

CHEM 5200 - Exam 3 - November 1, 2018

INFORMATION PAGE (Use for reference and for scratch paper)

Constants and Conversion Factors:

$$R = 8.31 \text{ J/mol-K} = 8.31 \text{ kPa-L/mol-K} = 0.00831 \text{ kJ/mol-K}$$

$$1 \text{ L-atm} = 101 \text{ J}$$

$$1 \text{ L-bar} = 100 \text{ J}$$

$$1 \text{ kPa-L} = 1 \text{ J}$$

$$1 \text{ bar} = 100 \text{ kPa}$$

$$1 \text{ bar} = 750 \text{ torr}$$

$$1 \text{ atm} = 760 \text{ torr}$$

$$1 \text{ kPa} = 7.50 \text{ torr}$$

The relation between the Molar Mass (M), density (ρ) and Molar Volume (V_m)

of a material is: $\rho = \frac{M}{V_m}$

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Name Solution

(36) MULTIPLE CHOICE [3 points per question] (Circle the ONE correct answer)

1. Consider a mixture of two liquids, A and B. When 8.0 moles of A and 4.0 moles of B are mixed together, the volume of the solution is 700 cm^3 . The Partial Molar Volume of B is $80. \text{ cm}^3/\text{mol}$. Therefore, the Partial Molar Volume of A is approximately:
(A) $48 \text{ cm}^3/\text{mol}$ (B) $15 \text{ cm}^3/\text{mol}$ (C) $62 \text{ cm}^3/\text{mol}$
(D) Cannot be determined without the density of the solution
2. The vapor pressure of CCl_4 is 54.6 kPa at $60 \text{ }^\circ\text{C}$. When an unknown amount of an organic solid is dissolved in 5.0 moles of CCl_4 , the vapor pressure above the solution at $60 \text{ }^\circ\text{C}$ is 50.6 kPa . Approximately how many moles of the solid were dissolved in the CCl_4 ?
(A) 0.27 mol (B) 0.40 mol (C) 0.083 mol
(D) Insufficient information. The Molar Mass of the organic solid is needed.
3. When a sample of glucose, $\text{C}_6\text{H}_{12}\text{O}_6$ ($M=180$), is dissolved in 600 grams of water ($K_b = 0.5 \text{ }^\circ\text{C}/m$), the boiling point is raised to $100.8 \text{ }^\circ\text{C}$. Approximately how many grams of glucose are in the sample?
(A) 290 g (B) 480 g (C) 220 g (D) 170 g
4. When 50 grams of an unknown compound is dissolved in 500 of water ($K_f=1.9 \text{ }^\circ\text{C}/m$), the freezing point of the solution is $-2.20 \text{ }^\circ\text{C}$. The Molar Mass of the compound is approximately
(A) 58 g/mol (B) 86 g/mol (C) 105 g/mol (D) 43 g/mol
5. When a solution of an unknown compound is prepared by putting 10 grams of an unknown compound into 500 mL of solution, the osmotic pressure of the solution is 1.0 bar at $25 \text{ }^\circ\text{C}$. The Molar Mass of the unknown compound is approximately
(A) 250 g/mol (B) 5,000 g/mol (C) 500 g/mol (D) 50,000 g/mol
6. The boiling point of pure toluene is $111.0 \text{ }^\circ\text{C}$ and the Boiling Point Elevation Constant is $3.40 \text{ }^\circ\text{C}/m$. When 25 grams a compound, A ($M_A=100$), is dissolved in 500 grams of Toluene, the boiling point of the solution is $113.2 \text{ }^\circ\text{C}$. Therefore, the activity coefficient of the compound (γ_A) in the solution is approximately:
(A) 1.3 (B) 0.65 (C) 0.8
(D) Insufficient data to determine activity coefficient

7. Consider the gas phase equilibrium, $4 \text{NO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{N}_2\text{O}_5(\text{g})$

For the above reaction, if $\text{N}_2(\text{g})$ is added to the container at **constant pressure**,

- (A) the equilibrium will move to the left and K will remain constant
- (B) the equilibrium will move to the right and K will remain constant
- (C) the equilibrium will be unchanged and K will remain constant
- (D) the equilibrium will move to the left and K will decrease

For #8 - #9: Consider the gas phase equilibrium, $2 \text{NO}_2(\text{g}) \rightleftharpoons \text{N}_2\text{O}_4(\text{g})$. At 25°C , the Gibbs Energies of Formation of $\text{NO}_2(\text{g})$ and $\text{N}_2\text{O}_4(\text{g})$ are $+51.3 \text{ kJ/mol}$ and $+97.9 \text{ kJ/mol}$, respectively.

