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CHEM 3410: Physical Chemistry I — Fall 2008

In-class practice problems

October 14, 2009

1. The decomposition of calcium carbonate can proceed as follows:

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$$

Some thermochemical data:

	$CaCO_3$ (s)	CaO (s)	CO_2 (g)
ΔG_f° (kJ/mol)	-1128.8	-604.0	-394.36
ΔH_f° (kJ/mol)	-1206.9	-635.09	-393.51

(a) What is the pressure of carbon dioxide at equilibrium at room temperature (25°C).

(b) What is the pressure of CO_2 at equilibrium at 1100 K?

2. For the equilibrium:

$$CH_4(g) \rightleftharpoons 2H_2(g) + C(s,\ graphite)$$

find an expression relating the equilibrium constant, K_p to the degree of dissociation of methane, α. (If n moles of methane are initially placed in the container, then αn moles will have dissociated at equilibrium).

Predict how an increase in pressure will affect the mole fraction of methane in an equilibrium mixture of methane, hydrogen, and solid graphite. Comment on this result in light of Le Chatelier's principle.

3. Consider the reaction:

$$CO(g) + 2\ H_2(g) \rightleftharpoons CH_3OH(g)$$

You are given the following data:

$$\Delta H_{rxn}^\circ = -90.2 \text{ kJ/mol} \quad \Delta S_{rxn}^\circ = -219.1 \text{ J/mol·K}$$

(a) Find ΔG_{rxn}° and K_p at 500 K for the reaction. You may assume that both ΔH_{rxn}° and ΔS_{rxn}° are independent of T.

(b) Write an expression of K_p in terms of the partial pressures of the species involved in the reaction. Feel free to omit the reference pressure for convenience.

(c) Starting from your expression in part (b), write K_p in terms of the mole fraction of each species and the total pressure, P_{tot}.

(d) In a particular experiment, you begin with 1 mole of CO(g) and 1 mole of H_2(g). The reactants are allowed to react to form CH_3OH(g) at 500 K and at constant total pressure P_{tot}.

What is P_{tot} if at equilibrium 0.25 moles of CH_3OH(g) are formed?

(e) Suppose that the yield of CH_3OH(g) needs to be increased to 0.3 mole. Should the pressure be increased, decreased, or not changed compared to the pressure in part c. Explain briefly. (No calculation is required).