

## Test 2 related problems/worksheets

**CHEM 1412 Acid/Base Theory:**

Dr. Ya-Ping Huang

### Conjugate acids/Bases: Give formulas for Conjugate acids and Bases

	Conjugate base, - H <sup>+</sup>		Conjugate acid, + H <sup>+</sup>
1	HSO <sub>4</sub> <sup>-</sup>	H <sub>2</sub> SO <sub>4</sub>	H <sub>3</sub> SO <sub>4</sub> <sup>+</sup>
2	NO <sub>3</sub> <sup>-</sup>	HNO <sub>3</sub>	H <sub>2</sub> NO <sub>3</sub> <sup>+</sup>
3	NH <sub>2</sub> <sup>-</sup>	NH <sub>3</sub>	NH <sub>4</sub> <sup>+</sup>
4	OH <sup>-</sup>	H <sub>2</sub> O	H <sub>3</sub> O <sup>+</sup>
5	CH <sub>3</sub> O <sup>-</sup>	CH <sub>3</sub> OH	CH <sub>3</sub> OH <sub>2</sub> <sup>+</sup>
6	H <sup>-</sup>	H <sub>2</sub>	n/a (H <sub>2</sub> has no lone pair e-)
7	NH <sup>2-</sup>	NH <sub>2</sub> <sup>-</sup>	NH <sub>3</sub>
8	O <sup>2-</sup>	OH <sup>-</sup>	H <sub>2</sub> O
9	CH <sub>3</sub> NH <sup>-</sup>	CH <sub>3</sub> NH <sub>2</sub>	CH <sub>3</sub> NH <sub>3</sub> <sup>+</sup>
10	HPO <sub>4</sub> <sup>2-</sup>	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>	H <sub>3</sub> PO <sub>4</sub>
11	PO <sub>4</sub> <sup>3-</sup>	HPO <sub>4</sub> <sup>2-</sup>	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>
12	CO <sub>3</sub> <sup>2-</sup>	HCO <sub>3</sub> <sup>-</sup>	H <sub>2</sub> CO <sub>3</sub> (H <sub>2</sub> O + CO <sub>2</sub> )

#### Compare acid strength:

- H<sub>2</sub>SO<sub>4</sub> and H<sub>2</sub>SO<sub>3</sub>: H<sub>2</sub>SO<sub>4</sub> > H<sub>2</sub>SO<sub>3</sub> (# of O)
- H<sub>2</sub>SO<sub>4</sub> and HSO<sub>4</sub><sup>-</sup>: H<sub>2</sub>SO<sub>4</sub> > HSO<sub>4</sub><sup>-</sup> (# of H)
- HCl, HBr, HI and HF: HI > HBr > HCl > HF (hydrides of same group)
- H<sub>2</sub>S and H<sub>2</sub>O: H<sub>2</sub>S > H<sub>2</sub>O (hydrides of same group)
- NH<sub>3</sub>, H<sub>2</sub>O and HF: NH<sub>3</sub> < H<sub>2</sub>O < HF (hydrides of same period)
- HOCl, HOBr, HOI: HOCl > HOBr > HOI (oxyacids of same group)
- HClO<sub>4</sub>, HClO<sub>3</sub>, HClO, HClO<sub>2</sub>: HClO<sub>4</sub> > HClO<sub>3</sub> > HClO > HClO<sub>2</sub> (# of O)
- H<sub>3</sub>PO<sub>4</sub>, H<sub>2</sub>PO<sub>4</sub><sup>-</sup>, HPO<sub>4</sub><sup>2-</sup>: H<sub>3</sub>PO<sub>4</sub> > H<sub>2</sub>PO<sub>4</sub><sup>-</sup> > HPO<sub>4</sub><sup>2-</sup> (# of H, or negative charge)
- H<sub>2</sub>SO<sub>4</sub> and H<sub>2</sub>SeO<sub>4</sub>: H<sub>2</sub>SO<sub>4</sub> > H<sub>2</sub>SeO<sub>4</sub> (oxyacids of same group)
- H<sub>2</sub>S and HBr: H<sub>2</sub>S < HBr (hydrides)

