

Chemical Equilibrium - Part A:

1. At 25°C and 101.3 kPa one mole of hydrogen gas and one mol of chlorine gas are reacted in a stoppered reaction vessel. After a certain time, three gases are detected in the vessel. The molar ratios  $H_2 = 0.22$ ,  $Cl_2 = 0.22$ ,  $HCl = 1.56$  do not change over an observable time period.

- a) Write an equation for the reaction \_\_\_\_\_  
b) What evidence suggests that a state of equilibrium exist?

c) Explain the observations in terms of the DYNAMIC NATURE of the equilibrium system.

d) Suggest THREE alternative explanations other than equilibrium to explain the constancy of macroscopic properties observed in (a)

(1)

(2)

(3)

(e) Can you suggest a way of distinguishing between the possible explanations given in questions (b) and (d)

(1)

(2)

(f) Would equilibrium exist if the reaction vessel was left open to the air? Explain.

2. Explain the DYNAMIC NATURE of the following phase equilibria. Be specific.

(1) Water and water vapour exist together in a closed vessel at constant temperature.

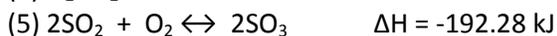
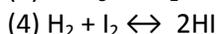
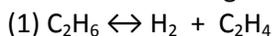
(2) A saturated sugar solution with excess solid in a closed container at constant temperature.

3. (a) Explain the dependence of Le Chatelier's Principle on the rates of the forward and reverse reactions.

(b) What is the relationship between "equilibrium shift" and the product / reactant (P/R) ratio?

(c) If the equilibrium is "disturbed", what effect does this have on the position of the equilibrium or the "extend" of the equilibrium?

4. Given the following chemical equilibria: (Substances are all gases)



Complete the following table:

Reaction	Stress	Effect on Rates Rf and Rb	Shift of equilibrium position P/R ratio up or down
1	Increase in H <sub>2</sub> concentration		
2	Decrease temperature		
3	Increase temperature		
5	Increase temperature		
4	Decrease volume		
5	Add a solid catalyst. Vessel vol. constant		
5	Add a solid catalyst. Vessel vol. Vary		
5	Add some inert gas. i.e. He T and P is constant.		
5	Add some He volume constant		

5. The formation of ammonia from its elements occurs industrially by the Haber process.

(1) Write the equation for the reaction \_\_\_\_\_

(2) Use Le Chatelier's Principle to determine the ideal conditions of temperature and pressure for maximizing the yield of ammonia for industrial and commercial application.

Pressure:

Temperature:

(3) Table 11a. Page 692 gives the yields of ammonia in the Haber Process as a function of temperature and pressure. Explain why the industrial conditions do not correspond to the conditions of maximum yield as given by the table.

6.  $2\text{SO}_2 + \text{O}_2 \leftrightarrow 2\text{SO}_3$  (all are gases)  $K = 43.6$

(a) Write the equilibrium law expression for this reaction

(b) The units of K are \_\_\_\_\_

(c) What is the equilibrium constant for the reverse reaction?

7. The water gas reaction:  $\text{CO}_2 + \text{H}_2 \leftrightarrow \text{CO} + \text{H}_2\text{O}$  (all are gases) was carried out at  $900^\circ\text{C}$  with the following results. P = Partial pressure

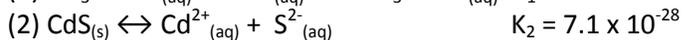
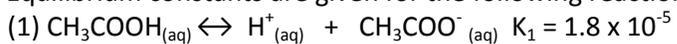
Trial	$P_{\text{CO}}$	$P_{\text{H}_2\text{O}}$	$P_{\text{CO}_2}$	$P_{\text{H}_2}$
1	0.352	0.352	0.648	0.148
2	0.266	0.266	0.234	0.234
3	0.186	0.686	0.314	0.314

(a) Write the equilibrium law expression for this reaction  $K_p =$

(b) Verify that the expression in (a) is indeed a numerical constant using the equilibrium constant based on partial pressures.

Solution:

8. Equilibrium constants are given for the following reactions.



Which reaction as written with the information given above, is the most spontaneous i.e the product are favoured over the reactants? Explain why.

