ACID/BASE II
REVIEW KEY

1a) $NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$

b) $NaHSO_3 \longrightarrow Na^+ + HSO_3^-$ (amphiprotic) ∴ find K_a and K_b

$K_a(HSO_3^-) = 1.0 \times 10^{-7}$ $\quad K_b = \dfrac{K_w}{K_a} = \dfrac{1.0 \times 10^{-14}}{1.5 \times 10^{-2}} = 6.7 \times 10^{-13}$

$HSO_3^- + H_2O \rightleftharpoons H_3O^+ + SO_3^{2-}$ $\quad HSO_3^- + H_2O \rightleftharpoons H_2SO_3 + OH^-$

$K_a > K_b$ ∴ resulting solution is ACIDIC.

2. $CH_3COOH + H_2O \rightleftharpoons H_3O^+ + CH_3COO^-$ $\quad$ Let $x = \Delta[CH_3COOH]$

	CH_3COOH	H_3O^+	CH_3COO^-
I	0.40 M	0 M	0 M
C	$-x$	$+x$	$+x$
E	$0.40-x$	x	x

$K_a = 1.8 \times 10^{-5} = \dfrac{x^2}{0.40-x}$ $\quad$ Assume $0.40-x \cong 0.40$

$1.8 \times 10^{-5} = \dfrac{x^2}{0.40}$ $\quad$ Check ✓

$x = 2.6832816 \times 10^{-3}$ M

∴ $pH = -\log(x) = \boxed{2.57}$

3. $C_6H_5O^- + H_2O \rightleftharpoons OH^- + C_6H_5OH$ $\quad$ Let $x = \Delta[C_6H_5O^-]$

	$C_6H_5O^-$	OH^-	C_6H_5OH
I	2.00 M	0 M	0 M
C	$-x$	$+x$	$+x$
E	$2.00-x$	x	x

$K_b = \dfrac{K_w}{K_a} = \dfrac{1.0 \times 10^{-14}}{1.3 \times 10^{-10}} = 7.6923 \times 10^{-5} = \dfrac{x^2}{2.00}$ $\quad$ Assume $2.00 - x \cong 2.00$ Check ✓

$x = 1.24035 \times 10^{-2}$ M

$pOH = -\log(x) = 1.9065$

$pH = 14 - 1.9065 = \boxed{12.09}$

4a) i) BUFFER SOLUTION ii) $H_3PO_4 + H_2O \rightleftharpoons H_2PO_4^- + H_3O^+$

b) $pH = -\log(K_a) = -\log(7.5 \times 10^{-3}) = \boxed{2.12}$

c) mol OH^- = MV = 1.0×0.0100 L = 0.0100 mol OH^- added BUT 1.00 mol H_3PO_4 available to neutralize. pH raises slightly as ratio of $H_3PO_4 : H_2PO_4^-$ changes but only slightly.

5) $H_2C_6H_6O_6 + H_2O \rightleftharpoons H_3O^+ + HC_6H_6O_6^-$

6a) ① $NaCH_3COO \longrightarrow Na^+ + CH_3COO^-$

② $CH_3COO^- + H_2O \rightleftharpoons OH^- + CH_3COOH$

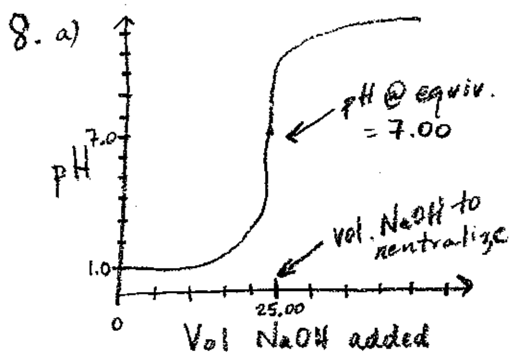
b) $K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{1.8 \times 10^{-5}} = \boxed{5.6 \times 10^{-10}}$