#### Compare base strength: opposite of conjugate acid strength

- N<sup>3-</sup> and P<sup>3-</sup>: N<sup>3-</sup> > P<sup>3-</sup> (same group smaller size stronger base)
- Cl<sup>-</sup>, Br<sup>-</sup>, I<sup>-</sup>, F<sup>-</sup>: F<sup>-</sup> > Cl<sup>-</sup> > Br<sup>-</sup> > I<sup>-</sup> (same group smaller size stronger base)
- OCl<sup>-</sup>, OBr<sup>-</sup>, OI<sup>-</sup>: OCl<sup>-</sup> < OBr<sup>-</sup> < OI<sup>-</sup> (w/ oxygen, less electronegative stronger base)
- O<sup>2-</sup>, S<sup>2-</sup>: O<sup>2-</sup> > S<sup>2-</sup> (same group smaller size stronger base)
- H<sub>2</sub>PO<sub>4</sub><sup>-</sup>, HPO<sub>4</sub><sup>2-</sup>, PO<sub>4</sub><sup>3-</sup>: H<sub>2</sub>PO<sub>4</sub><sup>-</sup> < HPO<sub>4</sub><sup>2-</sup> < PO<sub>4</sub><sup>3-</sup> (opposite of acidity)
- PH<sub>3</sub> and NH<sub>3</sub>: PH<sub>3</sub> < NH<sub>3</sub> (opposite of acidity of hydrides of same group)
- NO<sub>2</sub><sup>-</sup> and NO<sub>3</sub><sup>-</sup>: NO<sub>2</sub><sup>-</sup> > NO<sub>3</sub><sup>-</sup> (opposite of acidity of conjugate acids)
- ClO<sub>3</sub><sup>-</sup> and ClO<sub>2</sub><sup>-</sup>: ClO<sub>3</sub><sup>-</sup> < ClO<sub>2</sub><sup>-</sup> (opposite of acidity of conjugate acids)

#### Explain the following reactions using Lewis theory:

- NH<sub>3</sub> + H<sup>-</sup> → H<sub>2</sub> + NH<sub>2</sub><sup>-</sup>                      NH<sub>3</sub> Lewis acid, H<sup>-</sup> Lewis base
- S<sup>2-</sup> + H<sub>2</sub>O → HS<sup>-</sup> + OH<sup>-</sup>                      S<sup>2-</sup> Lewis base, H<sub>2</sub>O: Lewis acid
- C<sub>2</sub>H<sub>5</sub>OH + CH<sub>3</sub>O<sup>-</sup> → C<sub>2</sub>H<sub>5</sub>O<sup>-</sup> + CH<sub>3</sub>OH                      C<sub>2</sub>H<sub>5</sub>OH: Lewis acid, CH<sub>3</sub>O<sup>-</sup> Lewis base,

Dr. Ya-Ping Huang Fill the blanks. Show your work on separate sheet of paper.

	Compound	Initial Conc.	% ionization	[H <sup>+</sup> ]	pH	pOH	K	pK
1	unknown acid HX	0.10M	4.0 x 10 <sup>-1</sup>	4.0 x 10 <sup>-4</sup> M	3.40	10.60	1.6 x 10 <sup>-6</sup>	5.80
2	unknown acid HX	0.25M	0.85%	2.12 x 10 <sup>-3</sup> M	2.67	11.33	1.8x10 <sup>-5</sup>	4.74
3	unknown base B	1.5 x 10 <sup>-4</sup> M	16.7%	4.0 x 10 <sup>-10</sup> M	9.4	4.6	K <sub>b</sub> = 5.0 x 10 <sup>-6</sup>	5.30



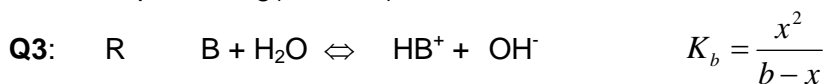
a.  $\left(\frac{x}{a}\right) \times 100 = 0.85$        $\left(\frac{[H^+]}{0.25}\right) \times 100 = 0.85$        $x = [H^+] = 2.12 \times 10^{-3} \text{ M}$ ,

b.  $\text{pH} = \log(2.12 \times 10^{-3}) = 2.67$

c.  $\text{pOH} = 14 - 2.67 = 11.33$

d.  $K_a = x^2/(a-x) = (2.12 \times 10^{-3})^2 / (0.25 - 2.12 \times 10^{-3}) = 1.8 \times 10^{-5}$

e.  $\text{pKa} = -\log(1.8 \times 10^{-5}) = 4.74$



a.  $[OH^-] = 10^{-\text{pOH}} = 10^{-4.6} = 2.5 \times 10^{-5} = x$

b.  $K_b = \frac{x^2}{b-x}$                        $5.0 \times 10^{-6} = \frac{(2.5 \times 10^{-5})^2}{(b - 2.5 \times 10^{-5})}$        $b = 1.5 \times 10^{-4}$

c.  $\% \text{ionization} = \frac{x}{b} \cdot 100 = \left(\frac{2.5 \times 10^{-5}}{1.5 \times 10^{-4}}\right) \cdot 100 = 16.7\%$

Complete information for the following conjugate acid-base pairs. Rank the acid and base from strongest (#1) to weakest