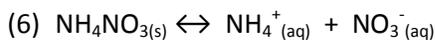
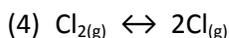
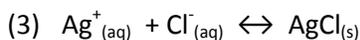
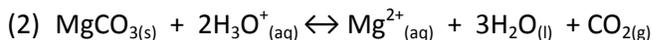
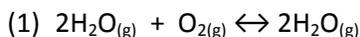
9.(a) Entropy is defined as

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(b) For each of the following processes, predict, with reasoning, whether the entropy of the system increases or decreases when the reactants forms products.



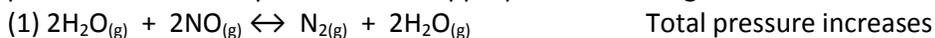
10.(a) The two driving factors affecting the extend of a reaction are entropy and enthalpy. A reaction would be very spontaneous and have a very high K if in proceeding to the right entropy \_\_\_\_\_ and enthalpy \_\_\_\_\_. These are the two governing principles for all chemical reactions.

(b) Explain using these principles why the melting of ice at 273 K is a spontaneous process even though the reaction is endothermic.

Remedial Problem Set: Chemical Equilibrium 92

Part A

1. Each of the following reactions has come to equilibrium. In this system using "Le Chatelier's Principle" predict the shift in equilibrium with appropriate reasoning.



2. Given the equilibrium  $\text{Fe}^{3+}_{(aq)} + \text{SCN}_{(aq)} \leftrightarrow \text{FeSCN}^{2+}_{(aq)}$ . What is the effect on colour intensity of the solution if NaF(s) is added? The following equilibrium has a very high K. It is known that  $\text{Fe}^{3+}$  reacts with  $\text{F}^-$  ions.  $\text{Fe}^{3+}_{(aq)} + 6\text{F}^{-}_{(aq)} \leftrightarrow [\text{FeF}_6]^{3-}_{(aq)}$

3. What experimental conditions of pressure and temperature will give the best yields of  $\text{HCl}_{(g)}$ ?

4. Explain how the tendencies towards minimum enthalpy and maximum entropy affect the following:



Part B 100

1. Silver chloride is sparingly soluble in water represented by this equation:



What is the effect on the position of the equilibrium if more AgCl solid is added to the system? Explain.

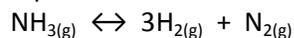
2. Calcium carbonate dissociates according to this equation:



(1) Write the equilibrium constant expression for this reaction

(2) What would happen to the vapour pressure of  $\text{CO}_2$  if some solid calcium carbonate or calcium oxide were added at constant temperature and constant container volume? Explain

3. When 1 mole of  $\text{NH}_{3(g)}$  and 0.4 mol of  $\text{N}_{2(g)}$  are placed in a five litre container and allowed to reach equilibrium at a certain temperature, it is found that 0.78 mol of  $\text{NH}_3$  is present. The reaction is



(1) Calculate the number of moles of hydrogen and nitrogen gases at equilibrium.

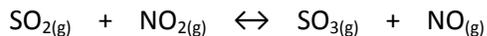
(2) Calculate the concentration of each product and reactant present.

4. The equilibrium constant for  $2X_{(g)} \leftrightarrow Y_{(g)} + Z_{(g)}$  is 3.0. How many moles of X are present at equilibrium when 1.00 mol of each of Y and Z are placed in a 5 L container.

5. When 0.04 mol of  $PCl_5$  is heated to  $250^\circ C$  in a 1 litre vessel, an equilibrium is established in which the concentration of  $Cl_2$  is 0.025 mol/L. Find the equilibrium constant value for the reaction.



6. At a given temperature, analysis of an equilibrium mixture shows that the concentrations in mol/L of  $SO_2$ ,  $SO_3$ ,  $NO_2$  and  $NO$  are 4.0, 3.0, 0.5 and 2.0 respectively. How many moles of  $NO_2$  must be added to increase the concentration of  $SO_3$  by 1.0 mol/L at constant temperature? The reaction is



7. Will there be a net reaction when 2.5 moles of  $\text{PCl}_5$ , 0.60 moles of  $\text{Cl}_2$ , 0.60 moles of  $\text{PCl}_3$  are placed in a 1 litre vessel and heated to  $250^\circ\text{C}$ . If so which reaction (forward or reverse) takes place? Explain.

8. At a specific concentration the substance  $\text{AO}_2$  is 10% dissociated at a given temperature as follows:



For these conditions, how many moles of EACH component will be present in a mixture at equilibrium if 2 moles of  $\text{A}_2\text{O}_3$  and 1 mol of  $\text{O}_2$  are present initially?

9. Predict the spontaneity of the following reactions by using the Gibbs Free Energy equation to approximate the sign of  $G$

