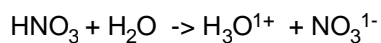


Solutions to: Acid-Base Homework Problem Set 1

S.E. Van Bramer 1/10/96

1. For the following reactions, write a balanced equation that describes what happens when the following are mixed. Identify the acid, base, conjugate base, and conjugate acid.

a. Nitric acid and water



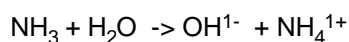
Acid HNO_3

Base H_2O

Conjugate base NO_3^{1-}

Conjugate acid H_3O^{1+}

b. Ammonia and water



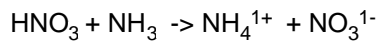
Acid H_2O

Base NH_3

Conjugate base OH^{1-}

Conjugate acid NH_4^{1+}

c. Nitric acid and ammonia



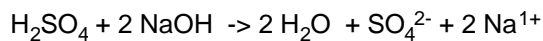
Acid HNO_3

Base NH_3

Conjugate base NO_3^{1-}

Conjugate acid NH_4^{1+}

d. Sulfuric acid and sodium hydroxide



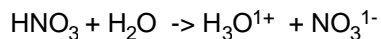
Acid H_2SO_4

Base NaOH

Conjugate base SO_4^{2-}

Conjugate acid H_2O

e. Sodium hydrogen sulfate and ammonia



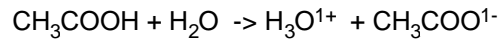
Acid HNO_3

Base H_2O

Conjugate base NO_3^{1-}

Conjugate acid H_3O^{1+}

f. Acetic acid and water



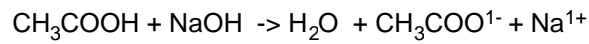
Acid CH_3COOH

Base H_2O

Conjugate base $\text{CH}_3\text{COO}^{1-}$

Conjugate acid H_3O^{1+}

g. Acetic acid and sodium hydroxide



Acid CH_3COOH

Base NaOH

Conjugate base $\text{CH}_3\text{COO}^{1-}$

Conjugate acid H_2O

2. Determine the equilibrium concentration of H_3O^{1+} and OH^{1-} . Identify the acid and the conjugate base (or the base and the conjugate acid). Calculate the pH.

Constants Used:

$$M := \frac{\text{mole}}{\text{liter}} \quad K_w := 1.0 \cdot 10^{-14} \cdot M^2$$

a. A 0.10 M solution of HNO_3

Given concentration of the acid:

$$C_{\text{acid}} := 0.10 \cdot M$$

The concentrations (this assumes that K_w is not significant):

$$C_{\text{H}_3\text{O}} := C_{\text{acid}} \quad C_{\text{H}_3\text{O}} = 0.1 \cdot M$$

$$\text{pH} := -\log(C_{\text{acid}} \cdot M^{-1}) \quad \text{pH} = 1$$

$$\text{pOH} := 14 - \text{pH} \quad \text{pOH} = 13$$

b. 1.00 g of HCl is diluted to 500.0 mL with water

The concentration of HCl

$$\text{mass}_{\text{acid}} := 1.00 \cdot \text{gm}$$

$$\text{MW}_{\text{acid}} := (1.00794 + 35.4527) \cdot \text{gm} \cdot \text{mole}^{-1} \quad \text{MW}_{\text{acid}} = 36.461 \cdot \text{gm} \cdot \text{mole}^{-1}$$

$$\text{mole}_{\text{acid}} := \frac{\text{mass}_{\text{acid}}}{\text{MW}_{\text{acid}}} \quad \text{mole}_{\text{acid}} = 0.027 \cdot \text{mole}$$

$$\text{volume}_{\text{acid}} := 500 \cdot \text{mL}$$

$$\text{C}_{\text{acid}} := \frac{\text{mole}_{\text{acid}}}{\text{volume}_{\text{acid}}} \quad \text{C}_{\text{acid}} = 0.0549 \cdot \text{M}$$

