} \rightarrow C_3H_{8(g)}$	-103.8
$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$	-394.0
$H_{2(g)} + ½\ O_{2(g)} \rightarrow H_2O_{(g)}$	-241.8

A) 21.1 g
B) 19.1 g
C) 9.6 g
D) 10.6 g

9 **Which of the following does not affect the reaction rate?**

A) Nature of products

B) Surface area of reactants

C) Concentration of reactants

D) Presence of a catalyst

10 Consider the following reactions at room temperature:

1. $Fe^{3+}_{(aq)} + SCN^{1-}_{(aq)} \rightarrow FeSCN^{2+}_{(aq)}$

2. $4\ Fe_{(s)} + 3\ O_{2(g)} \rightarrow 2\ Fe_2O_{3(s)}$

3. $8\ Fe_{(s)} + S_{8(s)} \rightarrow 8\ FeS_{(s)}$

Which combination below arranges the reactions from slowest to fastest?

A) $1 \rightarrow 2 \rightarrow 3$

B) $1 \rightarrow 3 \rightarrow 2$

C) $2 \rightarrow 3 \rightarrow 1$

D) $3 \rightarrow 2 \rightarrow 1$

11 The equilibrium constant (K_c) for the following reaction is 1.47×10^3.

$$H_3O^+_{(aq)} + F^-_{(aq)} \leftrightarrow HF_{(aq)} + H_2O_{(l)}$$

At equilibrium, which of the following statements about the reaction is true?

A) The concentration of H_3O^+ and F^- would be much larger than HF.

B) The concentration of HF would be much larger than H_3O^+ and F^-.

C) The concentration of H_3O^+ , F^- and HF would be approximately equal.

D) K_c has no effect on concentration.

12 Consider the following reaction at equilibrium in a closed container:

$$CaCO_{3(s)} \leftrightarrow CaO_{(s)} + CO_{2(g)}$$

Which of the following statements is true if the volume of the container is increased?

A) The concentration of $CaCO_3$ would increase.

B) The concentration of $CaCO_3$ would decrease.

C) The amount of CO_2 would increase.

D) The amount of CO_2 would decrease.

13 Propanoic acid (CH_3CH_2COOH which we simplify as HPr) is an organic acid whose salts are used to retard mould growth in foods.

The balanced equation is shown below:

$$HPr_{(aq)} + H_2O_{(l)} \leftrightarrow Pr^-_{(aq)} + H_3O^+_{(aq)}$$

Which of the following is the correct expression for the acid dissociation constant?

A) $K_a = [Pr^-][H_3O^+]$

B) $K_a = \dfrac{[Pr^-][H_3O^+]}{[HPr][H_2O]}$

C) $K_a = \dfrac{[Pr^-][H_3O^+]}{[HPr]}$

D) $K_a = \dfrac{[HPr][H_2O]}{[Pr^-][H_3O^+]}$

14 Consider the following redox reaction:

$$Sr_{(s)} + Mg^{2+}_{(aq)} \leftrightarrow Sr^{2+}_{(aq)} + Mg_{(s)}$$

Which is the oxidizing agent?

A) Sr

B) Mg^{2+}

C) Sr^{2+}

D) Mg

Part B
Questions 15, 16, 17 and 18 (Answer three questions only.)

15 A student produced $H_{2(g)}$ by performing the following chemical reaction:

$$Mg_{(s)} + 2\ HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$$

The hydrogen gas produced was collected and stored in a 2.00 L container at 20.0 °C.
Half of the original amount of the gas is transferred into a 0.50 L container at -20.0 °C.

What is the ratio of the gas pressure in the second container to the initial gas pressure in the first container?

Show all your calculations to justify your answer.

16 Nitroglycerine, $C_3H_5(ONO_2)_3$, has a density of 1.59 g/mL. When it explodes, the following reaction takes place:

$$4\ C_3H_5(ONO_2)_{3\,(l)} \rightarrow 12\ CO_{2(g)} + O_{2(g)} + 6\ N_{2(g)} + 10\ H_2O_{(g)}$$

What volume of water vapour, measured at STP, is produced when 1.0×10^2 mL of nitroglycerine explodes?

17 The product formed in a controlled fluorination of $CHCl_3$ is a gaseous compound. To identify it, a flask is evacuated and the unknown gas is transferred into the flask. The data below is collected:

Volume of evacuated flask	296.0 mL
Mass of evacuated flask	46.02 g
Mass of flask + unknown gas	46.71 g
Pressure	46.9 kPa
Temperature	18.0 °C

Which of the following is most likely the unknown gas?

$CFCl_3$ CF_2Cl_2 CF_3Cl CF_4

Show all your calculations and justify your choice.

18 **Using the Kinetic Molecular Theory of gases explain why:**

a) The rate of diffusion of a gas decreases when the temperature is reduced.

b) Under the same conditions, the rate of diffusion of helium gas is greater than the rate of diffusion of oxygen gas.

Part C
Questions 19, 20, 21 and 22 (Answer three questions only.)

19 An unknown metal with a mass of 150 g and a temperature of 95 °C is placed into a Styrofoam cup containing 65 g of water at a temperature of 14 °C. When the system reaches equilibrium, the resulting temperature is 26 °C.

What is the specific heat capacity of the unknown metal? (Assume no loss of heat energy to the surroundings.)

20 A calorimeter is filled with 50.0 mL of 1.0 mol/L $NaOH_{(aq)}$ at an initial temperature of 22.3 °C and 20.0 mL of 2.5 mol/L $HCl_{(aq)}$ is added at this same temperature. After the neutralization reaction comes to completion, the final temperature of the resulting solution is found to be 29.8 °C.

Determine the ΔH (kJ/mol) for the neutralization for the reaction with respect to the $NaOH_{(aq)}$ solution. (Assume the density and specific heat for all solutions to be equal to that of water)

21 A bomb calorimeter contains a 150.0 g of water at an initial temperature of 22.0 °C. When 1.00 g of diamond is burned in the calorimeter to produce CO_2, the final temperature of the water reaches 74.5 °C.

