

Chemistry 153  
First exam  
Monday 3 October, 2005

$\bar{x} = 71$



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 -----

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

### 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?

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

$$b = 0.04278 \text{ Lmol}^{-1}$$

## PROBLEM. 1

$$PV = nRT$$

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

$$P = 130 \text{ atm}$$

$$V = 1.000 \text{ L}$$

$$M = 60.00 \text{ g}$$

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

$$n = 3.748 \text{ mol}$$

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

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

FROM THE van der Waals

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

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

$$\frac{[1.000 \text{ L} - 3.748 \text{ mol} \cdot 0.04278 \text{ L mol}^{-1}]}{3.748 \text{ mol} \cdot 0.0820574 \text{ atm L mol}^{-1} \text{ K}^{-1}}$$

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

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

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

$$Z = 0.958 < 1 \quad \text{ATTRACTIVE FORCES DOMINATE}$$

$T \uparrow \Rightarrow$  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  $T = 298\text{ K}$  and one bar atmospheric pressure.

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

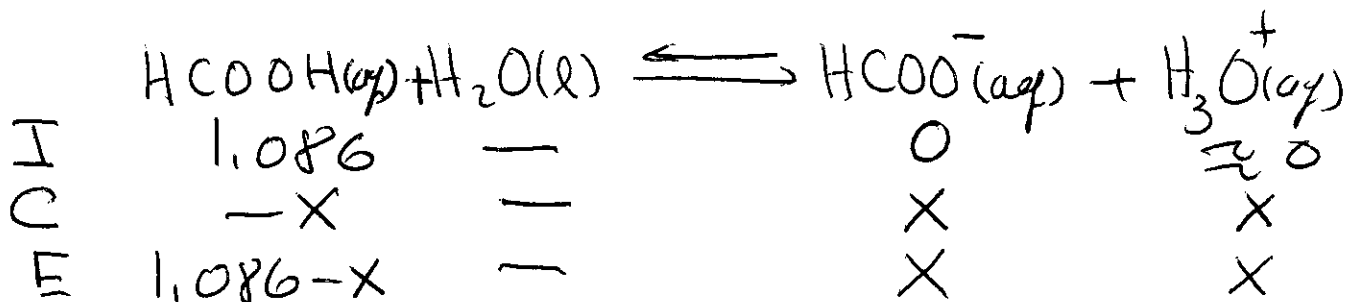
$$pK_a = 3.752$$

## PROBLEM 2

CONSIDER 1,000 L OF SOLUTION AND  
A DENSITY OF  $\rho = 1 \text{ g mL}^{-1}$ . THEREFORE  
5% OF THE WEIGHT IS DUE TO THE ACID,

$$M_{\text{ACID}} = 50,00 \text{ g} \quad (\text{ASSUME } 5,000\%) \\ (\text{ASSUME } 5. \Rightarrow 1 \text{ sig fig})$$

$$n_{\text{ACID}} = \frac{50,00 \text{ g}}{46,025 \text{ g mol}^{-1}} = 1,086 \text{ mol}$$



$$K_a = \frac{X^2}{1,086 - X} \approx \frac{X^2}{1,086}$$

$$\boxed{\% \text{diss} = 1,26\%}$$

$$X = \sqrt{1,086 K_a} = \sqrt{1,086 \cdot 1,77 \times 10^{-4}} = 1,37 \times 10^{-2}$$

$$[\text{H}_3\text{O}^{+}] = 1,37 \times 10^{-2} \Rightarrow \boxed{\text{pH} = 1,863}$$

### Problem 3 (25 points)

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

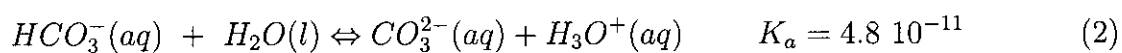
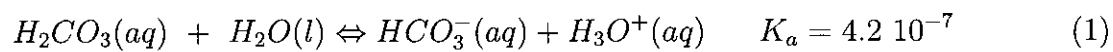
You are provided with:

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.

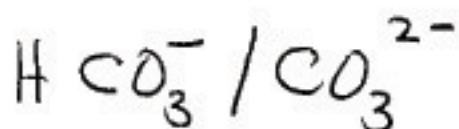


### PROBLEM 3

THE CLOSEST  $pK_a$  TO  $pH = 10.10$  IS

$$K_a = 4.8 \times 10^{-11} \text{ OR } pK_a = 10.32$$

SO WE CAN USE THE PAIR



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

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

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

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

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

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



$$1.000\text{L} = V_{\text{HCO}_3^-} + V_{\text{CO}_3^-}$$

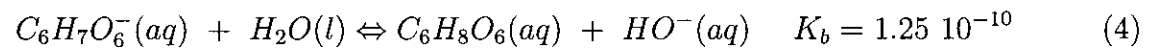
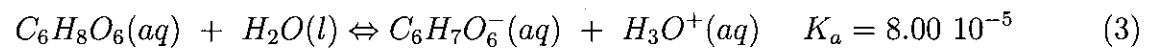
$$1.000\text{L} = 2.7 V_{\text{CO}_3^-}$$

$$V_{\text{CO}_3^-} = 380\text{ mL}$$

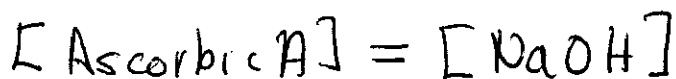
$$V_{\text{HCO}_3^-} = 620\text{ mL}$$

### 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  $T = 298 \text{ K}$  and  $P = 1 \text{ bar}$ .

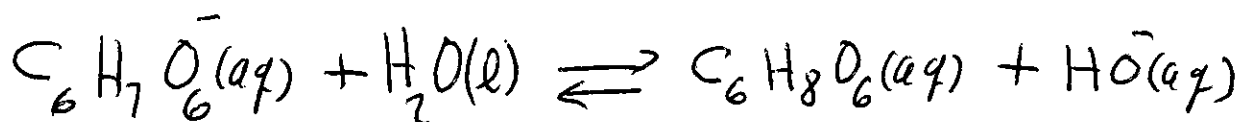


## PROBLEM 4



AT THE EQUIVALENCE POINT THE VOLUME HAS BEEN DOUBLED

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



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

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

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

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

$$\boxed{\text{pH} = 8.59}$$