CHEM 361 **Exam 3**

November 6, 2015, 7:55-8:55 AM **Name** KEY ____________ ____________
Last, First

4 x 6 note card

100 points in 8 questions on 5 pages including part of Table A.5

For full credit ***show all work and put correct units on final answers.***

Read, please: ***If you get a quantitative answer that is many powers of 10 from what you think it should be and cannot find the error, you will be rewarded for pointing out approximately what you expected and why. 25% will be deducted on a problem for sign and unit errors that lead to unreasonable results if you do not say why it is unreasonable.***

(16 pts) **1.** From Table A.5, calculate the Henry's Law constant for NH_3(gas) dissolving in water at 298 and at 373 K.

$NH_3(g) \rightarrow NH_3\,aq$ $\Delta G^o = -26.50 - (-16.45) = -10.05\,kJ$

$K_{298} = \boxed{57.75\ mol\,L^{-1}/bar}$ $\Delta H^o = -80.29 - (-46.11) = -34.19$

$\ln \frac{K_{373}}{K_{298}} = -\frac{\Delta H^o}{R}\left(\frac{1}{373} - \frac{1}{298}\right) = -2.77$

$K_{310} = K_{298} \times e^{-2.77} = 57.75 \times 0.0624 = \boxed{3.6\ M\ bar^{-1}}$

(12 pts) **2.** Given that 1 bar = 10 m of water, calculate the osmotic pressure in mm of water that would be created by a 1 g/L solution of protein with molecular weight = 100,000 g/mol at 298 K.

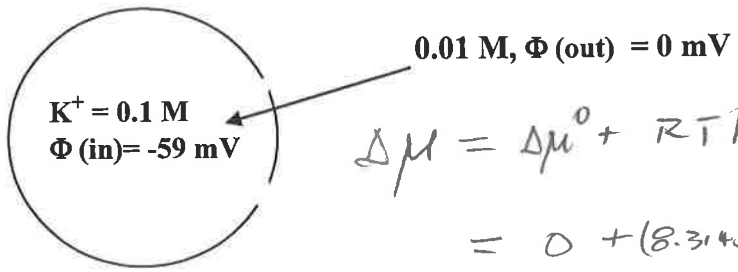
$\Pi V_{soln} = n_{solute} R T$ $n_{solute} = \frac{1\,g L^{-1}}{100\,000\,g\,mol^{-1}} = 10^{-5}\,M$

$\Pi = \frac{n_{solute}}{V_{soln}} RT = 10^{-5}\,\frac{mol}{L} \times 0.083145\,\frac{L\,bar}{mol\,K}\ 298\,K$

$= 0.00025\ bar \times \frac{10\,m\,H_2O}{bar} = 2.5\times10^{-3}\ m\ H_2O$

$= \boxed{2.5\ mm\ H_2O}$

(12 pts) 3. (a) Calculate the chemical potential change for moving potassium ions from the outside to the inside of the cell below at 298K.



always $\frac{C_{final}}{C_{initial}}$

$$\Delta\mu = \Delta\mu^0 + RT\ln\frac{C_{in}}{C_{OUT}} + z\Delta\Phi F$$

always $\Phi_{final} - \Phi_{initial}$

$$= 0 + (8.3145)(\ln 10) + 1(-.059V)\,96\,500\ C/mole$$

$$= +5705\ J/mol \quad - \quad 5694\ J/mol$$

$$\cong \boxed{0 \pm 15\ J/mol}$$

depending on accuracy.

(b) What is ΔG for moving 3 moles of K^+ from the inside to the outside of the cell?

$3 \times (0 \pm 15\ J)$

(12 pts) 4. If a protein molecule with average charge = +10***e*** is observed to move in an electric field of 100 V/m at a speed of 1x10⁻⁶ m/s, what are its ***electrophoretic mobility***, its ***frictional coefficient***, and its ***diffusion coefficient*** at 298 K? (the elementary charge, ***e***, = 1.6 x 10⁻¹⁹ Coulombs.)

$$\mu = \frac{m s^{-1}}{Volt\ m^{-1}} = \frac{1\times10^{-6} m s^{-1}}{100\ V m^{-1}} = \boxed{1\times10^{-8}}$$

$$u_{term} = \frac{Force}{f} \qquad f = \frac{Force}{u_{term}} = \frac{ze \cdot Field}{u_{term}} = \frac{(10 \times 1.6\times10^{-19} C)\ 100\ Volt/m}{10^{-6}\ m s^{-1}}$$

J/C ; $Kg\, m^2 s^{-2}/C$

$$\boxed{f = 1.6\times10^{-10} Kg\, s^{-1}}$$

$$D = \frac{kT}{f} = \frac{1.38\times10^{-23} Kg\, m^2 s^{-2} K^{-1}\ 298K}{1.6\times10^{-10} Kg\, s^{-1}} = \boxed{2.6\times10^{-11}\ \frac{m^2}{s}}$$

12 pts) 5. **(a)** For evaporating water from a solution H_2O(liquid, a) ---> H_2O(g, p_{H2O}), where a = activity of the liquid water, write the expression for Q using the usual concentration units for liquid and gas.