What is the ΔH (kJ/mol) for the combustion of carbon in the form of diamond?

$$C_{(diamond)} + O_{2(g)} \rightarrow CO_{2(g)} \qquad \Delta H = ?$$

22 The Haber process for the formation of ammonia (NH_3) from the elements can be derived from the following equations:

$$\tfrac{1}{2}\ N_{2(g)} + \tfrac{3}{2}\ H_{2(g)} \rightarrow N_{(g)} + 3\ H_{(g)} \quad E_{activation} = 1118\ kJ$$

$$NH_{3(g)} \rightarrow N_{(g)} + 3\ H_{(g)} \quad E_{activation} = 1164\ kJ$$

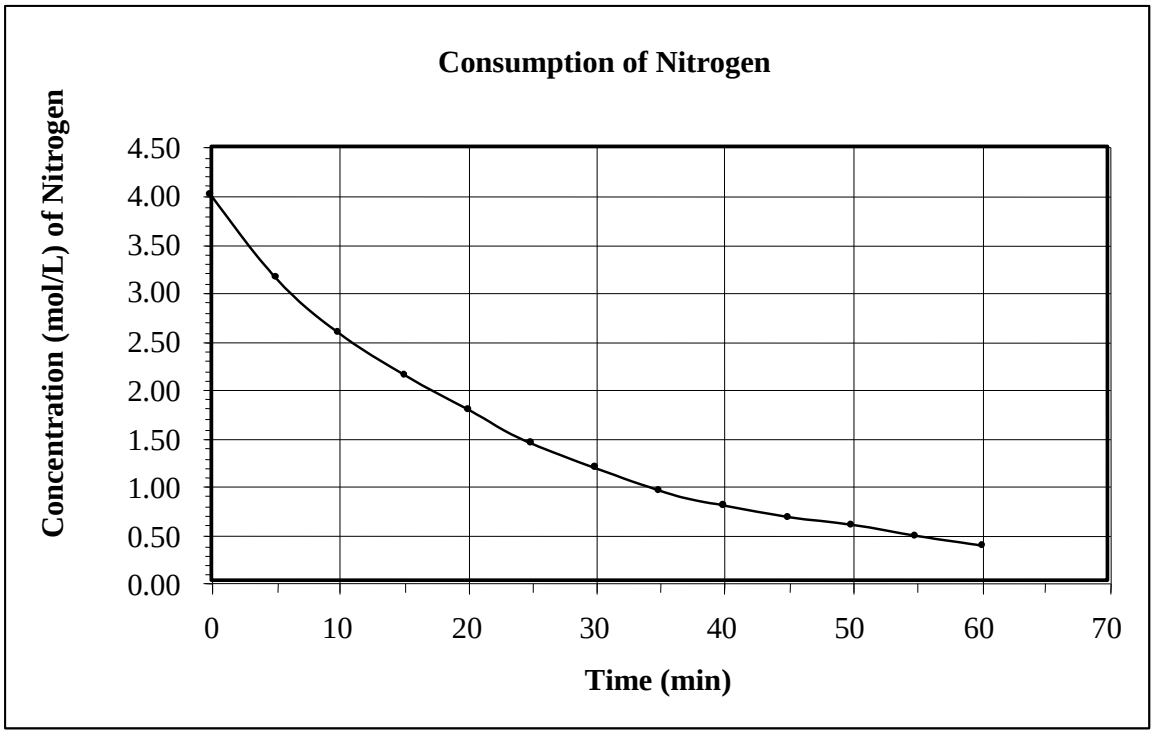
The Haber process can be written as $\tfrac{1}{2}\ N_{2(g)} + \tfrac{3}{2}\ H_{2(g)} \rightarrow NH_{3(g)}$

$N_{(g)} + 3\ H_{(g)}$ has been determined to be the activated complex for the overall reaction.

Draw an Enthalpy diagram to determine the ΔH for the Haber process. Indicate the ΔH on the diagram. The graph must indicate reactants, products, activated complex, ΔH, and appropriate values.

Part D
Questions 23, 24 and 25 (Answer two questions only.)

23 Consider the following graph, illustrating nitrogen consumption.



In the Haber reaction, nitrogen gas (N_2) is combined with hydrogen gas (H_2) under extremely high pressure and medium temperature, and using a catalyst (an iron catalyst prepared by reducing magnetite, Fe_3O_4), to produce ammonia ($NH_{3(g)}$).

$$N_{2(g)} + 3\ H_{2(g)} \rightarrow 2\ NH_{3(g)}$$

Using the graph above, calculate the average rate of ammonia production in mol/L/min over the first fifty (50) minutes.

24 Shown below are several reaction mechanisms involving Ozone gas (O_3).

(I) $NO_{(g)} + O_{3(g)} \rightarrow NO_{2(g)} + O_{(g)}$
$O_{(g)} + NO_{2(g)} \rightarrow NO_{(g)} + O_{2(g)}$

(II) $OH^- + O_{3(g)} \rightarrow HO_2 + O_{2(g)}$
$HO_2 + O_{3(g)} \rightarrow OH^- + 2O_{2(g)}$

(III) $CO_{(g)} + OH^- \rightarrow H_{(g)} + CO_{2(g)}$
$H_{(g)} + O_{2(g)} \rightarrow HO_2$
$HO_2 + NO_{(g)} \rightarrow OH^- + NO_{2(g)}$
$NO_{2(g)}$ + light energy $\rightarrow NO_{(g)} + O_{(g)}$
$O_{(g)} + O_{2(g)} \rightarrow O_{3(g)}$

For each mechanism, list the substance(s) that could have acted as a catalyst.

25 The reaction below was studied at 25 °C.

$$2I^-_{(aq)} + S_2O_8^{2-}{}_{(aq)} \rightarrow I_{2(aq)} + 2SO_4^{2-}{}_{(aq)}$$

The following data was collected:

Time (min)	$[I^-]$ (mol/L)	$[I_2]$ (mol/L)
0.0	0.0800	0
0.2	0.0400	
0.4	0.0200	
0.6	0.0100	
0.8	0.0050	
1.0	0.0025	

a) Complete the data table for $I_{2(aq)}$

b) Calculate the average rate of reaction for the production of $I_{2(aq)}$ over the course of the time given.

Part E
Questions 26, 27, 28 and 29 (Answer three questions only.)

26 When 0.0150 mol $NH_{3(g)}$ and 0.0150 mol $O_{2(g)}$ are introduced into a 1.00 L container at a certain temperature, the N_2 concentration at equilibrium is 1.96×10^{-3} mol/L.

$$4\ NH_{3(g)} + 3\ O_{2(g)} \leftrightarrow 2\ N_{2(g)} + 6\ H_2O_{(g)}$$

Calculate K_c for the reaction at this temperature.

27 A 0.15 mol/L solution of butanoic acid ($CH_3CH_2CH_2COOH$) has a H_3O^+ concentration of 1.51×10^{-3} mol/L. A 0.035 mol/L solution of hydrofluoric acid (HF) has a OH^- concentration of 7.59×10^{-10} mol/L.

Which of the two acids is stronger?
Justify your answer using appropriate calculations.

28 A galvanic cell consists of a Mg electrode in a 1.0 mol/L $Mg(NO_3)_2$ solution and a Ag electrode in a 1.0 mol/L $AgNO_3$ solution.

a) Draw a diagram of the cell specifying anode, cathode, and direction of electron flow.

b) Calculate the standard cell potential of this electrochemical cell.

c) Describe one method through which this cell potential may be increased.

29 A newly hired technician at a chemical factory was on night duty and had to decide whether the following solutions could be pumped, one at a time, from one lab to another using copper, Cu, pipes.