8. The value of the equilibrium constant, K, for the above reaction at 25°C , is approximately:

- (A) 6.7×10^{-9}
- (B) 0.15
- (C) $1.5 \times 10^{+8}$
- (D) 6.7

9. The value of ΔG for the above reaction at 25°C when the pressures of NO_2 and N_2O_4 are 0.3 bar and 5.0 bar, respectively, is approximately:

- (A) $+2.3 \text{ kJ}$
- (B) $+5.2 \text{ kJ}$
- (C) $+14.6 \text{ kJ}$
- (D) -2.3 kJ

10. Consider the gas phase equilibrium, $2 \text{A}(\text{g}) \xrightleftharpoons{K} \text{B}(\text{g})$. When the pressures of A and B are each 0.10 bar at 100°C , the Gibbs Energy change for the reaction is $+0.70 \text{ kJ}$. What is the approximate value of the equilibrium constant at 100°C ?

- (A) 1.3
- (B) 10.0
- (C) 8.0
- (D) 0.13

11. The gas phase molecule, A, dissociates according to the equilibrium,

$\text{A}(\text{g}) \rightleftharpoons 2 \text{B}(\text{g}) + \text{C}(\text{g})$. The equilibrium constant is 3×10^{-3} . If one puts an initial pressure of 6. bar of A into a flask, what is the approximate pressure of B at equilibrium? [NOTE: You may assume that very little A dissociates]

- (A) 0.33 bar
- (B) 0.17 bar
- (C) 0.13 bar
- (D) 0.52 bar

12. Consider the gas phase equilibrium, $\text{A}(\text{g}) \rightleftharpoons 2 \text{B}(\text{g})$. If one puts 2.0 moles of A (no B initially) into a container and the system is allowed to reach equilibrium, it is found that the equilibrium mixture contains 1.2 moles of A at a total pressure of 3.0 bar. The value of the equilibrium constant is approximately:

- (A) 0.3
- (B) 2.3
- (C) 0.8
- (D) 6.8

FIVE (5) problems follow: NOTE: You Must show your work to receive credit.

- (12) 1. The densities of solid and liquid Chromium [M = 52.] are 7.1 g/mL and 6.4 g/mL, respectively. The normal melting point of Chromium is 1907 °C. When a pressure of 800 atm. is applied to Chromium, its melting point rises to 1914 °C

Use the above data to calculate the Enthalpy of Fusion of Chromium, kJ/mol.

$$T = 1907^{\circ}\text{C} + 273 = 2180\text{K}$$

$$\Delta T = 1914 - 1907 = 7^{\circ}\text{C} = 7\text{K}$$

$$\Delta P = 800 - 1 = 799\text{ atm.}$$

$$\begin{aligned}\Delta V_m &= V_m(l) - V_m(s) = \frac{52\text{g}}{6.4\text{g/mL}} - \frac{52}{7.1\text{g/mL}} = 8.13\text{ mL} - 7.32\text{ mL} \\ &= 0.80\text{ mL} \times \frac{1\text{L}}{10^3\text{ mL}} = 8.0 \times 10^{-4}\text{ L}\end{aligned}$$

$$\frac{\Delta P}{\Delta T} = \frac{\Delta_{\text{fus}} H^{\circ}}{T \Delta V_m} \rightarrow \Delta_{\text{fus}} H^{\circ} = T \Delta V_m \frac{\Delta P}{\Delta T}$$

$$= 2180\text{K} (8.0 \times 10^{-4}\text{ L}) \frac{(799\text{ atm})}{7\text{K}} = 199\text{ L-atm/mL}$$

$$= 199 \frac{\text{L-atm}}{\text{mL}} \times \frac{101\text{ J}}{12\text{ L-atm}} + \frac{1\text{ kJ}}{1000\text{ J}}$$

$$= 19.9 \approx \boxed{20.0\text{ kJ/mol}}$$

- (12) 2. The normal boiling point of iodobenzene is 188 °C and the vapor pressure is 40. torr at 90 °C. Calculate the Enthalpy of Vaporization, $\Delta_{\text{vap}}H^\circ$ of iodobenzene (in kJ/mol)

$$T_1 = 188^\circ\text{C} = 461\text{K} \quad T_2 = 90^\circ\text{C} = 363\text{K}$$

$$P_1 = 1\text{bar} \Rightarrow 750\text{torr} \quad P_2 = 40\text{torr}$$

$$\ln\left(\frac{P_2}{P_1}\right) = -\frac{\Delta_{\text{vap}}H^\circ}{R} \left[\frac{1}{T_2} - \frac{1}{T_1} \right]$$

$$\Delta_{\text{vap}}H^\circ = \frac{-R \ln\left(\frac{P_2}{P_1}\right)}{\frac{1}{T_2} - \frac{1}{T_1}} = \frac{-8.31 \frac{\text{J}}{\text{K}} \ln\left(\frac{40}{750}\right)}{\frac{1}{363\text{K}} - \frac{1}{461\text{K}}}$$

$$= 41,600 \frac{\text{J}}{\text{mol}} \times \frac{1\text{kJ}}{1000\text{J}}$$

$$= 41.6 \text{ kJ/mol}$$

$$T = 85^\circ\text{C} = 358\text{K}$$

- (14). 3. Consider the mixing of two ideal gases, Ethane and Butane. Determine the following quantities when 120 grams of $\text{C}_2\text{H}_6(\text{g})$ [$M=30$], and 120. grams of $\text{C}_4\text{H}_{10}(\text{g})$ [$M=58$], are mixed together at 85°C .

