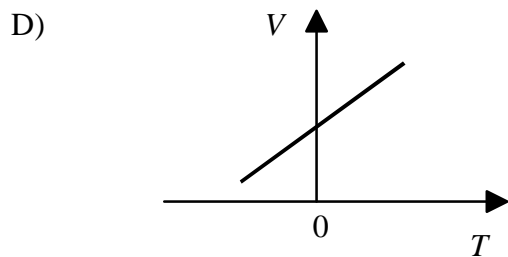
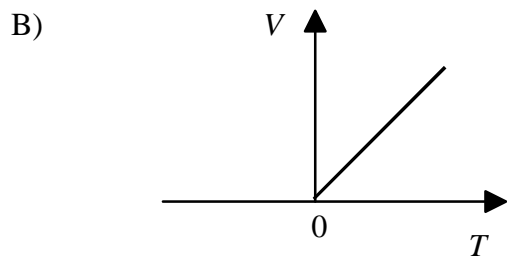
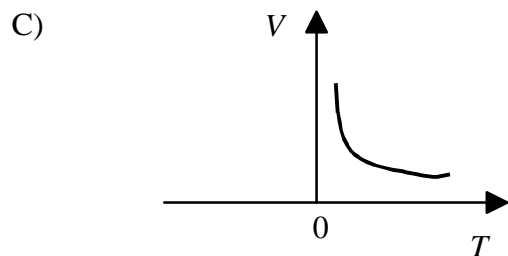
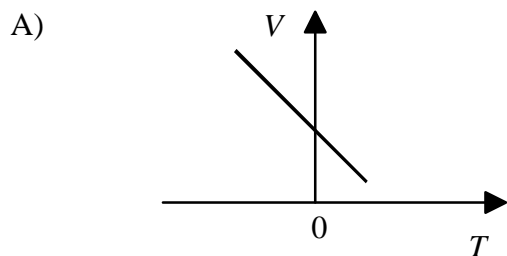


1 Based on the kinetic molecular theory of gases, which one of the following statements is INCORRECT?

- A) The collisions between gas molecules are perfectly elastic.
- B) At absolute zero, the average kinetic energy of all molecules is zero.
- C) At the same pressure, all gas molecules have the same average velocity.
- D) At the same temperature, all gas molecules have the same average kinetic energy.

2 Which of the following graphs best illustrates the volume of gas as a function of the temperature measured in degrees Celsius?



3 Which of the following factors influences the volume occupied by a gas?

1. pressure
2. temperature
3. density
4. solubility
5. number of moles

A) 1, 2 and 5

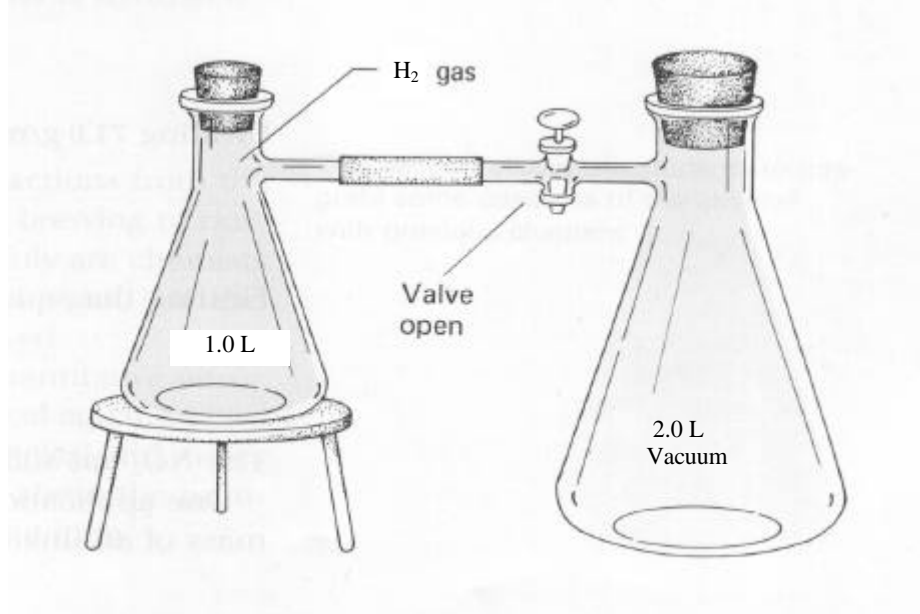
C) 2, 3 and 4

B) 1, 3 and 5

D) 2, 4 and 5

4 The diagram below represents two closed containers of different volumes connected by a tube with a valve. The 1.0 L bulb on the left contains hydrogen gas,  $H_2$ , at a pressure of 75 kPa. The 2.0 L bulb on the right is a vacuum.