	CA	$K_a$	$pK_a$	Rank of acid	CB	$K_b$	$pK_b$	Rank base
1	CH <sub>3</sub> COOH	$1.8 \times 10^{-5}$	4.74	7	CH <sub>3</sub> COO <sup>-</sup>	$5.6 \times 10^{-10}$	9.26	6
2	C <sub>6</sub> H <sub>5</sub> CO <sub>2</sub> H	$6.3 \times 10^{-5}$	4.20	5	C <sub>6</sub> H <sub>5</sub> CO <sub>2</sub> <sup>-</sup>	$1.6 \times 10^{-10}$	9.80	8
3	H <sub>2</sub> CO <sub>3</sub> (H <sub>2</sub> O + CO <sub>2</sub> )	$4.2 \times 10^{-7}$	6.38	9	HCO <sub>3</sub> <sup>-</sup>	$2.4 \times 10^{-8}$	7.62	4
4	HCOOH	$1.8 \times 10^{-4}$	3.74	4	HCOO <sup>-</sup>	$5.6 \times 10^{-11}$	10.26	9
5	HNO <sub>2</sub>	$4.5 \times 10^{-4}$	3.35	3	NO <sub>2</sub> <sup>-</sup>	$2.2 \times 10^{-11}$	10.65	10
6	H <sub>3</sub> PO <sub>4</sub>	$7.5 \times 10^{-3}$	2.12	2	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>	$1.3 \times 10^{-12}$	11.88	11
7	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>	$6.2 \times 10^{-8}$	7.21	10	HPO <sub>4</sub> <sup>2-</sup>	$1.6 \times 10^{-7}$	6.79	3
8	HSO <sub>4</sub> <sup>-</sup>	$1.2 \times 10^{-2}$	1.92	1	SO <sub>4</sub> <sup>2-</sup>	$8.3 \times 10^{-13}$	12.08	12
9	NH <sub>3</sub> OH <sup>+</sup>	$1.5 \times 10^{-6}$	5.82	8	NH <sub>2</sub> OH	$6.6 \times 10^{-9}$	8.18	5
10	NH <sub>4</sub> <sup>+</sup>	$5.6 \times 10^{-10}$	9.26	11	NH <sub>3</sub>	$1.8 \times 10^{-5}$	4.74	2
11	C <sub>6</sub> H <sub>5</sub> NH <sub>3</sub> <sup>+</sup>	$2.4 \times 10^{-5}$	4.62	6	C <sub>6</sub> H <sub>5</sub> NH <sub>2</sub>	$4.2 \times 10^{-10}$	9.38	7
12	(CH <sub>3</sub> ) <sub>2</sub> NH <sub>3</sub> <sup>+</sup>	$1.36 \times 10^{-11}$	10.87	12	(CH <sub>3</sub> ) <sub>2</sub> NH <sub>2</sub>	$7.4 \times 10^{-4}$	3.13	1

- Stronger acid has greater  $K_a$  and smaller  $pK_a$
- Stronger base has greater  $K_b$  and smaller  $pK_b$
- Strength of conjugate acid and conjugate base is complementary.
- Stronger acid has weaker conj base.

CHEM 1412 **Buffers**

Dr. Ya-Ping Huang

A. Find the pH range of the following buffers: **Calculate all pH to 2 decimal places.**

	Composition	K <sub>a</sub> or K <sub>b</sub> , indicate which	pK <sub>a</sub>	pK <sub>b</sub>	Effective pH range
1	Benzoic acid/benzoate: C <sub>6</sub> H <sub>5</sub> CO <sub>2</sub> H/ C <sub>6</sub> H <sub>5</sub> CO <sub>2</sub> <sup>-</sup>	6.3 x 10 <sup>-5</sup>	4.20	9.80	3.20 - 5.20
2	H <sub>2</sub> CO <sub>3</sub> /HCO <sub>3</sub> <sup>-</sup>	4.2 x 10 <sup>-7</sup>	6.38	7.62	5.38 – 7.38
3	Nitrous acid/nitrite: HNO <sub>2</sub> /NO <sub>2</sub> <sup>-</sup>	4.5 x 10 <sup>-4</sup>	3.35	10.65	2.35-4.35
4	H <sub>3</sub> PO <sub>4</sub> /H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>	7.5 x 10 <sup>-3</sup>	2.12	11.88	1.12 – 3.12
5	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup> /HPO <sub>4</sub> <sup>2-</sup>	6.2 x 10 <sup>-8</sup>	7.21	6.79	6.21 – 7.21
6	Aniline/anilium: C <sub>6</sub> H <sub>5</sub> NH <sub>2</sub> / C <sub>6</sub> H <sub>5</sub> NH <sub>3</sub> <sup>+</sup>	4.2 x 10 <sup>-10</sup>	4.62	9.38	3.62 – 5.62
7	Ammonia/ammonium: NH <sub>3</sub> /NH <sub>4</sub> <sup>+</sup>	1.8 x 10 <sup>-5</sup>	9.26	4.74	8.26-10.26