Iron nitrate	**$Fe(NO_3)_2$**
Lead nitrate	**$Pb(NO_3)_2$**
Silver nitrate	**$AgNO_3$**

The technician decided to go ahead and pump the three solutions one at a time through the pipes, flushing the pipes with water in between solutions to clean them.

Did the technician cause any chemical reactions to occur in the pipes?

EXAM #6
JUNE 2004

Part A

Questions 1 to 18
Blacken the letter that corresponds to your answer on the answer sheet provided.

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.

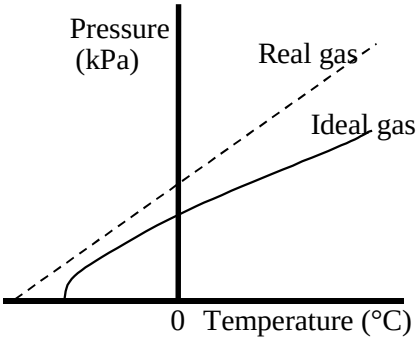
At what temperature will this occur?

A) 22°C
B) 45°C
C) 237°C
D) 510°C

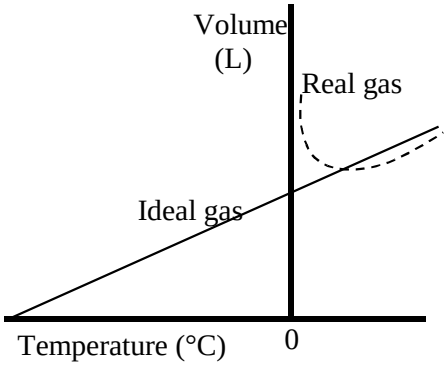
2 The illustrator of a chemical textbook wants to create a graph showing gas behaviour. The graph must show the difference between the behaviour of an ideal gas (using a solid line) and the behaviour of a real gas (using a dotted line).

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

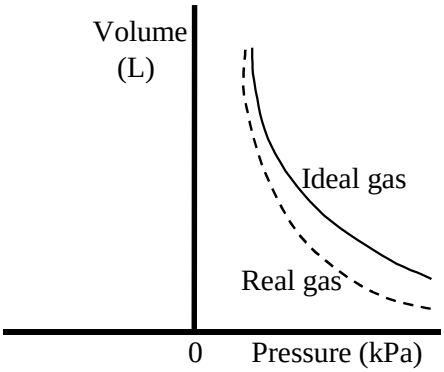
A)



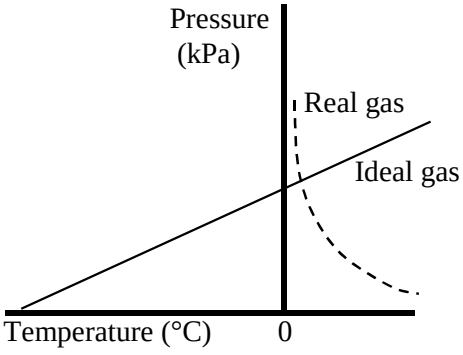
C)



B)



D)



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. 

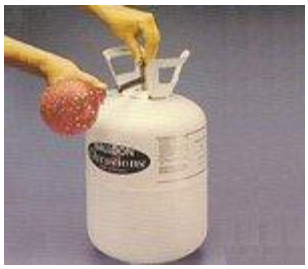
Carbon Dioxide Gas Cylinder

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

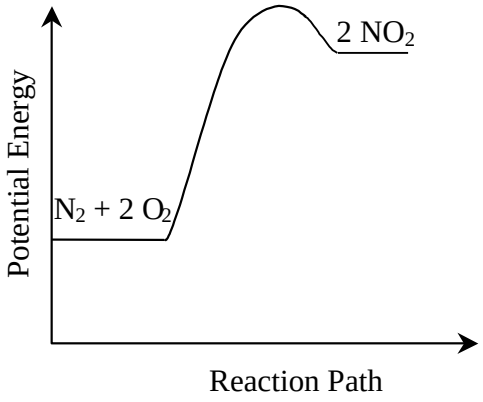
D) -220 kJ

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

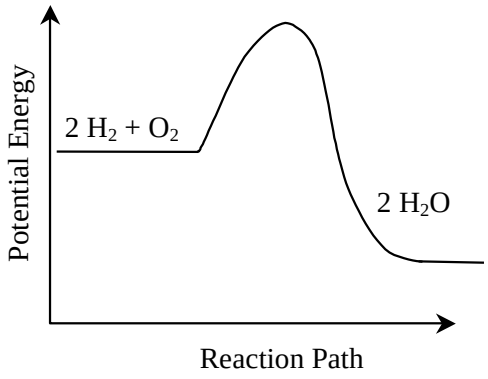
The graphs of four reactions all occurring at the same temperature, are shown below. The potential energy axes are drawn to the same scale.

Which reaction is most likely to be spontaneous?

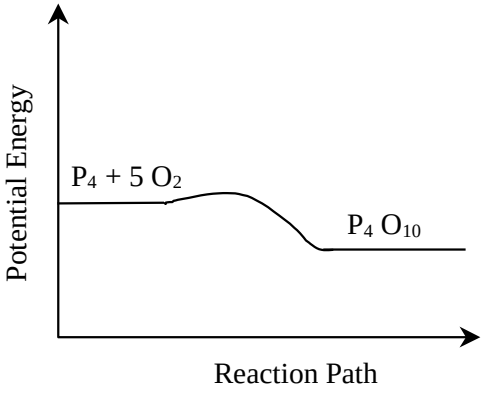
A)



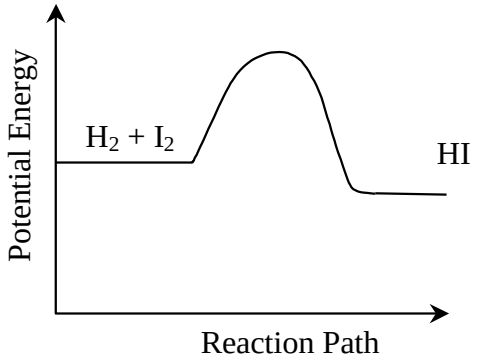
C)



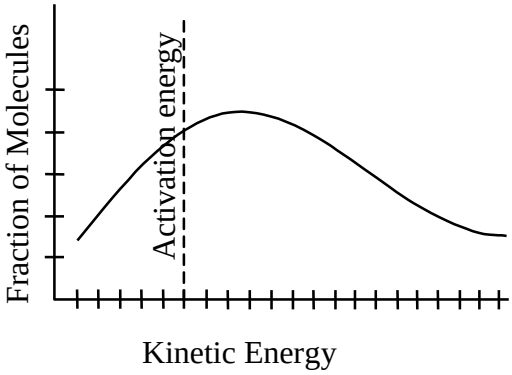
B)



D)

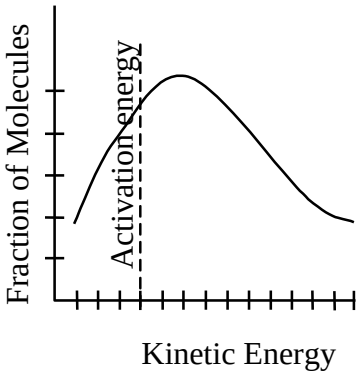


9 The graph below shows the distribution of energy for a sample of molecules. A catalyst is added and the temperature decreased.