**If the valve is opened, what will be the total pressure of hydrogen throughout the system?**



A)  $1.0 \times 10^2$  kPa

C)  $5.0 \times 10^1$  kPa

B)  $7.5 \times 10^1$  kPa

D)  $2.5 \times 10^1$  kPa

5 At which temperature and pressure is the molar volume of a gas the SMALLEST?

- A) 298 K and 25 kPa                      C) 323 K and 50 kPa  
B) 313 K and 101 kPa                    D) 373 K and 75 kPa

6 The pressure inside an aerosol can is  $3.00 \times 10^2$  kPa at 293 K.

**If the temperature of the gas changes to 100.0°C, what will be the new pressure inside the can?**  
(Assume a constant volume.)

- A)  $1.50 \times 10^3$  kPa                      C)  $3.42 \times 10^2$  kPa  
B)  $3.82 \times 10^2$  kPa                    D)  $1.02 \times 10^2$  kPa

7 Which of the following describe an exothermic phenomenon?

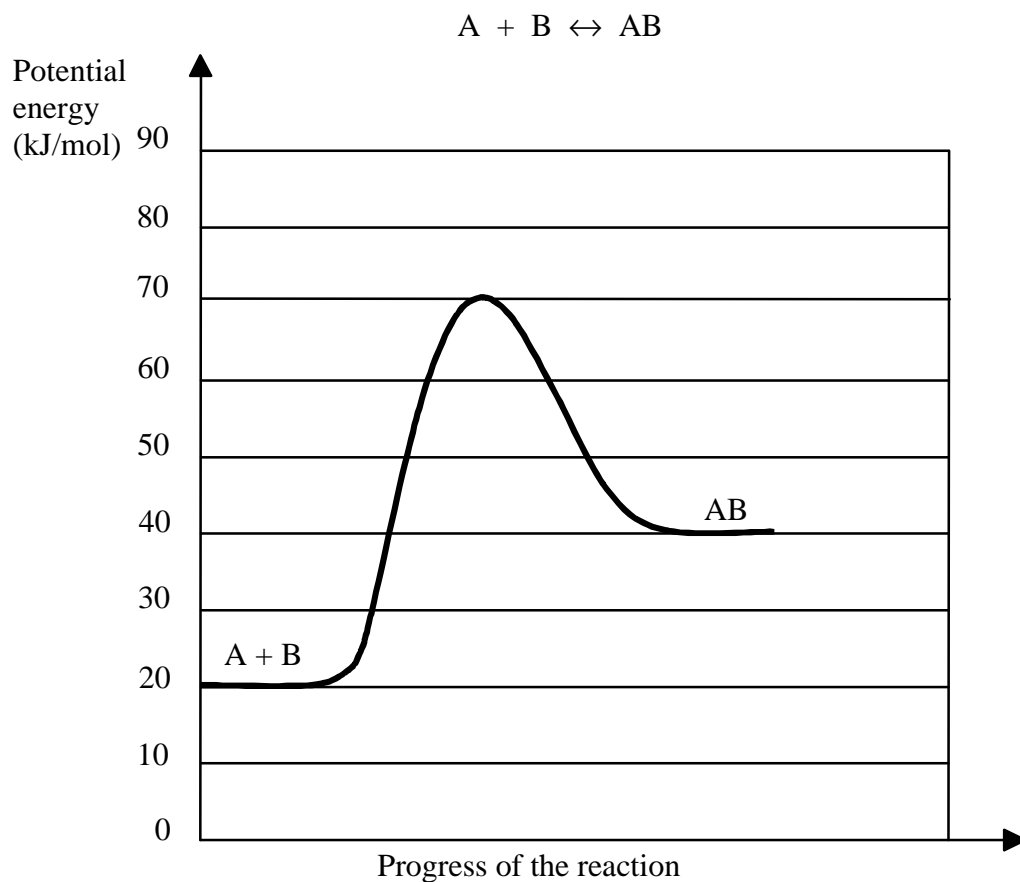
- A) Solid air fresheners sublime to form a scented gas.  
B) In the winter, ice crystals can form on a windowpane.  
C) In hot, arid countries the water in most rivers evaporates during the dry season.  
D) Dissolving ammonium chloride in water reduces the temperature of the solution.