B. Find the specific pH of the following buffers: pH = pK<sub>a</sub> + log([CB]/[CA])

	Composition	[CB]	[CA]	[CB]/[CA]	pH	[H <sup>+</sup> ]
8	0.10M C <sub>6</sub> H <sub>5</sub> CO <sub>2</sub> H/ 0.25 M C <sub>6</sub> H <sub>5</sub> CO <sub>2</sub> <sup>-</sup>	0.25	0.10	2.5	4.60	2.5 x 10 <sup>-5</sup>
9	0.69 g NaNO <sub>2</sub> in 25 mL 0.10 M HNO <sub>2</sub>	0.40	0.10	4.0	3.95	1.1 x 10 <sup>-4</sup>
10	0.36 g NaH <sub>2</sub> PO <sub>4</sub> in 100 mL 0.020 M H <sub>3</sub> PO <sub>4</sub>	0.03	0.02	1.5	2.30	5.0 x 10 <sup>-3</sup>
11	0.10 M NaH <sub>2</sub> PO <sub>4</sub> / 0.25 M Na <sub>2</sub> HPO <sub>4</sub>	0.25	0.10	2.5	7.61	2.5 x 10 <sup>-8</sup>
12	0.535 g NH <sub>4</sub> Cl in 50.mL 0.10M NH <sub>3</sub>	0.10	0.20	0.50	8.96	1.1 x 10 <sup>-9</sup>

C. Find the ratio of [CB]/[CA] required to prepare pH 6.40 solution using the following buffers.

	Buffer	Formula CA	Formula CB	[CB]/[CA]	[CA] =? If [CB] =0.10M	Is buffer effective?
13	H <sub>2</sub> CO <sub>3</sub> / HCO <sub>3</sub> <sup>-</sup>	H <sub>2</sub> CO <sub>3</sub> (CO <sub>2</sub> +H <sub>2</sub> O)	HCO <sub>3</sub> <sup>-</sup>	1.05	0.095	No
14	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup> / HPO <sub>4</sub> <sup>2-</sup>	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>	HPO <sub>4</sub> <sup>2-</sup>	0.155	0.645	Yes
15	C <sub>6</sub> H <sub>5</sub> NH <sub>2</sub> / C <sub>6</sub> H <sub>5</sub> NH <sub>3</sub> <sup>+</sup>	C <sub>6</sub> H <sub>5</sub> NH <sub>3</sub> <sup>+</sup>	C <sub>6</sub> H <sub>5</sub> NH <sub>2</sub>	60.26	0.0017	no

**CHEM 1412 ACIDS/BASE CLASSIFICATION**

Classify the following compounds and calculate the pH values & percent ionization (hydrolysis) of 0.10M solution. Fill answers in the blanks and show works on separate paper.