(10) (a) The Gibbs Energy of Mixing, $\Delta_{\text{mix}}G$ (in kJ)

$$n_E = 120\text{g} / 30\text{g/mol} = 4.00\text{mol}$$

$$n_B = 120\text{g} / 58\text{g/mol} = 2.07\text{mol}$$

$$x_E = \frac{4.00}{6.07} = 0.66$$

$$x_B = \frac{2.07}{6.07} = 0.34$$

$$n = 4.00 + 2.07 = 6.07\text{mol}$$

$$\Delta_{\text{mix}}G = nRT [x_E \ln x_E + x_B \ln x_B] = 6.07\text{mol} (8.31 \frac{\text{J}}{\text{mol}\cdot\text{K}}) (358\text{K})$$

$$= -11,580\text{J}$$

$$\approx -11.6\text{kJ}$$

$$[0.66 \ln(0.66) + 0.34 \ln(0.34)]$$

(4) (b) The Enthalpy of Mixing, $\Delta_{\text{mix}}H$ (in kJ)

$$\Delta_{\text{mix}}G = \Delta_{\text{mix}}H - T\Delta_{\text{mix}}S$$

$$\therefore \Delta_{\text{mix}}H = \Delta_{\text{mix}}G + T\Delta_{\text{mix}}S$$

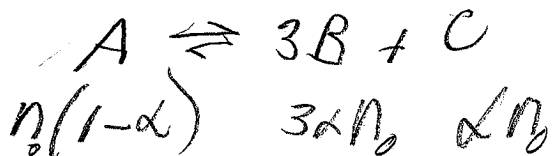
$$= nRT [x_E \ln(x_E) + x_B \ln(x_B)] + T(-nR [x_E \ln(x_E) + x_B \ln(x_B)])$$

$$\Delta_{\text{mix}}H = 0$$

you will receive full credit if you just write that $\Delta_{\text{mix}}H = 0$

- (12) 4. Consider the gas phase dissociation equilibrium, $A(g) \xrightleftharpoons{K} 3B(g) + C(g)$. At 25 °C, the percent dissociation of A is 40% at a total pressure of 3.0 bar. Calculate the equilibrium constant, K.

Note: You cannot assume that very little A reacts.



$$n_{\text{tot}} = n_0 - \alpha n_0 + 3\alpha n_0 + \alpha n_0$$

$$= n_0 + 3\alpha n_0$$

$$= n_0 (1 + 3\alpha)$$

$$x_i = \frac{n_i}{n_{\text{tot}}}$$

$$\begin{array}{ccc} \frac{1-\alpha}{1+3\alpha} & \frac{3\alpha}{1+3\alpha} & \frac{\alpha}{1+3\alpha} \end{array}$$

$$\begin{array}{ccc} 0.273 & 0.545 & 0.182 \end{array}$$

$$\begin{array}{ccc} 0.819 & 1.635 & 0.546 \end{array}$$

$\alpha = 0.40$
 $x_i =$
 $P_i = x_i P$
 $= x_i \times 3 \text{ bar}$

$$K = \frac{P_B^3 P_C}{P_A} = \frac{(1.635)^3 (0.546)}{0.819}$$

$$= 1.78 \approx 1.8$$

$$P_0 = 5.0 \text{ bar}$$

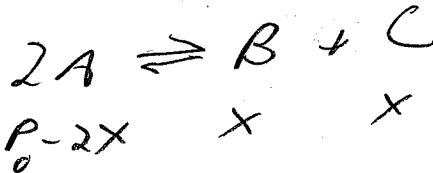
(14) 5. Consider the gas phase equilibrium: $2A(g) \xrightleftharpoons{K} B(g) + C(g)$.

The equilibrium constant for this reaction is $K = 2.0$

If one starts with pure A at an initial pressure of 5.0 bar (and no B or C initially), calculate the pressures of A and B at equilibrium.

Notes: 1. You **Cannot** assume that very little B and C react.

2. However, it should **not** be necessary to use the quadratic equation for this problem.



$$K = 2.0 = \frac{P_B P_C}{P_A^2} = \frac{x \cdot x}{(P_0 - 2x)^2}$$

$$\sqrt{K} = \sqrt{2} = \frac{x}{P_0 - 2x}$$

$$\sqrt{2} P_0 - 2\sqrt{2} x = x$$

$$x(1 + 2\sqrt{2}) = \sqrt{2} P_0$$

$$x = \frac{\sqrt{2} P_0}{1 + 2\sqrt{2}} = 1.85$$

$$P_A = 5 - 2x = 1.306 \approx 1.31 \text{ bar}$$

$$P_B = x = 1.85 \text{ bar}$$