8 A  $1.00 \times 10^2$  mL sample of water at 90.0°C is placed into a calorimeter containing  $1.00 \times 10^2$  mL of water at 25.0°C.

**What is the final temperature of the water in the calorimeter?**

- A) 57.5°C                                      C) 50.0°C  
B) 52.5°C                                      D) 37.0°C

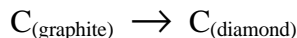
9 Consider the following potential energy diagram for a hypothetical reversible reaction.



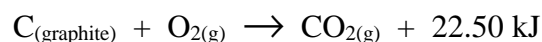
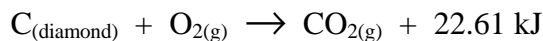
Which of the following sets of observations describes the forward reaction depicted in the graph?

	Reaction type	Activation energy	Change in enthalpy ( $\Delta H$ )
A)	exothermic	70 kJ/mol	+ 20 kJ/mol
B)	exothermic	50 kJ/mol	- 20 kJ/mol
C)	endothermic	70 kJ/mol	- 20 kJ/mol
D)	endothermic	50 kJ/mol	+ 20 kJ/mol

- 10 Carbon, in the form of graphite, can be compressed at high temperatures and high pressures to produce carbon in the form of diamond.



Which of the following is the heat of reaction,  $\Delta H$ , that will produce one mole of diamond from one mole of graphite, based on the equations below?



- A)  $\Delta H = +0.11 \text{ kJ}$                                       C)  $\Delta H = +45.11 \text{ kJ}$   
B)  $\Delta H = -0.11 \text{ kJ}$                                       D)  $\Delta H = -45.11 \text{ kJ}$

- 11 In an experiment, a piece of iron, Fe, with a mass of 4.0 grams was heated from 22°C to 42°C.

During the heating process, the piece of iron absorbed  $5.04 \times 10^{-1} \text{ kJ/mol}$ . What is the specific heat capacity of this piece of iron?

- A) 0.45 J/g•°C    C) 2.2 J/g•°C  
B) 0.90 J/g•°C    D) 180 J/g•°C

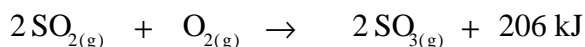
- 12 When one mole of glacial acetic acid,  $\text{CH}_3\text{COOH}_{(\text{l})}$ , is mixed with water to make an aqueous solution of acetic acid, 1.6 kJ is released.

When this prepared aqueous acetic acid solution is neutralized with an aqueous solution of sodium hydroxide,  $\text{NaOH}_{(\text{aq})}$ , 50.0 kJ is released.

On the basis of this information, which of the following equations is correct?

- A)  $\text{CH}_3\text{COOH}_{(\text{l})} + \text{NaOH}_{(\text{aq})} + 49.4 \text{ kJ} \rightarrow \text{NaCH}_3\text{COO}_{(\text{aq})} + \text{H}_2\text{O}_{(\text{l})}$   
B)  $\text{CH}_3\text{COOH}_{(\text{l})} + \text{NaOH}_{(\text{aq})} \rightarrow \text{NaCH}_3\text{COO}_{(\text{aq})} + \text{H}_2\text{O}_{(\text{l})} + 51.6 \text{ kJ}$   
C)  $\text{CH}_3\text{COOH}_{(\text{l})} + \text{NaOH}_{(\text{aq})} + 51.6 \text{ kJ} \rightarrow \text{NaCH}_3\text{COO}_{(\text{aq})} + \text{H}_2\text{O}_{(\text{l})}$   
D)  $\text{CH}_3\text{COOH}_{(\text{l})} + \text{NaOH}_{(\text{aq})} \rightarrow \text{NaCH}_3\text{COO}_{(\text{aq})} + \text{H}_2\text{O}_{(\text{l})} + 49.9 \text{ kJ}$

- 13 The combustion of sulfur dioxide,  $\text{SO}_{2(g)}$ , to sulfur trioxide,  $\text{SO}_{3(g)}$ , is represented by the following equation:



Which one of the following best describes the speed of the reaction?