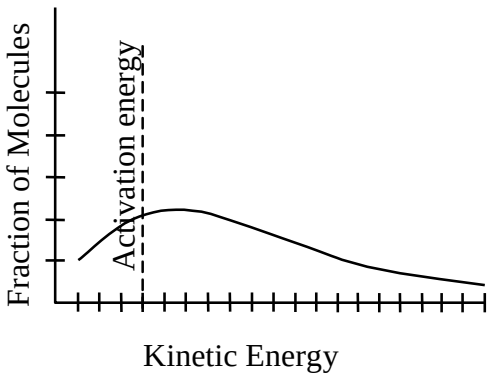


Which of the following graphs represents the change that would occur?

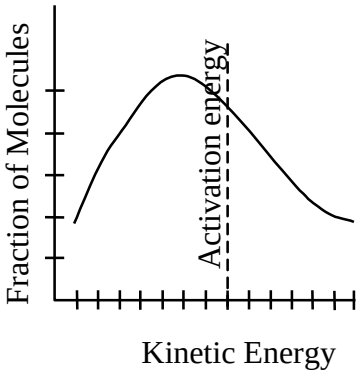
A)



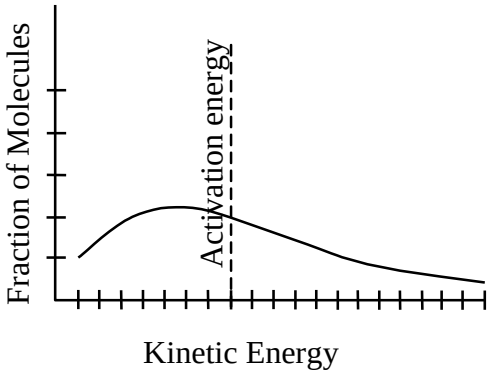
C)



B)



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.

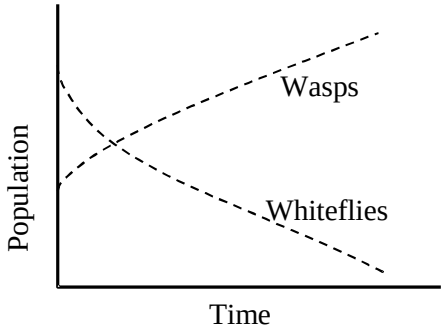
D) The amount of N_2O_4 increases due to a pressure decrease.

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".

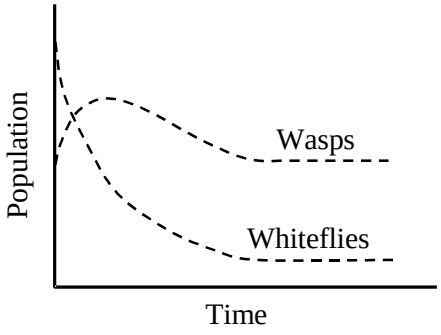
The graphs below show the results of four tests done in greenhouses with typical Whitefly infestations.

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

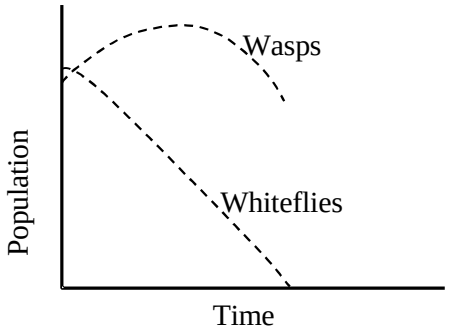
A)



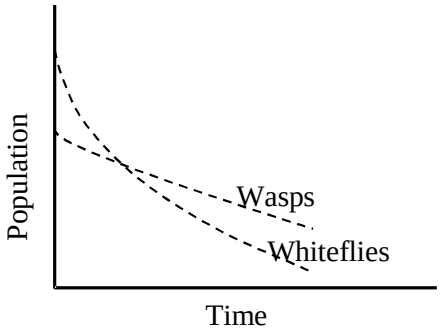
C)



B)



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.

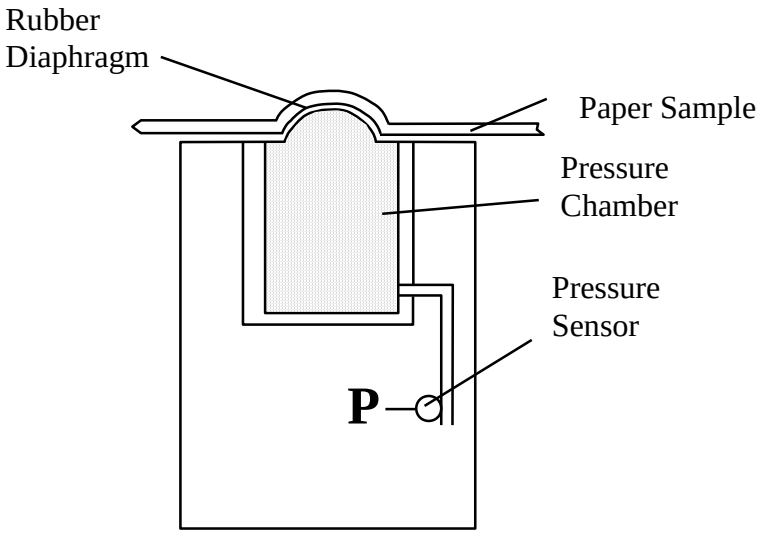
C) There will be a shift to re-establish equilibrium and K_w will decrease.

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

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

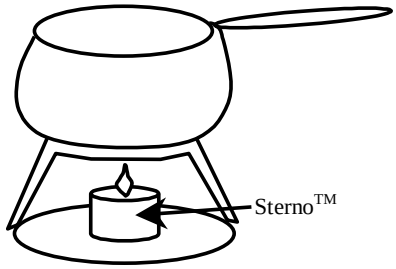
20 You were asked to mix 20.0 mL of a 1.0 M HCl solution with 100.0 mL of a 1.0 M NaOH solution. The initial temperature of both solutions was 18.9°C. The temperature of the final solution was 21.1°C.
Assume HCl and NaOH have the same specific heat capacity and density as water.

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.

