CHEMISTRY 12 – CALCULATIONS INVOLVING K_A & K_B WORKSHEET

1) Calculate the pH of 0.50 M H_2S. **(4 marks)**

$$H_2S + H_2O_{(l)} \rightleftharpoons HS^- + H_3O^+$$

	H_2S		HS^-	H_3O^+
I	0.50		0	0
C	−x		+x	+x
E	0.50−x		x	x

(1)

assume
$0.50 - x = 0.50$ (0.5)

$$K_a = \frac{[HS^-][H_3O^+]}{[H_2S]}$$ (0.5)

$$9.1\times10^{-8} = \frac{x^2}{0.50}$$

$$x = 2.1\times10^{-4}\,M$$ (1)

$$pH = -\log[H_3O^+]$$
$$= -\log(2.1\times10^{-4})$$
$$= 3.67$$ (1)

2) Calculate the pOH of 0.35 M H_2CO_3. **(5 marks)**

$$H_2CO_3 + H_2O_{(l)} \rightleftharpoons HCO_3^- + H_3O^+$$

	H_2CO_3		HCO_3^-	H_3O^+
I	0.35		0	0
C	−x		+x	+x
E	0.35 −x		x	x

(1)

assume
$0.35 - x = 0.35$ (0.5)

$$K_a = \frac{[HCO_3^-][H_3O^+]}{[H_2CO_3]}$$ (0.5)

$$4.3\times10^{-7} = \frac{x^2}{0.35}$$

$$x = 3.9\times10^{-4}\,M$$ (1)

$$pH = -\log[H_3O^+]$$
$$= -\log(3.9\times10^{-4})$$
$$= 3.41$$ (1)

$$pH + pOH = 14.00$$
$$3.41 + x = 14.00$$
$$x = 10.59$$ (1)

3) Nicotinic acid, $HC_6H_4NO_2$, is a weak acid found in vitamin B. Calculate the pH of 0.010 M $HC_6H_4NO_2$ ($K_a = 1.4 \times 10^{-5}$). **(4 marks)**

	$HC_6H_4NO_2 + H_2O_{(l)} \rightleftharpoons$	$C_6H_4NO_2^-$	$+ H_3O^+$
I	0.010	0	0
C	−x	+x	+x
E	0.010 − x	x	x

(1)

assume $0.010 - x = 0.010$ (0.5)

$$K_a = \frac{[C_6H_4NO_2^-][H_3O^+]}{[HC_6H_4NO_2]} \quad (0.5)$$

$$1.4\times10^{-5} = \frac{x^2}{0.010}$$

$$x = 3.7\times10^{-4}\,M \quad (1)$$

$$pH = -\log[H_3O^+] = -\log(3.7\times10^{-4}) = 3.43 \quad (1)$$

4) Using calculations, show why the electrical conductivity of 1.0 M H_2CO_3 will be less than that for 0.10 M HCl. **(4 marks)**

	$H_2CO_3 + H_2O_{(l)} \rightleftharpoons$	HCO_3^-	$+ H_3O^+$
I	1.0	0	0
C	−x	+x	+x
E	1.0 − x	x	x

(0.5)

$$HCl \rightarrow H^+ + Cl^- \quad (0.5)$$

0.10M 0.10M 0.10M

Total [ion] is: $0.10 + 0.10 = 0.20M$ (0.5)

assume $1.0 - x = 1.0$ (0.5)

$$K_a = \frac{[HCO_3^-][H_3O^+]}{[H_2CO_3]} \quad (0.5)$$

$$4.3\times10^{-7} = \frac{x^2}{1.0}$$

$$x = 6.6\times10^{-4}\,M \quad (0.5)$$

Total [ion] is: $6.6\times10^{-4} + 6.6\times10^{-4} = 1.3\times10^{-3}\,M$ (0.5)

H_2CO_3 has a smaller [ion] ∴ will have a lower conductivity (0.5)

5) A solution of 0.100 M HOCN has a pH of 2.24. Calculate the K_a value for this acid. **(4 marks)**

	$HOCN + H_2O_{(l)} \rightleftharpoons$	OCN^-	$+ H_3O^+$
I	0.100	0	0
C	−0.0058	+0.0058	+0.0058
E	0.094	0.0058	0.0058