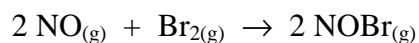
- A) The concentration of sulfur trioxide formed
- B) The number of moles of sulfur dioxide consumed
- C) The mass of oxygen gas consumed per unit of time
- D) The quantity of energy released per mole of product

- 14 Which of the following factors will affect the rate of a chemical reaction by altering the rate of collisions between reacting particles?

1. The nature of the reacting substances
2. The concentrations of the reacting substances
3. The temperature of the reacting substances
4. The presence of a suitable catalyst

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

- 15 Consider the following chemical reaction:



The experimental rate law for the reaction is given by the following mathematical expression:

$$\text{rate} = k [\text{NO}_{(g)}]^2 [\text{Br}_{2(g)}]$$

If the concentration of NO is tripled and that of  $\text{Br}_2$  is doubled, by what factor will the initial rate of the reaction increase?

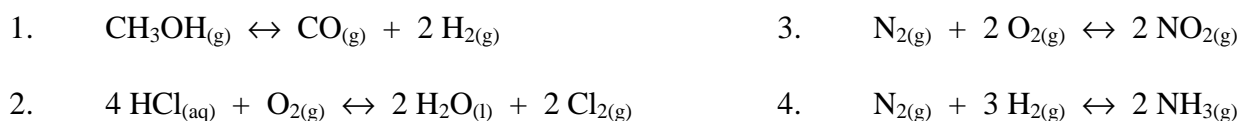
- A) 3 times
- B) 6 times
- C) 9 times
- D) 18 times

16 Which of the following factors are necessary to establish dynamic chemical equilibrium?

1. an open system
2. constant temperature
3. a reversible reaction
4. changing macroscopic properties

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

17 Examine the following four equilibrium systems.



**According to Le Chatelier's Principle, which systems will favour the products if the pressure is increased?**

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

18 Examine the following reaction in dynamic chemical equilibrium:



**Which of the following represents the equilibrium constant expression?**

- A)  $\frac{[\text{Na}_2\text{CO}_{3(s)}][\text{CO}_{2(g)}][\text{H}_2\text{O}_{(g)}]}{[\text{NaHCO}_{3(s)}]^2}$                       C)  $[\text{CO}_{2(g)}][\text{H}_2\text{O}_{(g)}]$   
B)  $\frac{[\text{NaHCO}_{3(s)}]}{[\text{Na}_2\text{CO}_{3(s)}][\text{CO}_{2(g)}][\text{H}_2\text{O}_{(g)}]}$                       D)  $\frac{1}{[\text{CO}_{2(g)}][\text{H}_2\text{O}_{(g)}]}$

- 19 Hydrogen cyanide gas, HCN, a powerful respiratory inhibitor, is highly toxic. It is a weak acid when dissolved in water, as shown by the equation below.

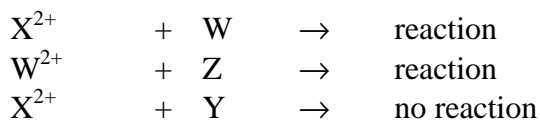


An aqueous solution of hydrogen cyanide, with a concentration of 0.23 mol/L, is prepared. The hydrogen ion concentration is  $1.2 \times 10^{-5}$  mol/L.

**What is the ionization constant ( $K_a$ ) of this acid?**

- A)  $5.2 \times 10^{-5}$                       C)  $6.3 \times 10^{-10}$   
B)  $2.8 \times 10^{-6}$                       D)  $5.5 \times 10^{-11}$

- 20 The information below was collected from an experiment on the reactivity of metals.



**Which of the following combinations classifies these metals in order of *increasing tendency to be oxidized*?**

- A) W, X, Y, Z                      C) Z, W, X, Y  
B) Y, X, W, Z                      D) Z, Y, W, X



## Part B

### Questions 21, 22 and 23

Choose any two (2) of these questions and answer them in the answer booklet.  
Each question is worth five (5) marks.

- 21 A metallic gas cylinder is found in a corner of a machine shop. The cylinder has not been used in some time and the label identifying the gas in the cylinder has fallen off.

Only five gases are used the machine shop.

They are:

Butane ( $C_4H_{10}$ )  
Acetylene ( $C_2H_4$ )  
Methane ( $CH_4$ )  
Oxygen ( $O_2$ )  
Helium (He)

Given the following data about the cylinder, which one of these five gases does it likely hold?

