

CHEM 3530 - Exam 3 - March 30, 2018

Constants and Conversion Factors

$$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$$

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

$$1 \text{ bar} = 100 \text{ kPa} = 750 \text{ torr}$$

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

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

$$1 \text{ kcal} = 4.18 \text{ kJ}$$

Molar Masses:

Given in the individual questions on this test.

Quadratic Equation: If $ax^2+bx+c=0$, then $x = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$

NOT needed on this year's test

CHEM 3530 - Exam 3 - March 31, 2017

Name Solutions

(76) PART I. MULTIPLE CHOICE (Circle the ONE correct answer)

For #1 - #2: When 45 grams of glucose [M=180] is added to 120 grams of water [M=18], the density of the solution is 1.25 g/mL.

- The **Molarity** of the above solution is approximately
(A) 1.5 Molar (B) 1.9 Molar (C) 2.6 Molar (D) 2.1 Molar
- The **molality** of the above solution is approximately
(A) 1.5 molal (B) 1.9 molal (C) 2.6 molal (D) 2.1 molal
- How many grams of sucrose [M=342] are required to prepare 2.5 L of a 0.40 Molar sucrose solution?
(A) 342 grams (B) 171 grams (C) 137 grams (D) 55 grams
- The vapor pressure of a **solution** containing 90 grams of water [M=18] and 144 grams of glucose [M=180] is 79. torr at 50 °C. What is the approximate vapor pressure of **pure water** at 50 °C?
(A) 211 torr (B) 68 torr (C) 92 torr (D) 30 torr
- The freezing point of pure CCl₄ is $T_f^\circ = -23.0$ °C. When a sample of naphthalene, C₁₀H₈ [M=128], is dissolved in 750 grams of CCl₄ ($K_f = 30$ °C/m), the freezing point of the solution is -37.0 °C. Approximately how many grams of naphthalene were dissolved?
(A) 60 g (B) 92 g (C) 80 g (D) 45 g
- The normal boiling point of pure benzene is 80.1 °C. When 50 grams of an unknown compound is dissolved in 700 grams of benzene ($K_b = 2.1$ °C/m), the boiling point of the solution is 81.8 °C. The Molar Mass of the compound is approximately
(A) 93 g/mol (B) 88 g/mol (C) 43 g/mol (D) 62 g/mol
- When 41 grams of the strong electrolyte, Na₃PO₄ [M=164], is dissolved in 150 grams of water ($K_b = 0.5$ °C/m), the boiling point of the solution is
(A) 103.3 °C (B) 96.7 °C (C) 100.8 °C (D) 102.5 °C
- The osmotic pressure of an aqueous solution of sucrose (C₁₂H₂₂O₁₁) is 6.40 bar at 30 °C. How many moles of sucrose are contained in 250 mL of this solution?
(A) 3.8×10^{-3} mol (B) 0.25 mol (C) 0.064 mol (D) 6.4×10^{-4} mol

9. When a solution of an unknown compound is prepared by putting 15. grams of an unknown compound into 750 mL of aqueous solution, the osmotic pressure of the solution is 0.50 bar at 25 °C. The Molar Mass of the unknown compound is approximately

- (A) 520 g/mol (B) 990 g/mol (C) 740 g/mol (D) 100,000 g/mol

For #10 - #13: Consider the gas phase equilibrium,
 $2 \text{NO}_2(\text{g}) + \frac{1}{2} \text{O}_2(\text{g}) \rightleftharpoons \text{N}_2\text{O}_5(\text{g})$. The enthalpy change for this reaction is -170 kJ and the equilibrium constant is 2.5 at 150 °C.

10. For the above reaction, if $\text{N}_2(\text{g})$ is added at a constant total pressure of 5 bar,

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

11. For the above reaction, if the temperature is increased,

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

12. The standard state Gibbs energy change, $\Delta_r G^\circ$, for the above reaction at 150 °C is approximately :

- (A) -3.2 kJ (B) -1.4 kJ (C) -3200 kJ (D) +1.4 kJ

13. What is K for the reaction, $2 \text{N}_2\text{O}_5(\text{g}) \rightleftharpoons 4 \text{NO}_2(\text{g}) + \text{O}_2(\text{g})$ at 150 °C ?