		Classification	reaction: ionization or hydrolysis	K <sub>a</sub> / or K <sub>b</sub>	pH	[OH <sup>-</sup> ]
1	NaCl	salt of SB/SA	none	none	7.00	1.0E-7
2	HClO <sub>4</sub>	Strong acid	HClO <sub>4</sub> → H <sup>+</sup> + ClO <sub>4</sub> <sup>-</sup>	none	1.00	1.0E-13
3	NaNO <sub>2</sub>	salt of SB/WA	NO <sub>2</sub> <sup>-</sup> +H <sub>2</sub> O ⇌ HNO <sub>2</sub> +OH <sup>-</sup>	K <sub>b</sub> = 2.2x10 <sup>-11</sup>	8.17	1.48 x10 <sup>-6</sup>
4	Fe(NO <sub>3</sub> ) <sub>3</sub>	salt of WB/SA	Fe(H <sub>2</sub> O) <sub>6</sub> <sup>3+</sup> ⇌ [Fe(H <sub>2</sub> O) <sub>5</sub> (OH)] <sup>2+</sup> + H <sup>+</sup>	K <sub>a</sub> = 4.0 x 10 <sup>-3</sup>	1.74	5.50 x10 <sup>-13</sup>
5	NaC <sub>6</sub> H <sub>5</sub> CO <sub>2</sub>	salt of SB/WA	C <sub>6</sub> H <sub>5</sub> CO <sub>2</sub> <sup>-</sup> +H <sub>2</sub> O ⇌ OH <sup>-</sup> +HC <sub>6</sub> H <sub>5</sub> CO <sub>2</sub>	K <sub>b</sub> =1.6 x 10 <sup>-10</sup>	8.60	4.0 x10 <sup>-6</sup>
6	NH <sub>4</sub> Br	salt of WB/SA	NH <sub>4</sub> <sup>+</sup> ⇌ NH <sub>3</sub> +H <sup>+</sup>	K <sub>a</sub> = 5.6x 10 <sup>-10</sup>	5.13	1.35 x10 <sup>-9</sup>
7	Ca(OH) <sub>2</sub>	strong base	Ca(OH) <sub>2</sub> → Ca <sup>2+</sup> + 2OH <sup>-</sup>	none	13.3	0.20
8	C <sub>6</sub> H <sub>5</sub> NH <sub>3</sub> Cl	salt of WB/SA	C <sub>6</sub> H <sub>5</sub> NH <sub>3</sub> ⇌ C <sub>6</sub> H <sub>5</sub> NH <sub>2</sub> +H <sup>+</sup>	K <sub>a</sub> =2.38x10 <sup>-5</sup>	2.81	6.46 x10 <sup>-12</sup>
9	Na <sub>2</sub> HPO <sub>4</sub>	salt of SB/WA amphiprotic	HPO <sub>4</sub> <sup>2-</sup> +H <sub>2</sub> O ⇌ OH <sup>-</sup> + H <sub>2</sub> PO <sub>4</sub> <sup>-</sup> HPO <sub>4</sub> <sup>2-</sup> ⇌ H <sup>+</sup> + PO <sub>4</sub> <sup>3-</sup>	K <sub>b</sub> =1.6 x 10 <sup>-7</sup> > K <sub>a</sub> = 3.6x 10 <sup>-13</sup>	10.10 (> 7)	1.26 x10 <sup>-4</sup>
10	NaHC <sub>2</sub> O <sub>4</sub>	salt of SB/WA amphiprotic	HC <sub>2</sub> O <sub>4</sub> <sup>-</sup> ⇌ H <sup>+</sup> + C <sub>2</sub> O <sub>4</sub> <sup>2-</sup> HC <sub>2</sub> O <sub>4</sub> <sup>-</sup> +H <sub>2</sub> O ⇌ OH <sup>-</sup> + H <sub>2</sub> C <sub>2</sub> O <sub>4</sub>	K <sub>a</sub> =6.4 x 10 <sup>-5</sup> > K <sub>b</sub> = 1.7x 10 <sup>-13</sup>	2.60 (< 7)	4.0 x10 <sup>-12</sup>

**You need to be able to calculate the pH of each solution. Not just estimate.**

Q9. Na<sub>2</sub>HPO<sub>4</sub> Salt of SB/WA, and is amphiprotic (H in the formula of anion). Consider HPO<sub>4</sub><sup>2-</sup> for pH

a. as CB of H<sub>2</sub>PO<sub>4</sub><sup>-</sup> : HPO<sub>4</sub><sup>2-</sup>+H<sub>2</sub>O ⇌ OH<sup>-</sup>+ H<sub>2</sub>PO<sub>4</sub><sup>-</sup>

$$K_b = K_w/K_{a2} \text{ of } H_3PO_4 = \frac{1.0 \times 10^{-14}}{6.2 \times 10^{-8}} = 1.6 \times 10^{-7}$$

b. as CA of PO<sub>4</sub><sup>3-</sup>, further ionization to PO<sub>4</sub><sup>3-</sup>      HPO<sub>4</sub><sup>2-</sup> ⇌ H<sup>+</sup>+ PO<sub>4</sub><sup>3-</sup>    K<sub>a</sub> = 3.6x10<sup>-13</sup>

c. Compare K<sub>a</sub> with K<sub>b</sub>. K<sub>a</sub> (=3.6x10<sup>-13</sup>) < K<sub>b</sub> (1.6x10<sup>-7</sup>)

Solve pH by using  $K_b$        $K_b = \frac{x^2}{(0.1-x)}$ ,       $\frac{0.1}{1.6 \times 10^{-7}} > 400$

$$x = [OH^-] = \sqrt{(0.1)(1.6 \times 10^{-7})} = 1.26 \times 10^{-4} \quad pOH = 3.90, \text{ pH} = 10.10$$

