

# Chemistry 114

## Fourth Hour Exam

1. (12 points) Give an example (either name or chemical formula) for :

A Strong Acid

HCl, HNO<sub>3</sub>, H<sub>2</sub>SO<sub>4</sub>, or HClO<sub>4</sub>

A Weak Acid

CH<sub>3</sub>COOH, NH<sub>4</sub><sup>+</sup> and others

A Weak Base

NH<sub>3</sub>, CH<sub>3</sub>COO<sup>-</sup> and others

A Strong base

NaOH, KOH, Ca(OH)<sub>2</sub> and others

A Polyprotic Acid

H<sub>2</sub>SO<sub>4</sub>, H<sub>3</sub>PO<sub>4</sub>, H<sub>2</sub>CO<sub>3</sub> and others

An Acidic Salt

NH<sub>4</sub>Cl, Al(NO<sub>3</sub>)<sub>3</sub> and others

2. (6 points) Calculate the pH of a 0.56 mM solution of HCl

$$0.56 \text{ mM} \times 1 \times 10^{-3} \text{ moles/mM} = 5.6 \times 10^{-4} \text{ M}$$

$$\text{Strong acid so } [\text{HCl}] = [\text{H}^+] = 5.6 \times 10^{-4} \text{ M}$$

$$\text{pH} = -\log[\text{H}^+] = -\log(5.6 \times 10^{-4} \text{ M})$$

$$= -\log(-3.2518)$$

$$= 3.25$$

3. (7 points) Calculate the pH of a  $1 \times 10^{-8}$  M solution of NaOH

Strong base so  $[\text{NaOH}] = [\text{OH}^-]$

$$[\text{OH}^-] = 1 \times 10^{-8}$$

$$\text{pOH} = -\log(1 \times 10^{-8}) = 8$$

$$\text{pH} = 14 - \text{pOH} = 6$$

But hold it. This is an acid pH and we are dealing with a base! Something is fishy. What is Dr. Z. Trying to pull ???

Ahhh... Rememer that there are two sources of  $\text{OH}^-$ , the base and the autoionization of water itself. Usually we don't deal with the water because its contribution is so small, but in this case, the base is so very dilute that we have to include it.

The quick and dirty answer  $[\text{OH}^-]$  from water =  $1 \times 10^{-7}$ ,  $[\text{OH}^-]$  from base =  $1 \times 10^{-8}$   
 Add them together and get  $[\text{OH}^-] = 1.1 \times 10^{-7}$ ;  $\text{pOH} = -\log(1.1 \times 10^{-7}) = 6.96$   
 $\text{pH} = 14 - 6.96 = 7.04$  which is basic so this is a better answer!

4A. (8 points) I have a weak acid that is 1.5% ionized when it is at a concentration of .025M. What is the  $K_a$  of this acid?

$$\% \text{ionization} = \frac{[\text{A}^-]}{[\text{HA}] + [\text{A}^-]} \times 100\%$$

$$15 = \frac{x}{.025} \times 100; \quad X = 15(.025) / 100 = 3.75 \times 10^{-4}$$

$$K_a = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]}; [\text{H}^+] = [\text{A}^-]; \text{HA} = .025 - 3.75 \times 10^{-4}$$

$$K_a = \frac{(3.75 \times 10^{-4})^2}{.025 - 3.75 \times 10^{-4}} = 5.71 \times 10^{-6}$$

B. (2 points) What will happen to the pH of this solution if the acid is diluted further?  
 (Will it go up, remain the same, or go down?)

pH will go up

C. (2 points) What will happen to the % ionization of the acid if the acid is diluted further?  
 (Will it go up, remain the same, or go down?)

% ionization will go up

5. (12 points) Predict the pH of the following salts.  
(Fill in A for acidic, B for basic or N for neutral)

KCl \_\_\_N\_\_\_

Cr(NO<sub>3</sub>)<sub>6</sub> \_\_\_A\_\_\_

NaCH<sub>3</sub>COO \_\_\_B\_\_\_

NH<sub>4</sub>NO<sub>3</sub> \_\_\_A\_\_\_

SeO<sub>2</sub> \_\_\_A\_\_\_

SnO<sub>2</sub> \_\_\_A or B\_\_\_

(Sn<sup>+4</sup> would be acidic, but the O<sup>-</sup> would be basic so it is hard to tell which would dominate)

6. (12 points) Define the following:

Nucleophile

A species that seeks + charge to donate electrons to, hence a Lewis Base

Lewis acid

An electron acceptor

Bronsted-Lowry Base

A proton acceptor

Free Energy

G, Energy available to do work or a measure of the spontaneity of a process

S

Entropy, a thermodynamic measure of randomness

The second law of thermodynamics

In any spontaneous process the randomness of the universe must increase.

7. ( 13 points) Calculate  $\Delta S_{\text{reaction}}$  for the reaction  $2\text{C}_2\text{H}_2(\text{g}) + 5\text{O}_2(\text{g}) \rightleftharpoons 4\text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g})$

Given the following data

Substance	S° (J/K·mol)
C <sub>2</sub> H <sub>2</sub> (g)	201
O(g)	161
O <sub>2</sub> (g)	205
O <sub>3</sub> (g)	239
CO(g)	198
CO <sub>2</sub> (g)	214
H <sub>2</sub> O(l)	70
H <sub>2</sub> O(g)	189

$$\begin{aligned}\Delta S_{r,m} &= \sum n_p S_p - \sum n_r S_r \\ &= [4(214) + 2(189)] - [2(201) + 5(205)] \\ &= 856 + 378 - 402 - 1025 \\ &= -194 \text{ J / K} \cdot \text{mol}\end{aligned}$$

8. (12 points) Given that the chemical reaction  $\text{N}_2\text{O}_4(\text{l}) \rightleftharpoons \text{N}_2\text{O}_4(\text{g})$  has a  $\Delta H^\circ$  of 30.0 kJ/mole and a  $\Delta S^\circ$  of 95 J/K·mol, what is the normal boiling point for  $\text{N}_2\text{O}_4$ ?

At the normal boiling point the liquid and the gas will be at equilibrium, so  $\Delta G=0$

$$\Delta G = \Delta H - T\Delta S$$

$$0 = 30,000 \text{ J/mol} - X(95 \text{ J/K}\cdot\text{mol})$$

$$X(95) = 30,000$$

$$X = (30,000 \text{ J/mol}) / (95 \text{ J/K}\cdot\text{mol}) = 316 \text{ K}$$

9A. (10 points) Calculate  $\Delta G^\circ$  for the reaction  $2\text{C}_2\text{H}_2(\text{g}) + 5\text{O}_2(\text{g}) \rightleftharpoons 4\text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g})$

Given the following data

Substance	$\Delta G_f^\circ$ (kJ/mol)
$\text{C}_2\text{H}_2(\text{g})$	209
$\text{O}(\text{g})$	232
$\text{O}_2(\text{g})$	0
$\text{O}_3(\text{g})$	163
$\text{CO}(\text{g})$	-137
$\text{CO}_2(\text{g})$	-394
$\text{H}_2\text{O}(\text{l})$	-237
$\text{H}_2\text{O}(\text{g})$	-229

$$\Delta G_{\text{rxn}} = \sum n_p \Delta G_p^\circ - \sum n_r \Delta G_r^\circ$$

$$= [4(-394) + 2(-229)] - [2(209) + 5(0)]$$

$$= -1576 - 418$$

$$= -2452 \text{ kJ/mol}$$

9B (3 points) Is this reaction spontaneous?

$\Delta G$  is negative, so the reaction is spontaneous