- (A) 6.25 (B) 0.20 (C) 0.16 (D) 0.63

14. For the gas phase equilibrium, $2\text{A}(\text{g}) + \text{B}(\text{g}) \rightleftharpoons 2\text{C}(\text{g})$, the equilibrium constant is $K = 1 \times 10^{-3}$. If one puts A and B into a vessel with initial pressures, $P_{\text{init}}(\text{A}) = P_{\text{init}}(\text{B}) = 3$. bar, what is the pressure of C at equilibrium?

NOTE: You may assume that very little A and B react.

- (A) 0.045 bar (B) 0.164 bar (C) 0.082 bar (D) 0.063 bar

For #15 - #16: We learned in class that the average number of ligands bound to a protein, R , is related to the ligand concentration, L , by:

$$R = \frac{n[L]}{K + [L]} \quad \text{where } n \text{ is the maximum number of bound ligands and } K \text{ is the dissociation constant}$$

For a given protein, it was determined from equilibrium dialysis experiments that the Dissociation Constant is 0.15 M and the maximum number of bound ligands is 80 .

15. The **slope** of the double reciprocal plot, $1/R$ vs. $1/[L]$, is (in units of M):
 (A) 1.25×10^{-2} (B) 5.33×10^3 (C) 8.33×10^{-2} (D) 1.88×10^{-3}
16. The **intercept** of the double reciprocal plot, $1/R$ vs. $1/[L]$, is:
 (A) 1.25×10^{-2} (B) 5.33×10^3 (C) 8.33×10^{-2} (D) 1.88×10^{-3}
17. A hypothetical biochemical reaction is written as: $A(aq) + 2H^+(aq) \rightarrow B(aq)$. The Gibbs energy difference using the Physical Chemists' Standard State is $\Delta G^{\circ} = -20 \text{ kJ}$. What is the Gibbs energy difference, ΔG° , for this reaction using the Biochemists' (or Biological) Standard State?
 (A) -60 kJ (B) $+60 \text{ kJ}$ (C) -100 kJ (D) $+20 \text{ kJ}$
18. The 5th. step in the glycolysis cycle is $GAP + P_i \rightleftharpoons DPG$ with $\Delta G^{\circ} = +6.3 \text{ kJ/mol}$. The 6th. step is $DPG + ADP \rightleftharpoons 3PG + ATP$ with $\Delta G^{\circ} = -18.8 \text{ kJ/mol}$. The 6th. step drives the 5th. step by removing DPG as it is formed. This is an example of a step driven by
 (A) Tandem Reactions (B) Coupled Reactions
 (C) Physiological Concentrations (D) Endergonic Reaction Imbalance
19. Which of the following statements is/are true concerning the binding of O_2 to Myoglobin (Mb) and Hemoglobin (Hb)?
 ✓ (i) In resting muscle tissue (in which the O_2 pressure is 40 torr), both Mb and Hb retain most of their bound O_2
 ✓ (ii) In muscle tissue after exercise (in which the O_2 has dropped to 20 torr), Mb retains most of its bound O_2 , but Hb has depleted its O_2 reserve
 ✗ (iii) The curve of O_2 saturation vs. P_{O_2} in Hb is sigmoidal because the first bound O_2 makes it more difficult for additional O_2 molecules to bind to Mb
 (A) ii only (B) i only (C) i and iii (D) i and ii

PART II. FOUR (4) PROBLEMS FOLLOW (Show work for partial credit)

(06) 1. As an introduction to Parts (a) and (b) below: If one has an equilibrium:
 $A \rightleftharpoons B + C$, if $P^0(A) = P^0(B) = 3.0$ bar, $P^0(C) = 0.0$ bar and $K = 10.0$, one would set up the
 expression to solve this equilibrium as: $10.0 = \frac{(3.0+x)(x)}{3.0-x}$

Set up the equivalent expressions for the following two equilibria. Your answer should have
 the numbers 10.0, 3.0 and the variable "x" (as above). As in the example above,
 $P^0(A) = P^0(B) = 3.0$ bar, $P^0(C) = 0.0$ bar and $K = 10$.