The concentrations:

$$\text{C}_{\text{H3O}} := \text{C}_{\text{acid}} \quad \text{C}_{\text{H3O}} = 0.055 \cdot \text{M}$$

$$\text{pH} := -\log(\text{C}_{\text{acid}} \cdot \text{M}^{-1}) \quad \text{pH} = 1.261$$

$$\text{pOH} := 14 - \text{pH} \quad \text{pOH} = 12.739$$

c. 10.0 g of HCl is diluted to 500.0 mL with water

The concentration of HCl

$$\text{mass}_{\text{acid}} := 10.00 \cdot \text{gm}$$

$$\text{MW}_{\text{acid}} := (1.00794 + 35.4527) \cdot \text{gm} \cdot \text{mole}^{-1} \quad \text{MW}_{\text{acid}} = 36.461 \cdot \text{gm} \cdot \text{mole}^{-1}$$

$$\text{mole}_{\text{acid}} := \frac{\text{mass}_{\text{acid}}}{\text{MW}_{\text{acid}}} \quad \text{mole}_{\text{acid}} = 0.274 \cdot \text{mole}$$

$$\text{volume}_{\text{acid}} := 500 \cdot \text{mL}$$

$$\text{C}_{\text{acid}} := \frac{\text{mole}_{\text{acid}}}{\text{volume}_{\text{acid}}} \quad \text{C}_{\text{acid}} = 0.5485 \cdot \text{M}$$

The concentrations:

$$\text{C}_{\text{H3O}} := \text{C}_{\text{acid}} \quad \text{C}_{\text{H3O}} = 0.549 \cdot \text{M}$$

$$\text{pH} := -\log(\text{C}_{\text{acid}} \cdot \text{M}^{-1}) \quad \text{pH} = 0.261$$

$$\text{pOH} := 14 - \text{pH} \quad \text{pOH} = 13.739$$

d.5.00 grams of acetic acid is diluted to 250.0 mL with water

The K_a for acetic acid:

$$K_a := 1.8 \cdot 10^{-5} \cdot M$$

The concentration of acetic acid

$$\text{mass}_{\text{acid}} := 5.00 \cdot \text{gm}$$

$$\text{MW}_{\text{acid}} := ((2 \cdot 12.001) + (4 \cdot 1.0079) + (2 \cdot 15.999)) \cdot \text{gm} \cdot \text{mole}^{-1}$$

$$\text{mole}_{\text{acid}} := \frac{\text{mass}_{\text{acid}}}{\text{MW}_{\text{acid}}} \quad \text{mole}_{\text{acid}} = 0.083 \cdot \text{mole}$$

$$\text{volume}_{\text{acid}} := 250 \cdot \text{mL}$$

$$C_{\text{acid}} := \frac{\text{mole}_{\text{acid}}}{\text{volume}_{\text{acid}}} \quad C_{\text{acid}} = 0.333 \cdot M$$

The equilibrium solution for	HA	+	H ₂ O	\leftrightarrow	H ₃ O ⁺	+	A ⁻
Initial Concentraion	C_{acid}						
Equilibrium Concentration	$C_{\text{acid}} - X$				X		X

Equilibrium expression:

$$K_a = \frac{X^2}{C_{\text{acid}} - X}$$

Assuming X is smaller than [acid], this reduces to:

$$K_a = \frac{X^2}{C_{\text{acid}}}$$

Solving for X:

$$X := \sqrt{K_a \cdot C_{\text{acid}}}$$

$$X = 2.4488 \cdot 10^{-3} \cdot M$$

Equilibrium Concentrations:

$$C_{\text{HA}} := C_{\text{acid}} - X \qquad C_{\text{HA}} = 0.331 \cdot \text{M}$$

$$C_{\text{H3O}} := X \qquad C_{\text{H3O}} = 0.002 \cdot \text{M}$$

$$C_{\text{A}} := X \qquad C_{\text{A}} = 0.002 \cdot \text{M}$$

$$\text{pH} := -\log(C_{\text{H3O}} \cdot \text{M}^{-1}) \qquad \text{pH} = 2.611$$

$$\text{pOH} := 14 - \text{pH} \qquad \text{pOH} = 11.389$$

Solving for X without assumptions:

$$K_a = \frac{X^2}{C_{\text{acid}} - X}$$

$$X := \left[\begin{array}{l} \frac{-1}{2} \cdot K_a + \frac{1}{2} \cdot \sqrt{K_a^2 + 4 \cdot K_a \cdot C_{\text{acid}}} \\ \frac{-1}{2} \cdot K_a - \frac{1}{2} \cdot \sqrt{K_a^2 + 4 \cdot K_a \cdot C_{\text{acid}}} \end{array} \right]$$

$$X = \left(\begin{array}{l} 2.4399 \cdot 10^{-3} \\ -2.4579 \cdot 10^{-3} \end{array} \right) \cdot \text{M}$$