$$Q = \frac{\gamma_{H_2O(g)} P_{H_2O}}{\gamma_{H_2O(l)} X_{H_2O}} = \frac{\gamma_{H_2O(g)} P_{H_2O}}{a} \cong \frac{P_{H_2O(g)}}{X_{H_2O(l)}}$$

if ideal

(b) On a planet where the atmospheric pressure = 0.031 bar (which happens to be the vapor pressure of water at 298 K), what will be the boiling point of pure water?

b.p. = 298 K = T when VP = P_{ext}

(c) Using Table A5, what will be the boiling point on that planet of an aqueous solution in which the mole fraction of solute is 0.1, assuming ideal behavior (activity coefficients = 1)?

$$\ln \frac{K_{bp}}{K_{298}} = -\frac{\Delta H^\circ}{R}\left(\frac{1}{T_{bp}} - \frac{1}{298}\right)$$

$\Delta H^\circ = -241.8 - (-285.8) = +44000$ J

$$\ln \frac{\frac{0.031}{1}}{\frac{0.031}{a}} = -\frac{44000}{8.3154}\left(\frac{1}{T_{bp}} - \frac{1}{298}\right)$$

$a = 1 - 0.1 = 0.9$

$$T_{bp} = \left[-\frac{8.3145}{44000}\ln\frac{1}{0.9} + \frac{1}{298} = \frac{1}{T_{bp}}\right]^{-1} = 299.8\ \text{K}$$

(12 pts) 6. (a) Calculate the root mean square speed of an N_2 molecule at 3K. (temperature of interstellar space).

$$u_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3\ 8.3145 \cdot 3}{0.028}} = \boxed{51.7\ m\,s^{-1}}$$

(b) **Estimate** the collisions s^{-1} and the mean free path for an N_2 at 3 K if the pressure = **1x10^{-10}** bar? (notice that an adjustment for the low temperature is necessary in addition to the low pressure)

T = 100 times lower so $u = \frac{1}{10}$ as fast. (as found above)

Z of u p = $10^{-10} \times 0.1 = 10^{-11} \times$ smaller = $\boxed{0.1\ col/sec}$

mean free path = $m\ col^{-1}$ = $\frac{u_{rms}\ m s^{-1}}{Z\ col\ s^{-1}} = \frac{0.1(500)}{10^{-11} \times 10^{10}}$

$\cong \boxed{500\ m\ col^{-1}}$

(12 pts) 7. What is the molecular weight of a protein with a diffusion coefficient equal to 1 x 10^{-13} m^2 s^{-1} if its sedimentation coefficient in Svedbergs is 100 S and its partial specific volume is 0.6 cm^3/g in water at 293 K? The density of water at this temperature = 1 g cm^{-3}.

$$s = \frac{m_{eff}}{f} = \frac{m(1-\rho v)}{f} = \frac{m(1-v\rho)D}{kT} = \frac{M(1-v\rho)D}{RT}$$

$$M = \frac{sRT}{(1-v\rho)D} = \frac{100 \times 10^{-13}\ 8.3145(293)}{(1-.6)\ 1 \times 10^{-13}\ m^2 s^{-1}}$$

$$= \boxed{609{,}000\ kg}$$

$$\boxed{6.09 \times 10^5\ kg}$$

(12 pts) **8.** (a) For a peptide with 1 histidine, 1 aspartic acid, and 1 arginine, indicate the fraction protonated and the average charge of each residue at **pH 7**, accurate to within 0.1 charge unit. What will be the total charge on the peptide at **pH 7**? Parts b) and c) are on the next page.

Amino acid	pKa	Charge when protonated	Fraction Protonated	Ave. Charge
N-terminus	10	+1	0.999 = 1	+1
Histidine	6	+1	0.1	0.1
Arginine	11	+1	1	1
Aspartic acid	4	0	$10^{-3} \simeq 0$	−1
C-terminus	3	0	10^{-4}	−1

Total charge = +0.1

(b) In a pH gradient gel with low pH at the positive electrode, is this peptide at a higher or lower pH than its isoelectric point? Explain very briefly. Lower pH than isoelectric point. It will move away from + electrode, which is always on the low pH end.

TABLE A.5 Inorganic Compounds*

	$\Delta H_f^0 = \bar{H}^0$ (kJ mol^{-1})	$\bar{S}^0$ (J K^{-1} mol^{-1})	$\Delta G_f^0 = \bar{G}^0$ (kJ mol^{-1})
$CO_2(g)$	−393.509	213.74	−394.359
$CO_2(aq)$	−413.80	117.6	−385.98
$HCO_3^-(aq)$	−691.99	91.2	−586.77
$CO_3^{2-}(aq)$	−677.14	−56.9	−527.81
$Fe(s)$	0	27.28	0
$Fe_2O_3(s)$	−824.2	87.40	−742.2
$H_2(g)$	0	130.684	0
$H_2O(g)$	−241.818	188.825	−228.572
$H_2O(l)$	−285.830	69.91	−237.129
$H^+(aq)$	0	0	0
$OH^-(aq)$	−229.994	−10.75	−157.244
$H_2O_2(aq)$	−191.17	143.9	−134.03
$H_2S(g)$	−20.63	205.79	−33.56
$N_2(g)$	0	191.61	0
$NH_3(g)$	−46.11	192.45	−16.45
$NH_3(aq)$	−80.29	111.3	−26.50
$NH_4^+(aq)$	−132.51	113.4	−79.31
$NO(g)$	90.25	210.761	86.55
$NO_2(g)$	33.18	240.06	51.31