(03) (a) $2A \rightleftharpoons B + 3C$

$$K = \frac{P_B P_C^3}{P_A^2} = \frac{(3+x)(3x)^3}{(3-2x)^2}$$

(03) (b) $A + 3B \rightleftharpoons C$

$$K = \frac{P_C}{P_A P_B^3} = \frac{x}{(3-x)(3-3x)^3}$$

(06) 2. For an equilibrium reaction, $A \rightleftharpoons B$, the slope and intercept of the van't Hoff plot
 $[\ln(K) \text{ vs } 1/T]$ are: Slope = +4850 K, Intercept = 7.60.

Calculate the values of ΔH^0 (in kJ/mol) and ΔS^0 (in J/mol-K) for this reaction.

$$\ln K = -\frac{\Delta H^0}{R} \frac{1}{T} + \frac{\Delta S^0}{R}$$

$$\begin{aligned} \text{Slope} = -\frac{\Delta H^0}{R} &= +4850 \text{ K} \rightarrow \Delta H^0 = -R \times \text{Slope} \\ &= -8.31 \frac{\text{J}}{\text{mol}\cdot\text{K}} (4850 \text{ K}) \\ &= -40,300 \frac{\text{J}}{\text{mol}} \times \frac{1}{1000} \\ &= \boxed{-40.3 \text{ kJ/mol}} \end{aligned}$$

$$\text{Intercept} = \frac{\Delta S^0}{R} = 7.60$$

$$\begin{aligned} \Delta S^0 &= R \times \text{Intercept} = 8.31 \frac{\text{J}}{\text{mol}\cdot\text{K}} \times 7.60 \\ &= \boxed{63.2 \frac{\text{J}}{\text{mol}\cdot\text{K}}} \end{aligned}$$

$$\Delta G = 8.7 \text{ kJ/mol} = 8700 \text{ J/mol}$$

$$T = 298 \text{ K}$$

- (06) 3. For an equilibrium reaction, $A \rightleftharpoons B + 2C$, the the Gibbs Energy is $\Delta G = +8.70 \text{ kJ/mol}$ at 25°C when the pressures of A, B, and C are: $P(A) = 0.50 \text{ bar}$, $P(B) = P(C) = 1.50 \text{ bar}$

Calculate the value of the equilibrium constant, K, at 25°C

$$\Delta G = \Delta G^\circ + RT \ln Q$$

$$\therefore \Delta G^\circ = \Delta G - RT \ln Q$$

$$= 8700 - (8.31)(298) \ln(6.75)$$

$$= 8700 - 4730$$

$$= +3970 \text{ J/mol}$$

$$Q = \frac{P_B P_C^2}{P_A} = \frac{(1.5)(1.5)^2}{0.5} = 6.75$$

$$\Delta G^\circ = -RT \ln K$$

$$\ln K = \frac{-\Delta G^\circ}{RT} = \frac{-(+3970)}{(8.31)(298)} = -1.60$$

$$K = e^{-1.60} = \boxed{0.20}$$

- (06) 4. For an equilibrium reaction, $C \rightleftharpoons D$, The equilibrium constant is $K = 50$ at $T = 100^\circ\text{C}$ and $K = 2.5$ at $T = 150^\circ\text{C}$. Calculate the value of the enthalpy change for the reaction, ΔH° (in kJ/mol).

$$K_1 = 50$$

$$T_1 = 373 \text{ K}$$

$$K_2 = 2.5$$

$$T_2 = 423 \text{ K}$$

$$\ln\left(\frac{K_2}{K_1}\right) = \frac{-\Delta H^\circ}{R} \left[\frac{1}{T_2} - \frac{1}{T_1} \right]$$

$$\therefore \Delta H^\circ = \frac{-R \ln(K_2/K_1)}{\frac{1}{T_2} - \frac{1}{T_1}} = \frac{-8.31 \text{ J/molK} \left(\frac{2.5}{50} \right)}{\frac{1}{423 \text{ K}} - \frac{1}{373 \text{ K}}}$$

$$= -78,560 \text{ J/mol} \times \frac{1}{1000}$$

$$= \boxed{-78.6 \text{ kJ/mol}}$$