Data Collected

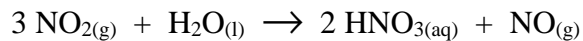
Mass of empty cylinder = 1.24 kg  
Mass of cylinder and the unknown gas = 1.56 kg  
Volume of the cylinder = 240.0 L  
Temperature = 20.0°C  
Gas Pressure = 101.5 kPa

- 22 Kernels of corn contain, on average, 15.0% water by mass.

What volume of water vapour, measured at 100.0°C and 101.3 kPa pressure, is formed from popping 155.0 g of popcorn?

23 Nitric acid,  $\text{HNO}_3$ , is an important industrial chemical used in the manufacture of a number of products including explosives and fertilizers. It is produced commercially by a chemical technique called the *Ostwald Process*.

The final step of this process is:



In one reaction, 96.6 grams of nitrogen dioxide ( $\text{NO}_2$ ) is completely reacted at  $215^\circ\text{C}$  and 505 kPa.

**What volume of nitrous oxide ( $\text{NO}_{(g)}$ ) will be produced at these conditions?**

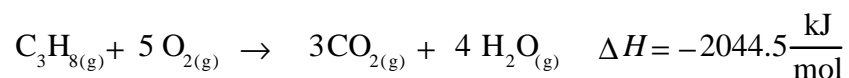
### Part C

#### Questions 24, 25 and 26

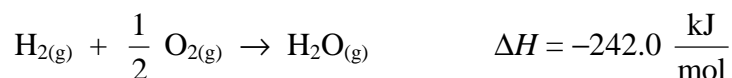
Choose any two (2) of these questions and answer them in the answer booklet.  
Each question is worth five (5) marks.

24 Some automobiles and buses are equipped to burn propane gas,  $C_3H_8$ , as a fuel.

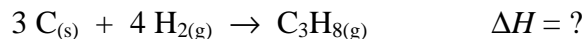
The complete combustion of propane is shown by the following chemical equation:



Given the following heats of formation.



**What is the heat of formation of propane?**

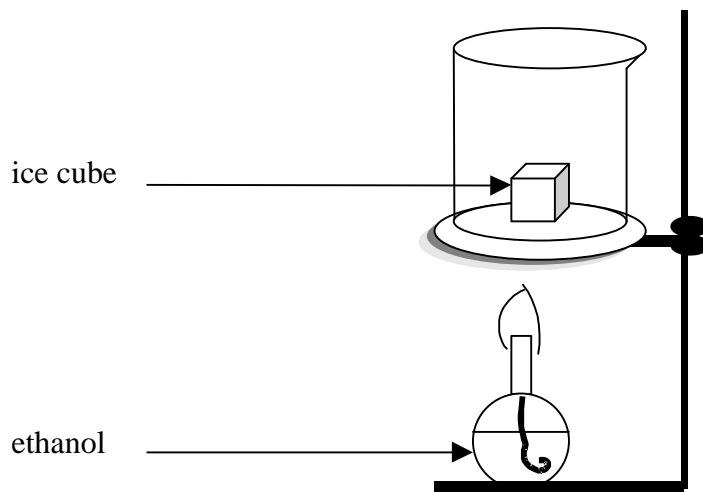


25 In an experiment, 1.40 grams of potassium hydroxide pellets,  $KOH_{(s)}$ , are placed in a calorimeter containing  $1.50 \times 10^2$  mL of water. The temperature of the water increases from  $25.0^\circ\text{C}$  to  $28.0^\circ\text{C}$ .

**What is the molar heat of solution of KOH?**

26

Ethanol is a liquid that combusts relatively easily. In a laboratory investigation, a sample of ethanol was placed into an alcohol burner and ignited. The heat from the combustion of the alcohol was used to melt a cube of ice placed into a beaker as shown below.



Some properties of ethanol and ice are listed below:

Heat of combustion of ethanol = 29.7 kJ/g

Heat of fusion of ice = 0.335 kJ/g

Density of ice =  $0.920 \text{ g/cm}^3$  at  $0^\circ\text{C}$

**Given this information, what *mass of ethanol* is needed to melt a cube of ice that is 5.0 cm on each side?**

(Assume 100% of the heat produced from the ethanol is transferred to the ice cube.)

**Part D**

**Questions 27 and 28**

**Choose only one (1) of these questions and answer it in the answer booklet.  
Each question is worth five (5) marks.**

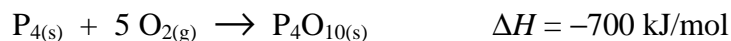
27 Give one justification for your choice based upon the "collision theory" of reactions.