Equilibrium Concentrations (Calculated for both roots, select the reasonable answer [top or bottom in ()]):

$$C_{\text{HA}} := C_{\text{acid}} - X \qquad C_{\text{HA}} = \left(\begin{array}{l} 0.331 \\ 0.336 \end{array} \right) \cdot \text{M}$$

$$C_{\text{H3O}} := X \qquad C_{\text{H3O}} = \left(\begin{array}{l} 0.002 \\ -0.002 \end{array} \right) \cdot \text{M}$$

$$C_{\text{A}} := X \qquad C_{\text{A}} = \left(\begin{array}{l} 0.002 \\ -0.002 \end{array} \right) \cdot \text{M}$$

$$i := 0, 1..1$$

$$\text{pH}_i := -\log(C_{\text{H3O}}_i \cdot \text{M}^{-1}) \qquad \text{pH} = \left(\begin{array}{l} 2.613 \\ 2.609 - 1.364i \end{array} \right)$$

$$\text{pOH} := 14 - \text{pH} \qquad \text{pOH} = \left(\begin{array}{l} 11.387 \\ 11.391 + 1.364i \end{array} \right)$$

e. 5.00 grams of sodium hydroxide is diluted to 500.0 mL with water

The concentration sodium hydroxide is:

$$\text{mass}_{\text{base}} := 5.00 \cdot \text{gm}$$

$$\text{MW}_{\text{base}} := (22.990 + 15.999 + 1.0079) \cdot \text{gm} \cdot \text{mole}^{-1}$$

$$\text{mole}_{\text{base}} := \frac{\text{mass}_{\text{base}}}{\text{MW}_{\text{base}}} \quad \text{mole}_{\text{base}} = 0.125 \cdot \text{mole}$$

$$\text{volume}_{\text{base}} := 500 \cdot \text{mL}$$

$$C_{\text{base}} := \frac{\text{mole}_{\text{base}}}{\text{volume}_{\text{base}}} \quad C_{\text{base}} = 0.2500 \cdot \text{M}$$

The concentrations (assumes K_w is not significant):

$$C_{\text{OH}} := C_{\text{base}} \quad C_{\text{OH}} = 0.25 \cdot \text{M}$$

$$\text{pOH} := -\log(C_{\text{base}} \cdot \text{M}^{-1}) \quad \text{pOH} = 0.602$$

$$\text{pH} := 14 - \text{pOH} \quad \text{pH} = 13.398$$

f. 5.00 grams of ammonia is diluted to 500.0 mL with water

The K_b for ammonia

$$K_b := 1.8 \cdot 10^{-5} \cdot \text{M}$$

The concentration of ammonia

$$\text{mass}_{\text{base}} := 5.00 \cdot \text{gm}$$

$$\text{MW}_{\text{base}} := (14.00674 + 3 \cdot 1.0079) \cdot \text{gm} \cdot \text{mole}^{-1}$$

$$\text{mole}_{\text{base}} := \frac{\text{mass}_{\text{base}}}{\text{MW}_{\text{base}}} \quad \text{mole}_{\text{base}} = 0.294 \cdot \text{mole}$$

$$\text{volume}_{\text{base}} := 500 \cdot \text{mL}$$

$$C_{\text{base}} := \frac{\text{mole}_{\text{base}}}{\text{volume}_{\text{base}}} \quad C_{\text{base}} = 0.587 \cdot \text{M}$$

The equilibrium solution for	$B + H_2O \rightleftharpoons HB^{1+} + OH^{1-}$
Initial Concentration	C_{base}
Equilibrium Concentration	$C_{\text{base}} - X \qquad X \qquad X$

Equilibrium expression:

$$K_b = \frac{X^2}{C_{\text{base}} - X}$$

Assuming X is smaller than [base], this reduces to:

$$K_b = \frac{X^2}{C_{\text{base}}}$$

Solving for X:

$$X := \sqrt{K_b \cdot C_{\text{base}}}$$

$$X = 3.251 \cdot 10^{-3} \cdot M$$

Equilibrium Concentrations:

$$C_B := C_{\text{base}} - X \qquad C_B = 0.584 \cdot M$$

$$C_{HB} := X \qquad C_{HB} = 0.003 \cdot M$$

$$C_{OH} := X \qquad C_{OH} = 0.003 \cdot M$$

$$pOH := -\log(C_{OH} \cdot M^{-1}) \qquad pOH = 2.488$$

$$pH := 14 - pOH \qquad pH = 11.512$$

Solving for X without assumptions:

$$K_b = \frac{X^2}{C_{\text{base}} - X}$$

$$X := \left[\begin{array}{l} \frac{-1}{2} \cdot K_b + \frac{1}{2} \cdot \sqrt{K_b^2 + 4 \cdot K_b \cdot C_{\text{base}}} \\ \frac{-1}{2} \cdot K_b - \frac{1}{2} \cdot \sqrt{K_b^2 + 4 \cdot K_b \cdot C_{\text{base}}} \end{array} \right]$$

$$X = \left(\begin{array}{l} 3.2421 \cdot 10^{-3} \\ -3.2601 \cdot 10^{-3} \end{array} \right) \cdot M$$

Equilibrium Concentrations (Calculated for both roots, select the reasonable answer [top or bottom in ()]):

$$C_B := C_{\text{base}} - X$$

$$C_B = \begin{pmatrix} 0.584 \\ 0.59 \end{pmatrix} \cdot M$$

$$C_{\text{HB}} := X$$

$$C_{\text{HB}} = \begin{pmatrix} 0.003 \\ -0.003 \end{pmatrix} \cdot M$$

$$C_{\text{OH}} := X$$

$$C_{\text{OH}} = \begin{pmatrix} 0.003 \\ -0.003 \end{pmatrix} \cdot M$$

$$i := 0, 1 \dots 1$$

$$pOH_i := -\log(C_{\text{OH}_i} \cdot M^{-1})$$

$$pOH = \begin{pmatrix} 2.489 \\ 2.487 - 1.364i \end{pmatrix}$$

$$pH := 14 - pOH$$

$$pH = \begin{pmatrix} 11.511 \\ 11.513 + 1.364i \end{pmatrix}$$

g. 5.00 grams of sodium chloride is diluted to 500.0 mL with water

Since sodium is the conjugate acid of a strong base (NaOH), and chloride is the conjugate base of a strong acid (HCl). NaCl will dissociate completely in water and will not effect the pH.

$$pH = 7$$

$$pOH = 7$$

h. 5.00 grams of potassium acetate is diluted to 500.0 mL with water

This salt contains acetate ions, the conjugate base for acetic acid. The equilibrium constant for acetic acid is:

$$K_a := 1.8 \cdot 10^{-5} \cdot M$$

$$K_b := \frac{K_w}{K_a} \quad K_b = 5.556 \cdot 10^{-10} \cdot M$$

The concentration of the potassium acetate:

$$\text{mass}_{\text{salt}} := 5 \cdot \text{gm}$$

$$\text{MW}_{\text{salt}} := (((39.0983) + (2 \cdot 12.001) + (3 \cdot 1.0079)) + (2 \cdot 15.999)) \cdot \text{gm} \cdot \text{mole}^{-1}$$

$$\text{mole}_{\text{salt}} := \frac{\text{mass}_{\text{salt}}}{\text{MW}_{\text{salt}}} \quad \text{mole}_{\text{salt}} = 0.051 \cdot \text{mole}$$

$$\text{volume}_{\text{salt}} := 500 \cdot \text{mL}$$

$$C_{\text{salt}} := \frac{\text{mole}_{\text{salt}}}{\text{volume}_{\text{salt}}} \quad C_{\text{salt}} = 0.102 \cdot M$$

The equilibrium solution for	A ⁻ + H ₂ O	<->	OH ⁻ + HA
Initial Concentraion	C _{salt}		
Equilibrium Concentration	C _{salt} - X		X

Equilibrium expression:

$$K_b = \frac{X^2}{C_{\text{salt}} - X}$$

Assuming X is smaller than [acid], this reduces to:

$$K_b = \frac{X^2}{C_{\text{salt}}}$$

Solving for X:

$$X := \sqrt{K_b \cdot C_{\text{salt}}}$$

$$X = 7.5246 \cdot 10^{-6} \cdot M$$

Equilibrium Concentrations:

$$C_{\text{HA}} := X \qquad C_{\text{HA}} = 7.525 \cdot 10^{-6} \cdot \text{M}$$

$$C_{\text{OH}} := X \qquad C_{\text{OH}} = 7.525 \cdot 10^{-6} \cdot \text{M}$$

$$C_{\text{A}} := C_{\text{salt}} - X \qquad C_{\text{A}} = 0.102 \cdot \text{M}$$