(1.5)

$$[H_3O^+] = 10^{-pH} = 10^{-2.24} = 5.8\times10^{-3}\,M \quad (1)$$

$$K_a = \frac{[OCN^-][H_3O^+]}{[HOCN]} \quad (0.5)$$

$$= \frac{(0.0058)^2}{(0.094)} = 3.5\times10^{-4} \quad (1)$$

6) At a particular temperature a 1.0 M H_2S solution has a pH = 3.75. Calculate the value of K_a at this temperature. **(4 marks)**

$$H_2S + H_2O_{(l)} \rightleftharpoons HS^- + H_3O^+$$

	H_2S		HS^-	H_3O^+
I	1.0		0	0
C	−0.00018		+0.00018	+0.00018
E	1.0		0.00018	0.00018

(1.5)

$[H_3O^+] = 10^{-pH} = 10^{-3.75} = 1.8 \times 10^{-4} M$ (1)

$Ka = \frac{[HS^-][H_3O^+]}{[H_2S]}$ (0.5) $= \frac{(0.00018)^2}{(1.0)} = 3.2 \times 10^{-8}$ (1)

7) A 3.50 x 10[-3] M sample of the unknown acid, HA, has a pH of 2.90. Calculate the value of K_a and identify this acid. **(4 marks)**

$$HA + H_2O_{(l)} \rightleftharpoons A^- + H_3O^+$$

	HA		A^-	H_3O^+
I	0.00350		0	0
C	−0.0013		+0.0013	+0.0013
E	0.0022		0.0013	0.0013

(1)

$[H_3O^+] = 10^{-pH} = 10^{-2.90} = 1.3 \times 10^{-3} M$ (1)

$Ka = \frac{[A^-][H_3O^+]}{[HA]}$ (0.5) $= \frac{(0.0013)^2}{(0.0022)} = 7.1 \times 10^{-4}$ (1)

Citric acid $H_3C_6H_5O_7$ (0.5)

8) What mass of CH_3COOH will produce 2.5 L of a solution having a pH of 5.50? **(5 marks)**

$$CH_3COOH + H_2O_{(l)} \rightleftharpoons CH_3COO^- + H_3O^+$$

	CH_3COOH		CH_3COO^-	H_3O^+
I	X		0	0
C	-3.2×10^{-6}		$+3.2\times10^{-6}$	$+3.2\times10^{-6}$
E	$X-3.2\times10^{-6}$		3.2×10^{-6}	3.2×10^{-6}

(1)

assume $X-3.2\times10^{-6} = X$ (0.5)

$[H_3O^+] = 10^{-pH} = 10^{-5.50} = 3.2 \times 10^{-6} M$ (1)

$Ka = \frac{[CH_3COO^-][H_3O^+]}{[CH_3COOH]}$ (0.5)

$1.8\times10^{-5} = \frac{(3.2\times10^{-6})^2}{X}$

$= 5.6 \times 10^{-7} M$ (1)

$g\ CH_3COOH = 2.5L \times \frac{5.6\times10^{-7} mol}{1L} \times \frac{60.0g}{1 mol} = 8.3\times10^{-5} g$ (1)

9) Calculate the pH of 1.50 M NH_3. **(5 marks)**

$$NH_3 + H_2O_{(l)} \rightleftharpoons NH_4^+ + OH^-$$

	NH_3		NH_4^+	OH^-
I	1.50		0	0
C	$-x$		$+x$	$+x$
E	$1.50-x$		x	x

(1)

assume (0.5)
$1.50 - x = 1.50$

$$K_b = \frac{[NH_4^+][OH^-]}{[NH_3]}$$ (0.5)

$$K_b = \frac{K_w}{K_a} = \frac{1.0\times10^{-14}}{5.6\times10^{-10}} = 1.8\times10^{-5}$$ (1)

$$1.8\times10^{-5} = \frac{x^2}{1.50}$$

$$x = 5.2\times10^{-3}\ M$$ (1)

$$pOH = -\log[OH^-] = -\log(5.2\times10^{-3}) = 2.29$$

$$pH + pOH = 14.00$$
$$x + 2.29 = 14.00$$
$$x = 11.71$$

(1)

10) Calculate the $[OH^-]$ in 0.50 M CN^-. **(5 marks)**

$$CN^- + H_2O_{(l)} \rightleftharpoons HCN + OH^-$$ (1)