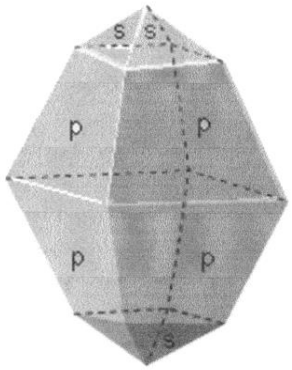


Given that ethanol burns as follow:

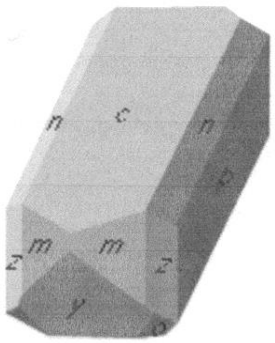
$C_2H_5OH_{(s)} + 3\ O_{2(g)} \rightarrow 2\ CO_{2(g)} + 3\ H_2O_{(g)}$ ΔH = -278 kJ/mol

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.

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

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

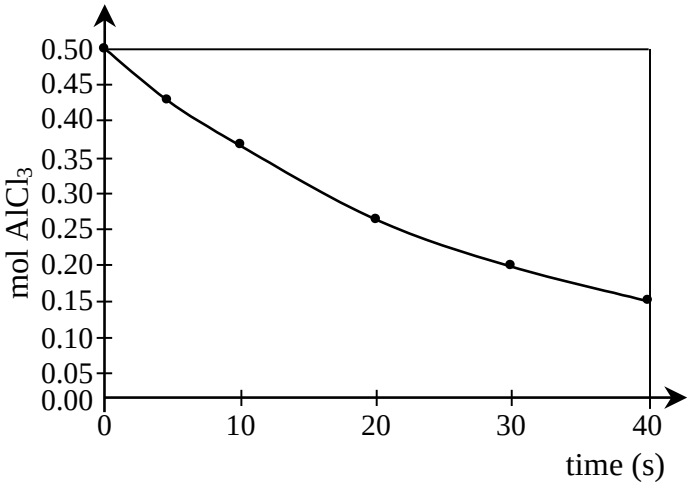
Part D

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:

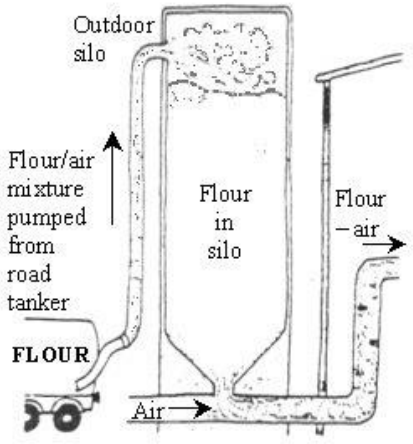
$$2\ AlCl_{3(aq)} \xrightarrow{\text{Electrical Energy}} 2Al_{(s)} + 3\ Cl_{2(g)}$$

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.

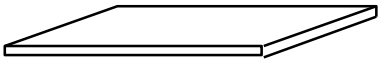


Explain what might have caused the fire.
Your explanation must take into account the factors affecting the rate of combustion and make reference to the collision theory.

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

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

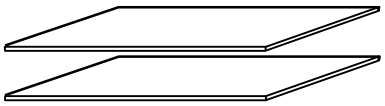
The experiment was done with a very thin rectangular slab of marble, ($CaCO_3$). The time required for the evolution of CO_2 gas is noted in the table below.


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}.

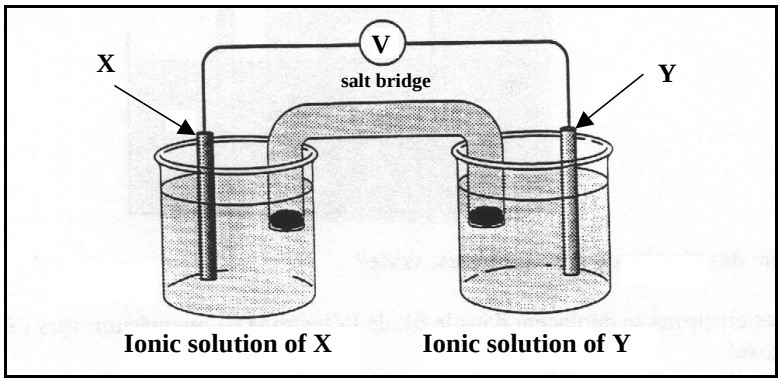
What will be the concentrations of the components at equilibrium?

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.

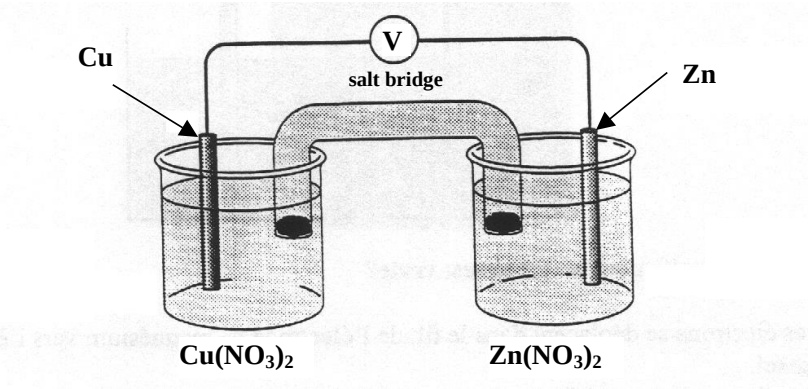


The student has a choice of the following electrodes:

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.**

EXAM #7
JUNE 2003

Part A

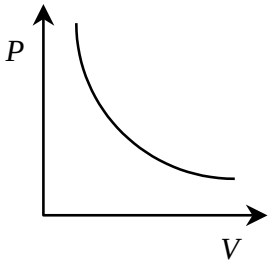
Questions 1 to 18
Blacken the letter that corresponds to your answer on the answer sheet provided.

1 In Bhopal, India, on December 3, 1984, approximately 3800 people died, 2680 experienced permanent partial disability and 40 people experienced permanent total disability.
A runaway reaction inside the tank resulted in a tremendous increase of temperature in the steel storage tank. Methyl isocyanate gas was released from an exploding tank.

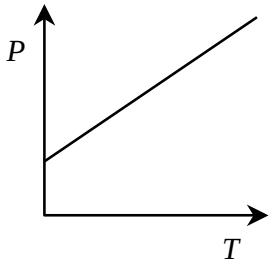
What caused the tank to explode?

A) Decreased volume of the tank
B) Increased pressure in the tank
C) Increased volume of the tank
D) Decreased pressure in the tank

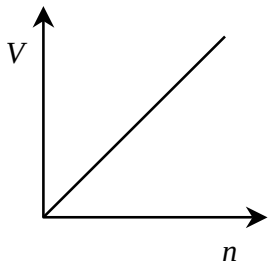
2 **Which of the following graphs does NOT represent a gas relationship?**

A)


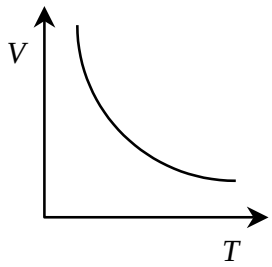
(T and n are constant)

C)


(V and n are constant)

B)


(P and T are constant)

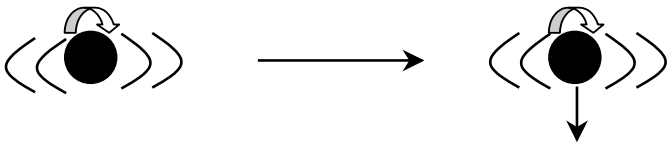
D)


(P and n are constant)

3 On a hot summer day a weather balloon was filled with 5.0 L of air. The temperature was 34°C and the pressure was 90.0 kPa. The following day, the balloon had shrunk to 4.0 L. A barometer read 110 kPa, but there was no thermometer available.
What was the temperature on the second day?