$$\text{pOH} := -\log(C_{\text{OH}} \cdot \text{M}^{-1}) \qquad \text{pOH} = 5.124$$

$$\text{pH} := 14 - \text{pOH} \qquad \text{pH} = 8.876$$

Solving for X without assumptions:

$$K_{\text{b}} = \frac{X^2}{C_{\text{salt}} - X}$$

$$X := \left[\begin{array}{l} \frac{-1}{2} \cdot K_{\text{b}} + \frac{1}{2} \cdot \sqrt{K_{\text{b}}^2 + 4 \cdot K_{\text{b}} \cdot C_{\text{salt}}} \\ \frac{-1}{2} \cdot K_{\text{b}} - \frac{1}{2} \cdot \sqrt{K_{\text{b}}^2 + 4 \cdot K_{\text{b}} \cdot C_{\text{salt}}} \end{array} \right]$$

$$X = \left(\begin{array}{l} 7.5243 \cdot 10^{-6} \\ -7.5248 \cdot 10^{-6} \end{array} \right) \cdot \text{M}$$

Equilibrium Concentrations (Calculated for both roots, select the reasonable answer [top or bottom in ()]):

$$C_{\text{HA}} := X \qquad C_{\text{HA}} = \left(\begin{array}{l} 7.524 \cdot 10^{-6} \\ -7.525 \cdot 10^{-6} \end{array} \right) \cdot \text{M}$$

$$C_{\text{OH}} := X \qquad C_{\text{OH}} = \left(\begin{array}{l} 7.524 \cdot 10^{-6} \\ -7.525 \cdot 10^{-6} \end{array} \right) \cdot \text{M}$$

$$C_{\text{A}} := C_{\text{salt}} - X \qquad C_{\text{A}} = \left(\begin{array}{l} 0.102 \\ 0.102 \end{array} \right) \cdot \text{M}$$

$$\text{pOH}_i := -\log(C_{\text{OH}_i} \cdot \text{M}^{-1}) \qquad \text{pOH} = \left(\begin{array}{l} 5.124 \\ 5.124 - 1.364i \end{array} \right)$$

$$\text{pH} := 14 - \text{pOH} \qquad \text{pH} = \left(\begin{array}{l} 8.876 \\ 8.876 + 1.364i \end{array} \right)$$

i.5.00 grams of sulfuric acid is diluted to 500 mL with water

Sulfuric acid is a diprotic acid. K_1 is very large (since sulfuric acid is a strong acid). Since K_1 is much larger than K_2 , we will ignore the contribution of K_2 to the reaction and simply treat this as a monoprotic strong acid.

The concentration of sulfuric acid is:

$$\text{mass}_{\text{acid}} := 5.00 \cdot \text{gm}$$

$$\text{MW}_{\text{acid}} := (2 \cdot 1.0079 + 32.066 + 4 \cdot 15.9994) \cdot \text{gm} \cdot \text{mole}^{-1}$$

$$\text{mole}_{\text{acid}} := \frac{\text{mass}_{\text{acid}}}{\text{MW}_{\text{acid}}}$$

$$\text{volume}_{\text{acid}} := 500 \cdot \text{mL}$$

$$C_{\text{acid}} := \frac{\text{mole}_{\text{acid}}}{\text{volume}_{\text{acid}}}$$

$$C_{\text{acid}} = 0.1020 \cdot \text{M}$$

The concentrations:

$$C_{\text{H}_3\text{O}^+} := C_{\text{acid}}$$

$$C_{\text{H}_3\text{O}^+} = 0.102 \cdot \text{M}$$

$$\text{pH} := -\log(C_{\text{acid}} \cdot \text{M}^{-1})$$

$$\text{pH} = 0.992$$

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

$$\text{pOH} = 13.008$$

j.5.00 grams of sodium hydrogen sulfate is diluted to 500.0 mL with water

This is a weak acid problem. Sodium hydrogen sulfate is a salt. When it dissolves in water it will dissociate into sodium ions (conjugate acid of a strong base, NaOH, so it will have no effect on the pH) and hydrogen sulfate.

Hydrogen sulfate is the conjugate base of a strong acid (sulfuric acid), so it will not act as a base. However, it is also a weak base. This is the equilibrium that we must pay attention to in this problem.