Q10. **NaHC<sub>2</sub>O<sub>4</sub>** Salt of SB/WA, and is amphoteric Consider HC<sub>2</sub>O<sub>4</sub><sup>-</sup> for pH

a. as CB of **H<sub>2</sub>C<sub>2</sub>O<sub>4</sub>** : HC<sub>2</sub>O<sub>4</sub><sup>-</sup> + H<sub>2</sub>O ⇌ OH<sup>-</sup> + **H<sub>2</sub>C<sub>2</sub>O<sub>4</sub>**

$$K_b = K_w/K_{a1} \text{ of } \mathbf{H_2C_2O_4} = \frac{1.0 \times 10^{-14}}{5.9 \times 10^{-2}} = 1.7 \times 10^{-13}$$

b. as CA of C<sub>2</sub>O<sub>4</sub><sup>2-</sup>, further ionization of HC<sub>2</sub>O<sub>4</sub><sup>-</sup> to C<sub>2</sub>O<sub>4</sub><sup>2-</sup>      **HC<sub>2</sub>O<sub>4</sub><sup>-</sup> ⇌ H<sup>+</sup> + C<sub>2</sub>O<sub>4</sub><sup>2-</sup>**  
 $K_a = 6.4 \times 10^{-5}$

c. Compare  $K_a$  with  $K_b$ .  $K_a (=6.4 \times 10^{-5}) > K_b (1.7 \times 10^{-13})$

Solve pH by using  $K_a$        $K_a = \frac{x^2}{(0.1-x)}$ ,       $\frac{0.1}{6.4 \times 10^{-5}} > 400$

$$x = [H^+] = \sqrt{(0.1)(6.4 \times 10^{-5})} = 2.53 \times 10^{-3} \quad \text{pH} = 2.60,$$

#### The test will have

- 19 multiple choices, 5 pts each
- 1 question about titration curve, 10 pts
- 1 question of Lewis structure and identify Lewis acid and base in a reaction, 8 pts
- 1 question to write net ionic equations for various compounds with HCl and NaOH, 12 pts
- 1 question of classification, 10 pts

Write the **balance net ionic equation** for the solutions in the far left column with HCl and NaOH. If no reaction, indicate with NR.

	solution	classification	Acid or base	reaction w/ HCl (H <sup>+</sup> )	reaction w/ NaOH (OH <sup>-</sup> )
1	HNO <sub>3</sub>	SA	acid	NR	H <sup>+</sup> + OH <sup>-</sup> → H <sub>2</sub> O
2	CH <sub>3</sub> CO <sub>2</sub> H	WA	acid	NR, ionization of HOAC ↓ by H <sup>+</sup> (common ion effect)	CH <sub>3</sub> CO <sub>2</sub> H + OH <sup>-</sup> → H <sub>2</sub> O + CH <sub>3</sub> CO <sub>2</sub> <sup>-</sup>
3	C <sub>6</sub> H <sub>5</sub> NH <sub>2</sub>	WB	base	C <sub>6</sub> H <sub>5</sub> NH <sub>2</sub> + H <sup>+</sup> → C <sub>6</sub> H <sub>5</sub> NH <sub>3</sub> <sup>+</sup>	NR, (WB ionization ↓ by common ion effect)
4	NH <sub>3</sub>	WB	base	NH <sub>3</sub> + H <sup>+</sup> → NH <sub>4</sub> <sup>+</sup>	NR. (WB ionization ↓ by common ion effect)
5	H <sub>3</sub> PO <sub>4</sub>	WA	acid	NR, (WA ionization ↓ by common ion effect)	H <sub>3</sub> PO <sub>4</sub> + OH <sup>-</sup> → H <sub>2</sub> O + H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>
6	KF	Salt of SB/WA	base	F <sup>-</sup> + H <sup>+</sup> → HF	NR, (hydrolysis ↓ by common ion effect)
7	NaCN	Salt of SB/WA	base	CN <sup>-</sup> + H <sup>+</sup> → HCN	NR (hydrolysis ↓ by common ion effect)
8	NaH <sub>2</sub> PO <sub>4</sub>	Salt of SB/WA	amphiprotic	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup> + H <sup>+</sup> → H <sub>3</sub> PO <sub>4</sub>	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup> + OH <sup>-</sup> → H <sub>2</sub> O + HPO <sub>4</sub> <sup>2-</sup>
9	C <sub>6</sub> H <sub>5</sub> NH <sub>3</sub> Cl	Salt of WB/SA	acid	NR (hydrolysis ↓ by common ion effect)	C <sub>6</sub> H <sub>5</sub> NH <sub>3</sub> <sup>+</sup> + OH <sup>-</sup> → H <sub>2</sub> O + C <sub>6</sub> H <sub>5</sub> NH <sub>2</sub>
10	NH <sub>4</sub> NO <sub>3</sub>	Salt of WB/SA	acid	NR (hydrolysis ↓ by common ion effect)	NH <sub>4</sub> <sup>+</sup> + OH <sup>-</sup> → H <sub>2</sub> O + NH <sub>3</sub>
11	HNO <sub>2</sub> -NaNO <sub>2</sub>	WA buffer	Conjugate pair	NO <sub>2</sub> <sup>-</sup> + H <sup>+</sup> → HNO <sub>2</sub>	HNO <sub>2</sub> + OH <sup>-</sup> → H <sub>2</sub> O + NO <sub>2</sub> <sup>-</sup>
12	NH <sub>3</sub> -NH <sub>4</sub> Cl	WB buffer	Conjugate pair	NH <sub>3</sub> + H <sup>+</sup> → NH <sub>4</sub> <sup>+</sup>	NH <sub>4</sub> <sup>+</sup> + OH <sup>-</sup> → H <sub>2</sub> O + NH <sub>3</sub>