A) 27°C
B) 31°C
C) 35°C
D) 41°C

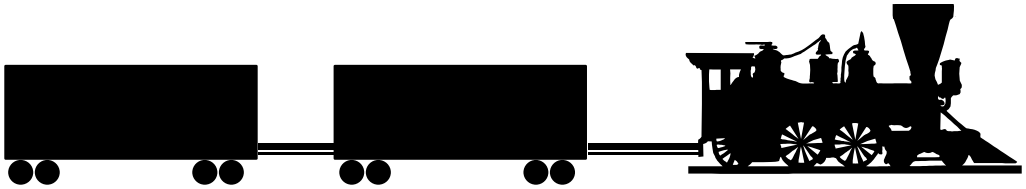
4 The molecules of a certain substance are initially vibrating and rotating. As they absorb kinetic energy, they begin to vibrate and rotate faster. The bonds between the molecules are overcome, and the molecules demonstrate high translational energy as well as rotational and vibrational energy.



Which of the following changes of state is being described at the molecular level?

A) Condensation
B) Evaporation
C) Melting
D) Sublimation

5 A train is carrying two large tanks of gas subjected to the same pressure and temperature. The first tank has a mass of 1000 kg, and contains 500 kg of ethane gas, C_2H_6.



The second tank is identical to the first tank in both mass and volume, but it contains methane gas, CH_4.

What is the mass of CH_4 gas found in the second tank?

A) 194 kg
B) 267 kg
C) 500 kg
D) 938 kg

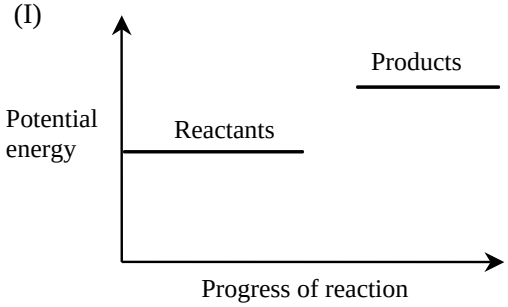
6 **Which of the following is the best definition of enthalpy?**

A) It is the average kinetic energy of molecules.
B) It is the amount of heat absorbed or released in reaction.
C) It is the total energy within a substance.
D) It is the heat of the products minus the heat of the reactants.

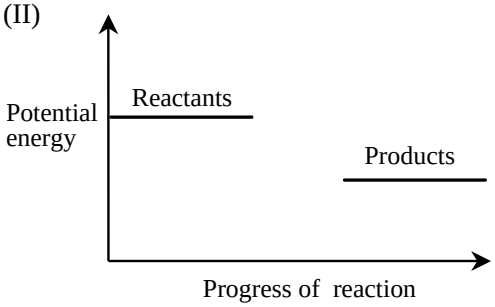
7 Consider the following energy diagrams and phenomena.

Energy Diagrams

(I)



(II)



Phenomena

a) $H_2O_{(l)} \rightarrow H_2O_{(g)}$

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

c) $NaOH_{(s)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$

d) $H_2O_{(s)} \rightarrow H_2O_{(l)}$

Which combination below correctly matches energy diagrams and phenomena?

A) I-a, II-b, II-c, I-d

B) II-a, I-b, II-c, II-d

C) I-a, II-b, I-c, II-d

D) I-a, I-b, II-c, I-d

8 **Which of the following reactions are endothermic?**

1) $CH_{4(g)} + 2\ O_{2(g)} \rightarrow CO_{2(g)} + 2\ H_2O_{(l)} + 890.4$ kJ

2) $2\ Al_2O_{3(s)} \rightarrow 4\ Al_{(s)} + 3\ O_{2(g)}$ $\Delta H = +3352$ kJ

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

4) $2\ NaHCO_{3(s)} + 129$ kJ $\rightarrow Na_2CO_{3(s)} + H_2O_{(g)} + CO_{2(g)}$

A) 3

B) 1 and 3

C) 2 and 4

D) 1, 2 and 4

9 Ammonium nitrate (NH_4NO_3), one of the active ingredients of commercial ice packs, has a change in enthalpy of +26.2 kJ/mol in the following reaction:

$$NH_4NO_{3(s)} \rightarrow NH_4^+{}_{(aq)} + NO_3^-{}_{(aq)}$$

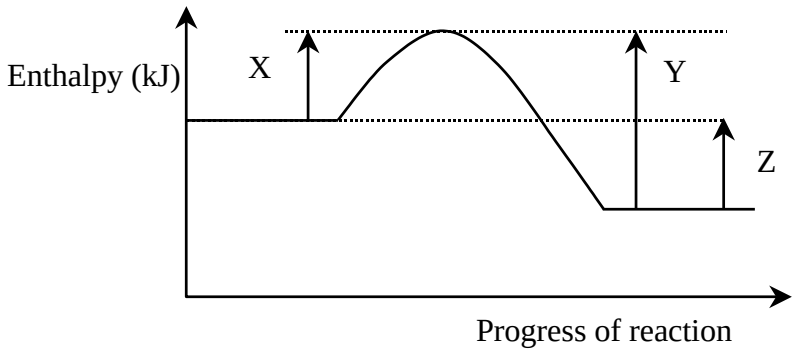
You want to design a practical ice pack with the following characteristics:

- It should contain 100.0 mL of water
- The water's temperature should drop by 20°C when the pouch containing the NH_4NO_3 bursts and its contents mix with water.

How much ammonium nitrate should you include in the pouch?

A) 0.25 g
B) 0.32 g
C) 26 g
D) 310 g

10 The following represents an enthalpy diagram:



Which of the following statements is correct?

A) Y represents ΔH of the reverse reaction, which is exothermic.
B) X represents ΔH of the forward reaction, which is exothermic.
C) Z represents ΔH of the reverse reaction, which is endothermic.
D) X represents ΔH of the forward reaction, which is endothermic.

11 Rags containing paint or oil will react slowly in the air. If there is insufficient ventilation, the rags will ignite.

Which of the following is NOT responsible for this reaction?