Given a weak acid where:

$$K_a := 1.2 \cdot 10^{-2} \cdot M$$

The concentration of hydrogen sulfide (the acid) is :

$$\text{mass}_{\text{acid}} := 5 \cdot \text{gm}$$

$$\text{MW}_{\text{acid}} := ((22.9897768) + (1.0079) + (32.066) + (4 \cdot 15.9994)) \cdot \text{gm} \cdot \text{mole}^{-1}$$

$$\text{mole}_{\text{acid}} := \frac{\text{mass}_{\text{acid}}}{\text{MW}_{\text{acid}}}$$

$$\text{volume}_{\text{acid}} := 500 \cdot \text{mL}$$

$$C_{\text{acid}} := \frac{\text{mole}_{\text{acid}}}{\text{volume}_{\text{acid}}} \quad C_{\text{acid}} = 0.083 \cdot M$$

The equilibrium solution for $\text{HA} + \text{H}_2\text{O} \leftrightarrow \text{H}_3\text{O}^+ + \text{A}^-$

Initial Concentration C_{acid}

Equilibrium Concentration $C_{\text{acid}} - X$ X X

Equilibrium expression:

$$K_a = \frac{X^2}{C_{\text{acid}} - X}$$

Assuming X is smaller than [acid], this reduces to:

$$K_a = \frac{X^2}{C_{\text{acid}}}$$

Solving for X:

$$X := \sqrt{K_a \cdot C_{\text{acid}}} \quad X = 3.1615 \cdot 10^{-2} \cdot M$$

Equilibrium Concentrations:

$$C_{\text{HA}} := C_{\text{acid}} - X \quad C_{\text{HA}} = 0.052 \cdot M$$

$$C_{\text{H}_3\text{O}^+} := X \quad C_{\text{H}_3\text{O}^+} = 0.032 \cdot M$$

$$C_{\text{A}^-} := X \quad C_{\text{A}^-} = 0.032 \cdot M$$

$$\text{pH} := -\log(C_{\text{H}_3\text{O}^+} \cdot M^{-1}) \quad \text{pH} = 1.5$$

$$\text{pOH} := 14 - \text{pH} \quad \text{pOH} = 12.5$$

Solving for X without assumptions:

$$K_a = \frac{X^2}{C_{\text{acid}} - X}$$

$$X := \left[\begin{array}{l} \frac{-1}{2} \cdot K_a + \frac{1}{2} \cdot \sqrt{K_a^2 + 4 \cdot K_a \cdot C_{\text{acid}}} \\ \frac{-1}{2} \cdot K_a - \frac{1}{2} \cdot \sqrt{K_a^2 + 4 \cdot K_a \cdot C_{\text{acid}}} \end{array} \right]$$

$$X = \left(\begin{array}{l} 2.6179 \cdot 10^{-2} \\ -3.8179 \cdot 10^{-2} \end{array} \right) \cdot \text{M}$$

Equilibrium Concentrations (Calculated for both roots, select the reasonable answer [top or bottom in ()]):

$$C_{\text{HA}} := C_{\text{acid}} - X \qquad C_{\text{HA}} = \left(\begin{array}{l} 0.057 \\ 0.121 \end{array} \right) \cdot \text{M}$$

$$C_{\text{H3O}} := X \qquad C_{\text{H3O}} = \left(\begin{array}{l} 0.026 \\ -0.038 \end{array} \right) \cdot \text{M}$$

$$C_{\text{A}} := X \qquad C_{\text{A}} = \left(\begin{array}{l} 0.026 \\ -0.038 \end{array} \right) \cdot \text{M}$$

$$i := 0, 1..1$$

$$\text{pH}_i := -\log(C_{\text{H3O}}_i \cdot \text{M}^{-1}) \qquad \text{pH} = \left(\begin{array}{l} 1.582 \\ 1.418 - 1.364i \end{array} \right)$$

$$\text{pOH} := 14 - \text{pH} \qquad \text{pOH} = \left(\begin{array}{l} 12.418 \\ 12.582 + 1.364i \end{array} \right)$$

k.5.00 grams of sodium sulfate is diluted to 500.0 mL with water

Sodium sulfate is a salt. When it dissolves in water it will produce sodium ions and sulfate ions.

Sodium ions are the conjugate acid of a strong base (NaOH) so they will have no effect on the pH.

Sulfate ions are the conjugate base of a weak acid (hydrogen sulfate). So it will behave as a weak base. Hydrogen sulfate in turn is the conjugate base of a strong acid (sulfuric acid) so it will have no additional effect on the pH.