	CN^-		HCN	OH^-
I	0.50		0	0
C	$-x$		$+x$	$+x$
E	$0.50-x$		x	x

(1)

assume (0.5)
$0.50 - x = 0.50$

$$K_b = \frac{[HCN][OH^-]}{[CN^-]}$$ (0.5)

$$K_b = \frac{K_w}{K_a} = \frac{1.0\times10^{-14}}{4.9\times10^{-10}} = 2.0\times10^{-5}$$ (1)

$$2.0\times10^{-5} = \frac{x^2}{0.50}$$

$$x = 3.2\times10^{-3}\ M$$ (1)

11) Calculate the $[H_3O^+]$ in 0.60 M SO_4^{2-}. **(5 marks)**

$$SO_4^{2-} + H_2O_{(l)} \rightleftharpoons HSO_4^- + OH^-$$

	SO_4^{2-}	HSO_4^-	OH^-
I	0.60	0	0
C	−x	+x	+x
E	0.60−x	x	x

(1)

assume (0.5)
$0.60 - x = 0.60$

$$K_b = \frac{[HSO_4^-][OH^-]}{[SO_4^{2-}]} \quad (0.5)$$

$$K_b = \frac{K_w}{K_a} = \frac{1.0\times10^{-14}}{1.2\times10^{-2}} = 8.3\times10^{-13} \quad (1)$$

$$8.3\times10^{-13} = \frac{x^2}{0.60}$$

$$x = 7.1\times10^{-7}\,M \quad (1)$$

$$K_w = [H_3O^+][OH^-]$$

$$1.0\times10^{-14} = x(7.1\times10^{-7})$$

$$x = 1.4\times10^{-8}\,M \quad (1)$$

12) A 0.0200 M solution of methylamine, CH_3NH_2, has a pH = 11.40. Calculate the K_b for methylamine. **(4 marks)**

$$CH_3NH_2 + H_2O_{(l)} \rightleftharpoons CH_3NH_3^+ + OH^-$$

	CH_3NH_2	$CH_3NH_3^+$	OH^-
I	0.0200	0	0
C	−0.0025	+0.0025	+0.0025
E	0.0175	0.0025	0.0025

(1)

$$pH + pOH = 14.00$$

$$11.40 + x = 14.00$$

$$x = 2.60 \quad (1)$$

$$[OH^-] = 10^{-pOH} = 10^{-2.60} = 2.5\times10^{-3}\,M \quad (1)$$

$$K_b = \frac{[CH_3NH_3^+][OH^-]}{[CH_3NH_2]} = \frac{(0.0025)^2}{(0.0175)}$$

$$x = 3.6\times10^{-4} \quad (1)$$

13) The pH of a 0.70 M solution of the weak base X^- is 12.55. What is the K_b for X^-?

$$X^- + H_2O_{(l)} \rightleftharpoons HX + OH^-$$

	X^-		HX	OH^-
I	0.70		0	0
C	−0.035		+0.035	+0.035
E	0.66		0.035	0.035

(1)

$pH + pOH = 14.00$

$12.55 + x = 14.00$

$x = 1.45$ (1)

$[OH^-] = 10^{-pOH}$

$= 10^{-1.45}$

$= 0.035\ M$ (1)

$$K_b = \frac{[HX][OH^-]}{[X^-]}$$

$$= \frac{(0.035)^2}{(0.66)}$$

$x = 1.9 \times 10^{-3}$ (1)

14) Calculate the initial concentration of a solution of NH_3 which has a pH = 11.33. **(5 marks)**

$$NH_3 + H_2O_{(l)} \rightleftharpoons NH_4^+ + OH^-$$

	NH_3		NH_4^+	OH^-
I	x		0	0
C	−0.0021		+0.0021	+0.0021
E	x−0.0021		0.0021	0.0021

(1)

$pH + pOH = 14.00$

$11.33 + x = 14.00$

$x = 2.67$ (0.5)

$[OH^-] = 10^{-pOH}$

$= 10^{-2.67}$

$= 0.0021\ M$ (0.5)

assume

$x - 0.0021 = x$ (0.5)

$$K_b = \frac{[NH_4^+][OH^-]}{[NH_3]}$$ (0.5)

$$1.8 \times 10^{-5} = \frac{(0.0021)^2}{x}$$

$x = 0.26\ M$ (1)

$$K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{5.6 \times 10^{-10}}$$

$= 1.8 \times 10^{-5}$ (1)