<p>1. <b>10.0mL 0.10M NaOH +.25.0mL 0.10M HCl</b></p> <p><math>[H^+] = .1 \times 25 / 35 = 0.0714M</math>  <math>[OH^-] = .10 \times 10 / 35 = 0.0286M</math>  <math>H^+ + OH^- \rightarrow H_2O</math>  <math>.0714 \quad .0286</math>  <math>[H^+] = .0714 - .0286 = .0428M</math>  <b><u>pH = 1.37</u></b></p>	<p>2. <b>10.0mL 0.10M NaOH +.25.0mL 0.10M HNO<sub>2</sub></b></p> <p><math>[HNO_2] = 0.0714M</math> <math>[OH^-] = 0.0286M</math>  <math>R \quad HNO_2 + OH^- \rightarrow NO_2^- + H_2O</math>  <math>I \quad .0714 \quad .0286</math>  <math>C \quad -.0286 \quad -.0286 \quad +.0286</math>  <math>E \quad .0428 \quad \sim 0 \quad .0286</math>  buffer, <math>pH = 3.34 + \log(CB/CA) = 3.17</math></p>
<p>3. <b>25.0mL 0.10M NaOH +.25.0mL 0.10M HCl</b></p> <p><math>[H^+] = 0.050M</math> <math>[OH^-] = 0.050M</math>  <math>H^+ + OH^- \rightarrow H_2O</math>  <math>.050 \quad .050</math>  complete neutralization  <math>[H^+] = [OH^-] = 1.0 \times 10^{-7}M</math>  <b><u>pH = 7.0</u></b></p>	<p>4. <b>25.0mL 0.10M NaOH +.25.0mL 0.10M HNO<sub>2</sub></b></p> <p><math>[HNO_2] = 0.050M</math> <math>[OH^-] = 0.050M</math>  <math>HNO_2 + OH^- \rightarrow NO_2^- + H_2O</math>  After neutralization, only 0.05 M <math>NO_2^-</math> left  hydrolysis <math>NO_2^- + H_2O \rightleftharpoons HNO_2 + OH^-</math>  <math>K_b = 2.2 \times 10^{-11} = x^2 / (.05 - x)</math>  <math>X = [OH^-] = 1.05 \times 10^{-6}M</math>, <b><u>pH = 8.02</u></b></p>
<p>5. <b>50.0mL 0.10M NaOH +.25.0mL 0.10M HCl</b></p> <p><math>[H^+] = 0.033M</math> <math>[OH^-] = 0.067M</math>  <math>H^+ + OH^- \rightarrow H_2O</math>  After neutralization,  <math>[OH^-] = .034</math> <b><u>pH = 12.53</u></b></p>	<p>6. <b>50.0mL 0.10M NaOH +.25.0mL 0.10M HNO<sub>2</sub></b></p> <p><math>[HNO_2] = 0.033M</math> <math>[OH^-] = 0.067M</math>  <math>HNO_2 + OH^- \rightarrow NO_2^- + H_2O</math>  After neutralization,  <math>[OH^-] = .034M</math>, <math>pOH = 1.47</math>, <b><u>pH = 12.53</u></b></p>
<p>7. <b>25.0mL 0.10M NH<sub>3</sub> +25.0mL 0.10M HCl.</b></p> <p><math>[H^+] = 0.050M</math> <math>[NH_3] = 0.050M</math>  <math>H^+ + NH_3 \rightarrow NH_4^+</math>  After neutralization, only 0.05 M <math>NH_4^+</math> left  hydrolysis,  <math>NH_4^+ \rightarrow H^+ + NH_3</math>  <math>K_a = x^2 / (0.5 - x) = K_w / K_b</math>  <math>= 1.0E-14 / 1.8E-5 = 5.6E-10</math>  <math>X = [H^+] = 7.48E-6M</math>  <b><u>pH = 5.13</u></b></p>	<p>8. <b>50.0mL 0.10M NH<sub>3</sub> +25.0mL 0.10M HCl</b></p> <p><math>[H^+] = 0.033M</math> <math>[NH_3] = 0.067M</math>  <math>H^+ + NH_3 \rightarrow NH_4^+</math>  neutralization, buffer, <b><u>pH = 9.27</u></b></p>

