$\bar{X} = 71$

Chemistry 153
First exam
Monday 3 October, 2005

Name --

Full credit will be given to correct answers only when ALL the necessary steps are shown.

DO NOT GUESS THE ANSWER.

This is a close book exam, and you are responsible to be sure that your exam has no missing pages (5 pages).

If you consider that there is not enough information to solve a problem you have to specify the missing information and describe the problem solving procedure.

Honor Statement
I have neither give nor received aid in this examination.

Full signature ----------------------------

R = 8.3144765 $Jmol^{-1}K^{-1}$ = 0.0820574 $L\ atm\ mol^{-1}K^{-1}$

Problem 1 (25 points)

When 60.00 g of methane (CH_4) is placed in a 1.000 L vessel, the pressure is measured to be 130 atm. Calculate the temperature of the gas using (a) the ideal gas equation and (b) the van der Waals equation. Do attractive or repulsive forces dominate?

a = 2.253 $atmL^2mol^{-2}$

b = 0.04278 $Lmol^{-1}$

PROBLEM. 1

$$PV = nRT$$

$$T = \frac{PV}{nR}$$

$P = 130\ \text{atm}$

$V = 1.000\ \text{L}$

$m = 60.00\ \text{g}$

$M = 16.01\ \text{g mol}^{-1}$

$n = 3.748\ \text{mol}$

$$T = \frac{130\ \text{atm}\ 1.000\ \text{L}}{3.748\ \text{mol}\ 0.0820574\ \text{atm L mol}^{-1}\text{K}^{-1}}$$

$$\boxed{T = 423\ \text{K}}$$

FROM THE van der Waals

$$T = \frac{[P + a(n/V)^2][V - nb]}{nR}$$

$$= \frac{[130\ \text{atm} + 2.253\ \text{atm L}^2\text{mol}^{-2}\ (3.748)^2\ \text{mol}^2\ \text{L}^{-2}]\ [1.000\ \text{L} - 3.748\ \text{mol}\ 0.04278\ \text{L mol}^{-1}]}{3.748\ \text{mol}\ 0.0820574\ \text{atm L mol}^{-1}\ \text{K}^{-1}}$$

$$\boxed{T = 441\ \text{K}}$$

$T = 441\,K$

$$Z = \frac{PV}{nRT} = \frac{130\,atm\ 1.000\,L}{3.748\,mol\ 441\,K\ 0.0820574\,atm\,L\,mol^{-1}\,K^{-1}}$$

$Z = 0.958 < 1$ ATTRACTIVE FORCES DOMINATE

$T\uparrow \Rightarrow$ RELEASE OF ENERGY

$\Rightarrow$ ATTRACTION

$T\uparrow \Rightarrow KE\uparrow \Rightarrow PE\downarrow \Rightarrow$ ATTRACTION $\uparrow$

Problem 2 (25 points)

What is the pH of a 5% by weight solution of formic acid $HCOOH$ at T = 298 K and one bar atmospheric pressure.

$$K_a = 1.77\ 10^{-4}$$

$$pKa = 3.752$$

PROBLEM 2

CONSIDER 1.000 L OF SOLUTION AND A DENSITY OF $\rho = 1\, g\, mL^{-1}$. THEREFORE 5% OF THE WEIGHT IS DUE TO THE ACID.

$$m_{ACID} = 50.00\, g$$ (ASSUME 5.000%)
(ASSUME 5. ⇒ 1 sig fig)

$$n_{ACID} = \frac{50.00\, g}{46.025\, g\, mol^{-1}} = 1.086\, mol$$

	$HCOOH(aq) + H_2O(l)$		$\rightleftharpoons$	$HCOO^-(aq)$	+ $H_3O^+(aq)$
I	1.086	—		0	≈ 0
C	−X	—		X	X
E	1.086−X	—		X	X

%diss = 1.26 %

$$K_a = \frac{X^2}{1.086 - X} \approx \frac{X^2}{1.086}$$

$$X = \sqrt{1.086\, K_a} = \sqrt{1.086 \cdot 1.77 \times 10^{-4}} = 1.37 \times 10^{-2}$$

$[H_3O^+] = 1.37 \times 10^{-2} \Rightarrow$ **pH = 1.863**

Problem 3 (25 points)

How would you prepare a liter of carbonate buffer at pH of 10.10?