7. $HX + H_2O \rightleftharpoons H_3O^+ + X^-$ $\quad [H_3O^+] = [X^-] = \text{invlog}(-2.44)$ $= 3.6308 \times 10^{-3}\,M$

	HX		H_3O^+	X^-
I	0.200M		0 M	0 M
C	-3.6308×10^{-3}M		3.6308×10^{-3} M ⟶	
E	0.19637		3.6308×10^{-3}M ⟶	

$K_a = \frac{[H_3O^+]^2}{[HX]} = \frac{(3.6308 \times 10^{-3})^2}{0.19637} = 6.7 \times 10^{-5}$ The acid is BENZOIC

8. a)



$pH_{initial} = -\log(0.10\,M)$ *because HCl is strong
$= 1.00$

mol HCl = mol H_3O^+ = MV = $(0.10M)(0.0250L) = 0.00250$ m

mol OH^- = mol NaOH = 0.00250 mol

$V = \frac{mol}{M} = \frac{0.00250\,mol}{0.10\,M} = 0.0250\,L$
$= 25.00$ mL

pH at equiv. point = 7.00 (Strong-Strong titration)

b) Suitable Indicator: Bromthymol blue, Phenol Red, Neutral Red

OR

*Phenolphthalein (cheap)

9. 2 characteristics of Strong Acid / Weak Base Titration Curve:

i) Initial noticeable drop in curve (pH).

ii) pH @ equiv. pt < 7.00. (around pH 4-6)

due to hydrolysis of weak acid...

$HCl + NH_3 \longrightarrow \underset{\text{weak acid}}{NH_4^+} + \underset{\text{spectator}}{Cl^-}$

Indicator: Bromcresol Green, Methyl Red

10. a) $N_2H_4 + H_2O \rightleftharpoons OH^- + HN_2H_4^+$ $K_b = 8.5 \times 10^{-6}$

b) CONJUGATE ACID IS $HN_2H_4^+$ $K_a = \frac{K_w}{K_b} = \frac{1.0 \times 10^{-14}}{8.5 \times 10^{-6}} = \boxed{1.2 \times 10^{-9}}$

11. MgO is a metal oxide (basic anhydride) ∴ it forms a BASE w/ water.

$$MgO + H_2O \longrightarrow Mg(OH)_2$$

Student is wrong!

12. a) pH of distilled water = 7.00 ∴ Bromcresol green is BLUE.

b) Acetic acid produces some H_3O^+ which shifts the indicator's equilibrium left. $\underbrace{[HInd]}_{\text{yellow}} > \underbrace{[Ind^-]}_{\text{blue}}$ ∴ more yellow than blue ... pH must be ≤ 3.8. (see ind. table)

13. Transition Point = End Point ∴ $[HInd] = [Ind^-]$ COMBINATION OF THE 2 COLOURS

$$K_a = \frac{[H_3O^+]\cancel{[Ind^-]}}{\cancel{[HInd]}}$$

14. $Mor + H_2O \rightleftharpoons OH^- + HMor^+$

	Mor		OH^-	$HMor^+$
I	0.010 M		0	0
C	-1.2589×10^{-4} M		1.2589×10^{-4} M $\longrightarrow$	
E	0.009874 M		1.2589×10^{-4} M $\longrightarrow$	

pH = 10.10 pOH = 3.90

$[OH^-]_{eq}$ = invlog(−3.90)
= 1.2589×10^{-4} M

$$K_b = \frac{[OH^-]^2}{[Mor]} = \frac{(1.2589 \times 10^{-4})^2}{0.009874} = \boxed{2 \times 10^{-6}}$$

1 sig fig.