### SAMPLE TEST 2

2. Which of the following pair can be used to prepare a buffer? Why?

- |   |  |
|---|--|
| a. 0.1 M HCl and 0.1 M NaOH   | No, SA and SB  |
| b. 0.1 M NaOH and 0.1 M NaC <sub>2</sub> H <sub>3</sub> O <sub>2</sub>  | No, SB (NaOH) and WB (NaC <sub>2</sub> H <sub>3</sub> O <sub>2</sub> as salt of SB/WA)   |
| c. 0.1 M HC <sub>2</sub> H <sub>3</sub> O <sub>2</sub> and 0.1 M NaC <sub>2</sub> H <sub>3</sub> O <sub>2</sub> | Yes, Conjugate pair, WA (HC <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) and CB (C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> <sup>-</sup> of NaC <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) |
| d. 0.1 M HCl and 0.1 M NH <sub>3</sub>  | No, SA and WB in equal concentration   |
| e. 0.2 M NaOH and 0.1 M HC <sub>2</sub> H <sub>3</sub> O <sub>2</sub>   | No, [SB] > [WA]  |
| f. 0.2 M HCl and 0.1 M NH <sub>3</sub>  | No, [SA] > [WB]  |
| g. 0.1 M NaOH and 0.1 M HC <sub>2</sub> H <sub>3</sub> O <sub>2</sub>   | No, [SB] = [WA]  |

- h. 0.1 M HCl and 0.1 M HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub>      No, two acids, SA (HCl) and WA (HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub>)  
 i. 0.1 M NaOH and 0.2 M HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub>      Yes, [WA] > [SB]  
 j. 0.1 M HCl and 0.2 M NH<sub>3</sub>      Yes, [WB] > [SA]  
 k. 0.1 M HCl and 0.1 M NaCl      No, SA and its CB

5. Which of the following solution can neutralize the most NaOH? The least NaOH? Explain.

- a. 50.0mL of 0.10M HCl    b. 50.0mL of 0.10M HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub>    c. 50.0mL of 0.10M H<sub>2</sub>SO<sub>4</sub>

Ans: the amount of NaOH neutralized by acid depends on the moles of available acidic H (equivalent) = M x V x (#acidic H per molecule)

It does not matter if an acid is SA or WA

&

7. a.  $pH = pK_a + \log\left(\frac{[CB]}{[CA]}\right) = 4.74 + \log\left(\frac{0.20}{0.10}\right) = 4.74 + 0.30 = 5.04$        $K_a = 1.8 \times 10^{-5}$

b. If 0.50 mL 3.0M HCl is added to the 100 mL buffer solution

1. HCl will be diluted by the buffer.  $[HCl]_{mix} = \frac{M_{HCl} \times V_{HCl}}{V_{mix}} = \frac{(0.3M)(0.50mL)}{(100.50mL)} = 0.015M$

The effect of 0.50 mL HCl on the concentration of buffer will only be minimal, and is negligible

2. HCl will react with CB of the buffer according to the following equation:

R	H <sup>+</sup>	+ C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> <sup>-</sup>	→	HC <sub>2</sub> H <sub>3</sub> O <sub>2</sub>
I	0.015	0.20		0.10
C	-0.015	-0.015		+0.015
E	~0	0.185		0.115

after the neutralization, the mixture is still a buffer

$$pH = pK_a + \log\left(\frac{[CB]}{[CA]}\right) = 4.74 + \log\left(\frac{0.185}{0.115}\right) = 4.74 + 0.21 = 4.95$$

pH of buffer decreases slightly after addition of small amount of HCl

c. If 0.50 mL 3.0M NaOH is added to the 100 mL buffer solution

The effect of 0.50 mL NaOH on the concentration of buffer will only be minimal, and is negligible

1. NaOH will be diluted by the buffer.

$$[NaOH]_{mix} = \frac{M_{NaOH} \times V_{NaOH}}{V_{mix}} = \frac{(0.3M)(0.50mL)}{(100.50mL)} = 0.015M$$

2. NaOH will react with the CA of buffer according to the following equation:

R	OH <sup>-</sup>	+ HC <sub>2</sub> H <sub>3</sub> O <sub>2</sub>	→	C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> <sup>-</sup>	+ H <sub>2</sub> O
I	0.015	0.10		0.20	
C	-0.015	-0.015		+0.015	
E	~0	0.085		0.215	

after the neutralization, the mixture is still a buffer

$$pH = pK_a + \log\left(\frac{[CB]}{[CA]}\right) = 4.74 + \log\left(\frac{0.215}{0.085}\right) = 4.74 + 0.40 = 5.14$$

pH of buffer increases slightly after addition of small amount of NaOH

Q8. Is about the effect of common ion ( $H^+$ ) on the ionization of acetic acid



The greater the  $[H^+]$  (lower pH), the less is % ionization (reaction less likely to go forward)