You are provided with:

Carbonic acid (H_2CO_3) 1M

Sodium Hydrogen Carbonate ($NaHCO_3$) 1M

Sodium Carbonate (Na_2CO_3) 1M

all at temperature T=298 K, and pressure of one bar.

$$H_2CO_3(aq) \; + \; H_2O(l) \Leftrightarrow HCO_3^-(aq) + H_3O^+(aq) \qquad K_a = 4.2\ 10^{-7} \tag{1}$$

$$HCO_3^-(aq) \; + \; H_2O(l) \Leftrightarrow CO_3^{2-}(aq) + H_3O^+(aq) \qquad K_a = 4.8\ 10^{-11} \tag{2}$$

PROBLEM 3

THE CLOSEST pK_a TO $pH = 10.10$ is

$K_a = 4.8 \times 10^{-1}$ OR $pK_a = 10.32$

SO WE CAN USE THE PAIR

HCO_3^- / CO_3^{2-}

$$pH = pK_a + \log_{10} \frac{[CO_3^{2-}]}{[HCO_3^-]}$$

$$pK_a - pH = -\log_{10} \frac{[CO_3^{2-}]}{[HCO_3^-]}$$

$$= \log_{10} \frac{[HCO_3^-]}{[CO_3^{2-}]}$$

$$10.32 - 10.10 = 0.22 = \log_{10} \frac{[HCO_3^-]}{[CO_3^{2-}]}$$

$$\frac{[HCO_3^-]}{[CO_3^{2-}]} = 10^{0.22} = 1.7 = \frac{\#\text{ moles } HCO_3^-}{\#\text{ moles } CO_3^{-2}}$$

$$1.7 = \frac{V_{HCO_3^-} \text{ mol } L^{-1}}{V_{CO_3^{2-}} \text{ mol } L^{-1}}$$

$$1.000\,L = V_{HCO_3^-} + V_{CO_3^-}$$

$$1.000\,L = 2.7\,V_{CO_3^-}$$

$$V_{CO_3^-} = 380\,mL$$

$$V_{HCO_3^-} = 620\,mL$$

Problem 4 (25 points)

Calculate the pH at the equivalence point for the following titration: 0.20 M Ascorbic acid versus 0.20 M NaOH at T = 298 K and P = 1 bar.

$$C_6H_8O_6(aq) \ + \ H_2O(l) \Leftrightarrow C_6H_7O_6^-(aq) \ + \ H_3O^+(aq) \quad K_a = 8.00 \ 10^{-5} \tag{3}$$

$$C_6H_7O_6^-(aq) \ + \ H_2O(l) \Leftrightarrow C_6H_8O_6(aq) \ + \ HO^-(aq) \quad K_b = 1.25 \ 10^{-10} \tag{4}$$

PROBLEM 4

$[\text{Ascorbic A}] = [NaOH]$

AT THE EQUIVALENCE POINT THE VOLUME HAS BEEN DOUBLE

ALSO WE ASSUME THAT ALL THE ACID HAS BEEN DEPROTONATED BY THE BASE SO

$$C_6H_7O_6^-(aq) + H_2O(l) \rightleftharpoons C_6H_8O_6(aq) + HO^-(aq)$$

I	0.10	—	0	≈ 0
C	− y	—	y	y
E	0.10 − y	—	y	y

$$K_b = \frac{y^2}{0.10-y} \simeq \frac{y^2}{0.10}$$

$$y = \sqrt{0.10\ K_b} = 0.39 \times 10^{-5}$$

$$[OH^-] = 3.9 \times 10^{-6} \Rightarrow pOH = 5.41$$

$$\boxed{pH = 8.59}$$