A) The presence of flammable materials
B) A spark caused by faulty wiring next to the oil soaked rags
C) The heat generated by the oil soaked rags in the air
D) The presence of oxygen in the unventilated room

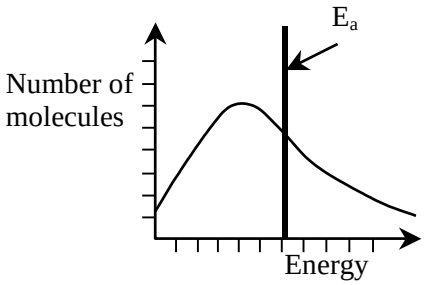
12 A student would like to carry out a reaction between sodium (Na) and water. Aware of the potential dangers of sodium, the student wants to control the rate of this reaction.

Which of the following would produce the slowest reaction between sodium and water?

1. Add sodium to water at 10°C.
2. Add sodium to water at 30°C.
3. Use a 2.0 g chunk of sodium.
4. Use 2.0 g of sodium cut into pieces.

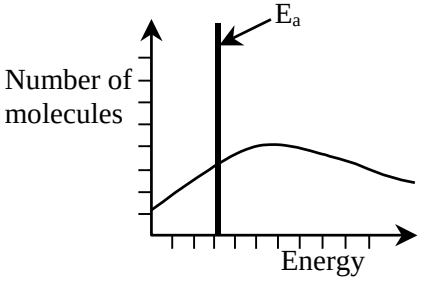
A) 1 and 3
B) 1 and 4
C) 2 and 3
D) 2 and 4

13 Study the kinetic energy distribution curve below:

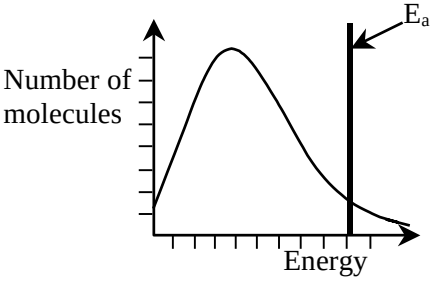


Which of the following energy distribution curves represents the effect of adding a catalyst and increasing temperature?

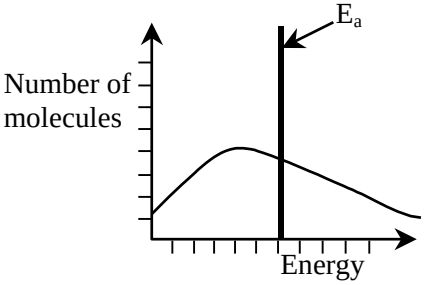
A)



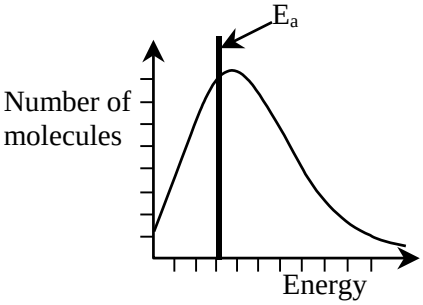
C)



B)



D)



14 A mixture of reddish-brown $NO_{2(g)}$ and colourless $N_2O_{4(g)}$ is put into a sealed glass container. The container is placed in boiling water.

After equilibrium is established, **which of the following is a microscopic property of the system?**

A) The pressure of the system remains constant.

B) The colour of the system remains constant.

C) The temperature remains constant.

D) The atomic configuration remains constant.

15 The ozone layer is not damaged in certain areas of our planet because of the following equilibrium shift:

$$NO_{(g)} + Cl_{(g)} + \text{energy} \leftrightarrow NOCl_{(g)}$$

According to Le Chatelier's principle, **which set of conditions would lower the concentration of the ozone-damaging Cl?**

A) Lower temperature and a higher atmospheric pressure

B) Higher temperature and a higher atmospheric pressure

C) Lower temperature and a lower atmospheric pressure

D) Higher temperature and a lower atmospheric pressure

16 Experiments show that pure water at 25°C will dissociate as follows:

$$H_2O_{(l)} \leftrightarrow H^+_{(aq)} + OH^-_{(aq)}$$

Which of the following correctly defines $[H^+]$ and $[OH^-]$?

A) $[H^+] = 7$ mol/L $[OH^-] = 7$ mol/L

B) $[H^+] = 14$ mol/L $[OH^-] = 1$ mol/L

C) $[H^+] = 1 \times 10^{-14}$ mol/L $[OH^-] = 1 \times 10^{-1}$ mol/L

D) $[H^+] = 1 \times 10^{-7}$ mol/L $[OH^-] = 1 \times 10^{-7}$ mol/L

17 Standard electrode potentials are based on a concentration of 1 M for dissolved ions. Given the following overall reaction:

$$Zn_{(s)} + Cu^{2+}_{(aq)} \leftrightarrow Zn^{2+}_{(aq)} + Cu_{(s)} \qquad E° = 1.10\ V$$

Which of the following conditions would increase the oxidation-reduction potential of the above electrochemical cell?

A) Reducing the concentration of both $Cu^{2+}_{(aq)}$ and $Zn^{+2}_{(aq)}$

B) Reducing the concentration of $Cu^{2+}_{(aq)}$ and increasing the concentration of $Zn^{+2}_{(aq)}$

C) Increasing the concentration of both $Cu^{2+}_{(aq)}$ and $Zn^{+2}_{(aq)}$

D) Increasing the concentration of $Cu^{2+}_{(aq)}$ and reducing the concentration of $Zn^{+2}_{(aq)}$

18 The versatility of baking soda (hydrogen carbonate) is demonstrated by its use in extinguishing fires, in baking biscuits, and in neutralizing excess stomach acids.

The ionization of hydrogen carbonate (HCO_3^-) is demonstrated below:

$$HCO_3^-{}_{(aq)} \leftrightarrow H^+_{(aq)} + CO_3^{2-}{}_{(aq)} \qquad K_a = 2.7 \times 10^{-8}$$

The concentration of hydrogen carbonate is 0.5 mol/L.

What is the molar concentration of $H^+_{(aq)}$ in this solution?

A) 1.3×10^{-8}

B) 5.4×10^{-8}

C) 1.2×10^{-4}

D) 3.7×10^{-7}

Part B

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

19 Antoine Lavoiser produced oxygen by heating mercury (II) oxide (HgO) according to the following equation:

$$2\ HgO_{(s)} \rightarrow 2\ Hg_{(l)} + O_{2(g)}$$

What volume of oxygen will be produced by heating 54.0 g of mercury (II) oxide at STP?

20 A sample of carbon tetrachloride vapour (CCl_4) was obtained at 95.2 kPa pressure and a temperature of 125°C.

Determine the density of that sample in g/L under the given conditions.

21 A science student would like to identify a pure gas sample. She finds the following information:

Mass of empty container	4.40 g
Mass of container + unknown gas	6.00 g
Volume	1210 mL
Temperature	18°C
Pressure	102 kPa

Which of the following is the unknown gas?

H_2, O_2, OCl_2, BCl_3

Part C

Questions 22, 23 and 24
Choose any **two** of these questions and answer them in the answer booklet.