**In each of the following pairs of reactions, choose the one that will be the *slower*.**

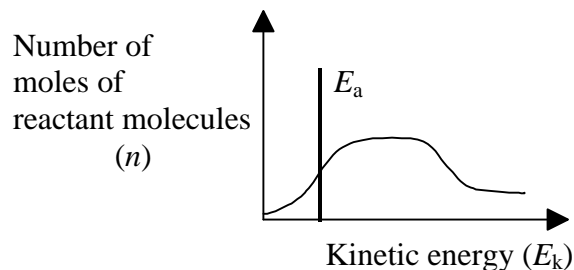
(Assume that all other variables are constant in all reactions.)

1. A) The burning of a strip of magnesium,  $\text{Mg}_{(s)}$ , in air.  
B) The burning of finely powdered magnesium,  $\text{Mg}_{(s)}$ , in air.
2. A) The oxidation of hydrogen peroxide,  $\text{H}_2\text{O}_{2(l)}$ , in air.  
B) The oxidation of hydrogen peroxide,  $\text{H}_2\text{O}_{2(l)}$ , in air, with a catalyst.
3. A) The reaction of 2.5 g of powdered zinc metal,  $\text{Zn}_{(s)}$ , with  $1.0 \frac{\text{mol}}{\text{L}} \text{HCl}_{(aq)}$  at  $50^\circ\text{C}$ .  
B) The reaction of 5.0 g of powdered zinc metal,  $\text{Zn}_{(s)}$ , with  $1.0 \frac{\text{mol}}{\text{L}} \text{HCl}_{(aq)}$  at  $20^\circ\text{C}$ .
4. A) The reaction of hydrogen gas,  $\text{H}_{2(g)}$ , with oxygen,  $\text{O}_{2(g)}$ , in air to produce water vapour,  $\text{H}_2\text{O}_{(g)}$ .  
B) The reaction of hydrogen gas,  $\text{H}_{2(g)}$ , with pure oxygen,  $\text{O}_{2(g)}$ , to produce water vapour,  $\text{H}_2\text{O}_{(g)}$ .
5. A)  $\text{Pb}^{+2}_{(aq)} + 2 \text{I}^{-}_{(aq)} \rightarrow \text{PbI}_{2(s)}$   
B)  $\text{C}_{11}\text{H}_{22}\text{O}_{11(s)} + 11 \text{O}_{2(g)} \rightarrow 11 \text{CO}_{2(g)} + 11 \text{H}_2\text{O}_{(g)}$

28 The spontaneous reaction of a solid piece of phosphorous ( $P_4$ ) with oxygen ( $O_2$ ) in air has an activation energy of 30 kJ/mol and is represented by the following equation.



Here is a sketch of the kinetic energy distribution curve that corresponds to this reaction at 20°C and 101 kPa.