15. i) $(NH_4)_2C_2O_4 \longrightarrow 2NH_4^+ + C_2O_4^{2-}$

K_a of $NH_4^+ = 5.6 \times 10^{-10}$

K_b of $C_2O_4^{2-} = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{6.4 \times 10^{-5}} = 1.6 \times 10^{-10}$

$K_a > K_b$ so ACIDIC

16. i) $CH_3COOH + NaOH \longrightarrow NaCH_3COO + H_2O$

ii) $NaCH_3COO \longrightarrow \underset{\text{Spectator}}{Na^+} + CH_3COO^-$

Na^+ is conjugate acid of <u>strong</u> base; cannot <u>act</u> as an acid!

iii) $CH_3COO^- + H_2O \rightleftharpoons CH_3COOH + OH^-$

basic ∴ pH > 7.00.

17. i) $\underset{1.0M}{NaNO_2} \longrightarrow \underset{1.0M}{Na^+} + \underset{1.0M}{NO_2^-}$

ii) $\underset{1.0\ M}{CH_3COOH} + H_2O \rightleftharpoons \underset{<< 1.0M}{CH_3COO^-} + \underset{<< 1.0M}{H_3O^+}$

$NaNO_2$ would have greater conductivity (2.0 M total ions)!

18. $CO_2 + H_2O \longrightarrow H_2CO_3$ OR $SO_3 + H_2O \longrightarrow H_2SO_4$

OR OR

$SO_2 + H_2O \longrightarrow H_2SO_3$ $2NO_2 + H_2O \longrightarrow HNO_2 + HNO_3$

19. Any weak acid in equal conc. with its conjugate base (and vice versa)

eg: 1.0 M CH_3COOH and 1.0 M CH_3COO^- (as $NaCH_3COO$)

$\underset{1.0M}{CH_3COOH} + H_2O \rightleftharpoons \underset{1.0M}{CH_3COO^-} + \underset{\text{small M}}{H_3O^+}$

add HCl → ↑ $[H_3O^+]$ ∴ $[CH_3COO^-]$ ↓ (to neutralize) ∴ $[CH_3COOH]$ ↑

EQUIL. shifts LEFT

Therefore, there exists more CH_3COOH after neutralization than CH_3COO^-.

But pH only decreases slightly ... a tenth?

Buffer works though b/c without it, 'raw' HCl would affect pH <u>much</u> <u>much</u> more.

20. $HCOOH + H_2O \rightleftharpoons COOH^- + H_3O^+$

	$HCOOH$	$COOH^-$	H_3O^+
I	x	0	0
C	-5.6885×10^{-4}	$\uparrow$	$\uparrow$
E	$x - 5.6885 \times 10^{-4}$	5.6885×10^{-4} M	5.6885×10^{-4} M

Let $x = [HCOOH]_i$

$$[H_3O^+]_{eq} = \text{invlog}(-pH) = \text{invlog}(-3.245) = 5.6885 \times 10^{-4}\ M$$

$$K_a = 1.8 \times 10^{-4} = \frac{[H_3O^+]^2}{[HCOOH]} = \frac{(5.6885 \times 10^{-4})^2}{x - 5.6885 \times 10^{-4}}$$

$$x = 2.3666 \times 10^{-3}\ M$$

$$[HCOOH]_i = \boxed{2.4 \times 10^{-3}\ M}$$

21. $CN^- + H_2O \rightleftharpoons HCN + OH^-$

Let $x = [CN^-]_i$

	CN^-	HCN	OH^-
I	x	0	0
C	-1.6982×10^{-2}	$\uparrow$	$\uparrow$
E	$x - 1.6982 \times 10^{-2}$	1.6982×10^{-2} M	1.6982×10^{-2} M

$$[OH^-]_{eq} = \text{invlog}(-pOH) = \text{invlog}(-1.77) = 1.6982 \times 10^{-2}\ M$$

$$K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{4.9 \times 10^{-10}} = 2.0408 \times 10^{-5}$$

$$2.0408 \times 10^{-5} = \frac{[OH^-]^2}{[CN^-]} = \frac{(1.6982 \times 10^{-2})^2}{x - 1.6982 \times 10^{-2}}$$

$$x = 14.15\ M$$

$$[CN^-] = \boxed{14\ M}$$

22. $HNO_3 + H_2O \longrightarrow H_3O^+ + NO_3^-$ STRONG ACID

1.0M 1.0M 1.0M (complete dissociation)