22

Specific Heat Capacities of Some Common Substances (J/g°C)					
Silver	0.238	Lead	0.159	Ice (solid)	2.06
Iron	0.453	Nickel	0.105	Glass	0.84
Copper	0.385	Gold	0.130		

A crime investigator had to find the identity of an unknown solid that was found at a crime scene. The investigator placed this solid in 100.0°C water and allowed it to heat up to the temperature of the water. She then placed the hot metal in a calorimeter containing cool water and collected the data recorded in the data table below.

Mass of the unknown solid	52.8 g
Temperature of the hot water bath	100.0°C
Initial temperature of the water in the calorimeter	21.3°C
Final temperature of the water in the calorimeter	26.0°C
Volume of the water in the calorimeter	90.0 mL

Using the data given and the table of Specific Heat Capacities, determine the identity of the unknown solid. (Assume no heat loss to the calorimeter)

23 A lab technician took 50 mL of a 1.0 mol/L solution of hydrochloric acid (HCl) to neutralize 50 mL of a 1.0 mol/L solution of sodium hydroxide (NaOH). The initial temperature of the two solutions was 22.5°C. The final mixing temperature was 29.2°C.

What was the molar heat of neutralization (ΔH) of the sodium hydroxide?

(Assume the specific heat of solution is equivalent to the specific heat of water.)

24 A lab student is asked to completely evaporate 1.0 mol of water (H_2O) from an initial temperature of 25.0°C. This requires the heating and boiling of water under normal pressure conditions.

$$H_{2(g)} + 1/2\ O_{2(g)} \rightarrow H_2O_{(l)} \qquad \Delta H = -285.9\ kJ/mol$$
$$H_{2(g)} + 1/2\ O_{2(g)} \rightarrow H_2O_{(g)} \qquad \Delta H = -241.8\ kJ/mol$$

How much heat is required to bring 1 mole of water from 25°C to evaporation under the stated conditions?

Part D

Questions 25 and 26
Choose only **one** of these questions and answer it in the answer booklet.

25 Many people keep a 3% solution of hydrogen peroxide (H_2O_2) in their medicine cabinets. One liter of hydrogen peroxide decomposes to oxygen gas and water as suggested below:

$$2\ H_2O_{2(aq)} \rightarrow 2\ H_2O_{(l)} + O_{2(g)}$$

A simple method of showing the rate of this decomposition reaction would be to allow the oxygen gas to escape and to mass the accumulated oxygen gas.

Time, s	Accumulated mol of $O_{2(g)}$	$[H_2O_2]$, mol/L remaining
0	0	0.882
60	0.0925	
120	0.158	
180	0.212	
240	0.255	
300	0.292	

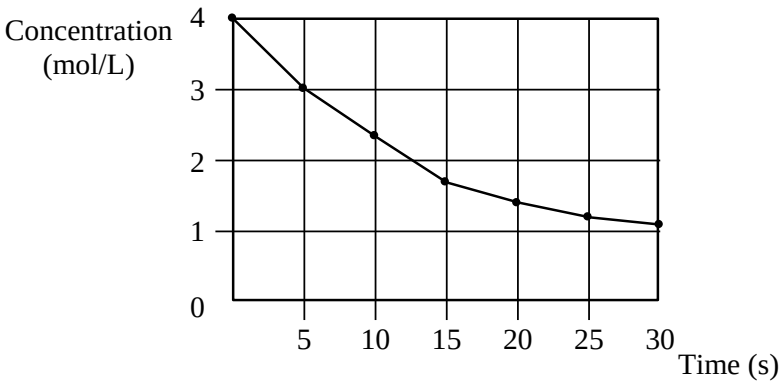
Based on the information given in the table, what is the average rate of decomposition of hydrogen peroxide solution from 60 s to 300 s in mol/L $H_2O_{2(aq)}$ consumed per second?

26 Study the following hypothetical chemical reaction:

$$A_{(s)} + 2\,BC_{(aq)} \rightarrow AC_{2(aq)} + B_{2(g)}$$

Both the graph and the chart below show the consumption of the reactant BC.

Consumption of BC



Time (seconds)	Concentration of BC (mol/L)
0	4.0
5	3.0
10	2.3
15	1.7
20	1.4
25	1.2
30	1.1

Complete the table and graph the average rate of formation of the product B_2 between 5 and 30 seconds in mol/L/s.

Part E

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

27 The following equilibrium situation is at constant temperature.

$$CO_{(g)} + 2\,H_{2(g)} \rightarrow CH_3OH_{(g)}$$

Initially 4.0 moles of $CO_{(g)}$ and 9.0 moles of $H_{2(g)}$ are placed in a 4.0 L container. At equilibrium, 2 moles of $CH_3OH_{(g)}$ are found.

Calculate the equilibrium constant for this reaction.

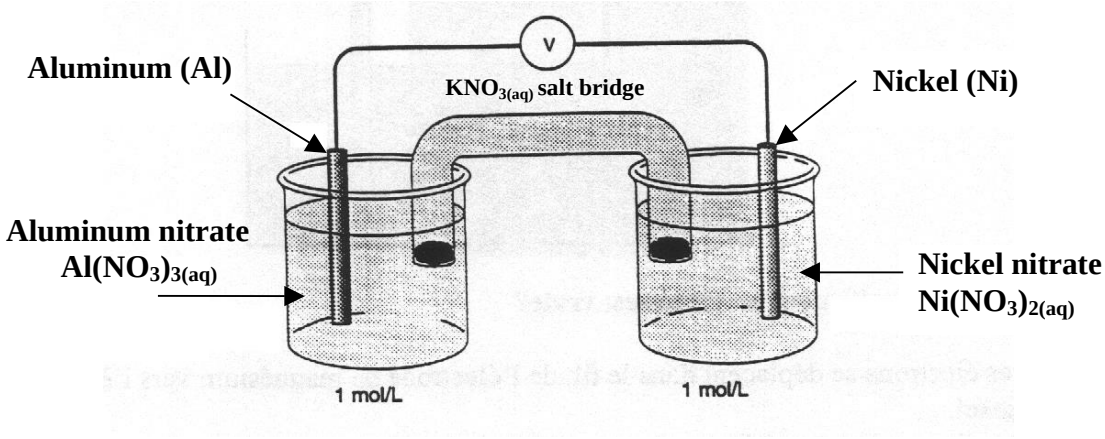
28 A solution is made by dissolving 0.50 mol of acetic acid (CH_3COOH) in 2.00 L of water.

$$CH_3COOH_{(aq)} \leftrightarrow CH_3COO^-_{(aq)} + H^+_{(aq)}$$

The K_a of this system is 1.8×10^{-5}.

What is the pH of the acetic acid?

29



Using the above diagram, determine each of the following:

A. The balanced REDOX reaction

B. *E°*

C. The oxidizing agent

D. The direction of flow of the electrons in the external circuit