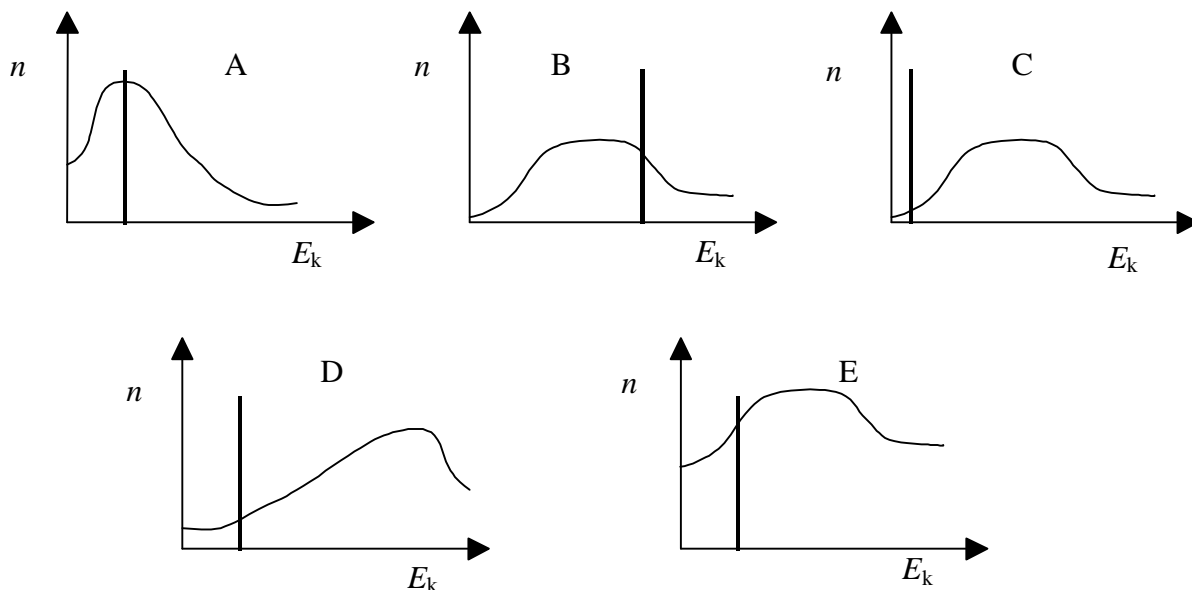


Below is a list of five changes in reaction conditions, along with five kinetic energy distribution curves.

**Which distribution curve best corresponds to each change in conditions listed below?**

Changes in conditions

1. The concentration of oxygen gas is increased.
2. An inhibitor (negative catalyst) is added.
3. The temperature is lowered.
4. A positive catalyst is added.
5. The temperature is raised.



**Part E**

**Questions 29, 30 and 31**

*There are no choices given in this section.*

**Answer all three of these questions in the answer booklet.**

**Each question is worth five (5) marks.**

- 29 Under constant conditions, 2.5 moles of ammonia,  $\text{NH}_3$ , and 2.5 moles of oxygen,  $\text{O}_2$ , are injected into a closed 1.0 L container.

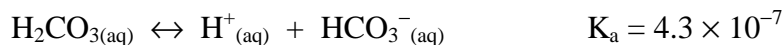
After a period of time the following equilibrium is established.



At equilibrium, 2.4 moles of water vapour are present.

**What is the equilibrium constant for this reaction?**

- 30 Carbonic acid,  $\text{H}_2\text{CO}_3$ , is a weak acid. The dissociation of carbonic acid and the ionization constant,  $K_a$ , are shown below.

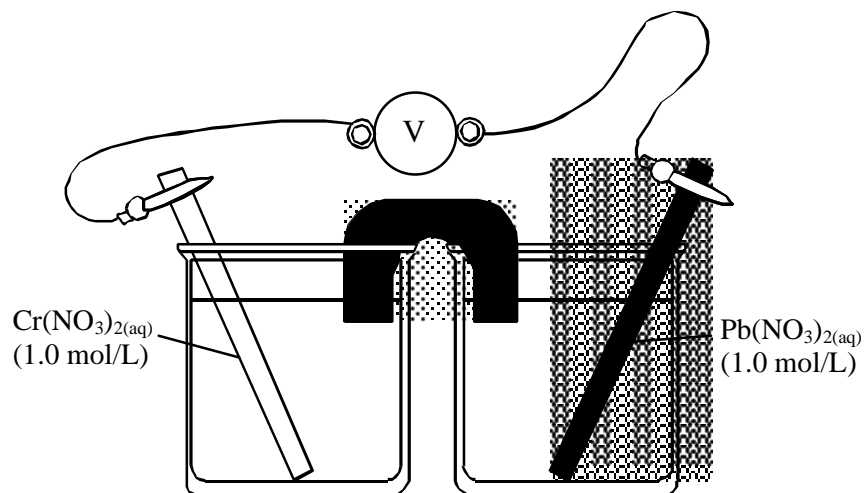


A chemistry student places  $3.1 \times 10^{-2}$  grams of carbonic acid into  $5.0 \times 10^2$  mL of distilled water.

**What is the pH of this solution?**

- 31 A chromium, Cr, rod is placed into a beaker of 1.0 mol/L chromium nitrate,  $\text{Cr}(\text{NO}_3)_2$ , and a lead, Pb, rod is placed into a beaker of 1.0 mol/L lead nitrate,  $\text{Pb}(\text{NO}_3)_2$ .

An electrochemical cell is then constructed and is illustrated below.



Use the table of reduction potentials to answer the following:

1. What is the half-cell reaction at the anode?
2. Which electrode increases in mass?
3. What is the oxidizing agent of the cell?
4. What is the complete cell reaction?
5. What is the cell voltage?