$HIO_3 + H_2O \longrightarrow H_3O^+ + IO_3^-$ WEAK ACID

1.0M << 1.0M << 1.0M (< 5% dissociation)

LESS IONS = LESS CONDUCTIVITY

23 a) since $[HCOOH] = [HCOO^-]$, we have a 'perfect' buffer so

$K_a = [H_3O^+]$ and $pH = pK_a$

$$pH = -\log(1.8 \times 10^{-4})$$
$$= \boxed{3.74}$$

b) $HCOOH + H_2O_{(l)} \rightleftharpoons HCOO^- + H_3O^+$

Adding OH^- will do the following:

$[H_3O^+] \downarrow \uparrow = \downarrow$

$[HCOO^-] \uparrow$

$[HCOOH] \downarrow$

pH goes up slightly

24. i) use a pH meter

ii) use an indicator or a combination of indicators

iii) perform a titration with a known [base].

pH = 11.78 pOH = 2.22

$[OH^-]_{eq} = \text{inv}\log(-2.22) = 6.0256 \times 10^{-3}$ M

25. $B^- + H_2O_{(l)} \rightleftharpoons HB + OH^-$

	B^-	HB	OH^-
I	$\boxed{0.2956 \text{ M}}$	0	0
C	-0.0060256		$+6.0256 \times 10^{-3}$
E	0.28957		$\boxed{6.0256 \times 10^{-3}}$ M

from titr. data

from pH data

$$K_b = \frac{[OH^-]^2}{[B^-]}$$

$$= \frac{(6.0256 \times 10^{-3})^2}{0.28957}$$

$$\boxed{K_b = 1.3 \times 10^{-4}}$$

Titration:

mol HCl added = MV

= (0.25 M)(0.02956 L)

= 0.00739 mol HCl

= 0.00739 mol H_3O^+

= 0.00739 mol OH^-

= 0.00739 mol B^-

$$[B^-]_i = \frac{\text{mol}}{V} = \frac{0.00739 \text{ mol}}{0.02500 \text{ L}}$$

= 0.2956 M

26 a) M: $Sr(OH)_2 + 2HClO_4 \longrightarrow Sr(ClO_4)_2 + 2H_2O_{(l)}$

C: $\cancel{Sr^{2+}} + 2OH^- + 2H^+ + \cancel{2ClO_4^-} \longrightarrow \cancel{Sr^{2+}} + 2ClO_4^- + 2H_2O_{(l)}$

N: $2H^+ + 2OH^- \longrightarrow 2H_2O_{(l)}$

$H^+ + OH^- \longrightarrow H_2O_{(l)}$

b) M: $HBr + NH_3 \longrightarrow NH_4Br$

C: $H^+ + \cancel{Br^-} + NH_3 \longrightarrow NH_4^+ + \cancel{Br^-}$

N: $H^+ + NH_3 \longrightarrow NH_4^+$

c) M: $KOH + HPO_4^{2-} \longrightarrow KPO_4^{2-} + H_2O_{(l)}$

C: $\cancel{K^+} + OH^- + HPO_4^{2-} \longrightarrow \cancel{K^+} + PO_4^{3-} + H_2O_{(l)}$

N: $OH^- + HPO_4^{2-} \longrightarrow PO_4^{3-} + H_2O_{(l)}$

d) M: $NaF + HSO_4^- \longrightarrow NaSO_4^- + HF$

C: $\cancel{Na^+} + F^- + HSO_4^- \longrightarrow \cancel{Na^+} + SO_4^{2-} + HF$

N: $F^- + HSO_4^- \rightleftharpoons SO_4^{2-} + HF$