So we will treat this problem as the conjugate base of a weak acid.

The equilibrium constant for the weak acid (Input appropriate value here):

$$K_a := 1.2 \cdot 10^{-2} \cdot M$$

$$K_b := \frac{K_w}{K_a}$$

$$K_b = 8.333 \cdot 10^{-13} \cdot M$$

The concentration of the sodium sulfate is

$$\text{mass}_{\text{salt}} := 5 \cdot \text{gm}$$

$$\text{MW}_{\text{salt}} := ((2 \cdot 22.990) + (32.066)) + (4 \cdot 15.999) \cdot \text{gm} \cdot \text{mole}^{-1}$$

$$\text{mole}_{\text{salt}} := \frac{\text{mass}_{\text{salt}}}{\text{MW}_{\text{salt}}}$$

$$\text{volume}_{\text{salt}} := 500 \cdot \text{mL}$$

$$C_{\text{salt}} := \frac{\text{mole}_{\text{salt}}}{\text{volume}_{\text{salt}}}$$

$$C_{\text{salt}} = 0.07 \cdot M$$

The equilibrium solution for	$A^- + H_2O \rightleftharpoons OH^- + HA$
Initial Concentration	C_{salt}
Equilibrium Concentration	$C_{\text{salt}} - X$ X X

Equilibrium expression:

$$K_b = \frac{X^2}{C_{\text{salt}} - X}$$

Assuming X is smaller than [acid], this reduces to:

$$K_b = \frac{X^2}{C_{\text{salt}}}$$

Solving for X:

$$X := \sqrt{K_b \cdot C_{\text{salt}}}$$

$$X = 2.4221 \cdot 10^{-7} \cdot M$$

Equilibrium Concentrations:

$$C_{\text{HA}} := X \qquad C_{\text{HA}} = 2.422 \cdot 10^{-7} \cdot M$$

$$C_{\text{OH}} := X \qquad C_{\text{OH}} = 2.422 \cdot 10^{-7} \cdot M$$

$$C_{\text{A}} := C_{\text{salt}} - X \qquad C_{\text{A}} = 0.07 \cdot M$$

$$\text{pOH} := -\log(C_{\text{OH}} \cdot M^{-1}) \qquad \text{pOH} = 6.616$$

$$\text{pH} := 14 - \text{pOH} \qquad \text{pH} = 7.384$$

Solving for X without assumptions:

$$K_b = \frac{X^2}{C_{\text{salt}} - X}$$

$$X := \left[\begin{array}{l} \frac{-1}{2} \cdot K_b + \frac{1}{2} \cdot \sqrt{K_b^2 + 4 \cdot K_b \cdot C_{\text{salt}}} \\ \frac{-1}{2} \cdot K_b - \frac{1}{2} \cdot \sqrt{K_b^2 + 4 \cdot K_b \cdot C_{\text{salt}}} \end{array} \right]$$

$$X = \left(\begin{array}{l} 2.4221 \cdot 10^{-7} \\ -2.4222 \cdot 10^{-7} \end{array} \right) \cdot \text{M}$$

Equilibrium Concentrations (Calculated for both roots, select the reasonable answer [top or bottom in ()]):

$$C_{\text{HA}} := X \qquad C_{\text{HA}} = \left(\begin{array}{l} 2.422 \cdot 10^{-7} \\ -2.422 \cdot 10^{-7} \end{array} \right) \cdot \text{M}$$

$$C_{\text{OH}} := X \qquad C_{\text{OH}} = \left(\begin{array}{l} 2.422 \cdot 10^{-7} \\ -2.422 \cdot 10^{-7} \end{array} \right) \cdot \text{M}$$

$$C_{\text{A}} := C_{\text{salt}} - X \qquad C_{\text{A}} = \left(\begin{array}{l} 0.07 \\ 0.07 \end{array} \right) \cdot \text{M}$$

$$\text{pOH}_i := -\log(C_{\text{OH}_i} \cdot \text{M}^{-1}) \qquad \text{pOH} = \left(\begin{array}{l} 6.616 \\ 6.616 - 1.364i \end{array} \right)$$

$$\text{pH} := 14 - \text{pOH} \qquad \text{pH} = \left(\begin{array}{l} 7.384 \\ 7.384 + 1.364i \end{array} \right)$$