More Acid/Base

This worksheet should help you identify how we can determine the pH of salt solutions in the laboratory. It is intended for you to work through it in order. *(Don't skip ahead.)*

Two salt solutions are made:

A: 4.68 g of NaBrO is added to 300.0 mL of pure H_2O
B: 2.94 g of NaClO is added to 300.0 mL of pure H_2O

What are the molarities of the two solutions?

$$4.68\text{ g NaBrO} \times \frac{1\text{ mole NaBrO}}{118.8\text{ g NaBrO}} = \frac{0.03936\text{ mole}}{0.300\text{ L}} = 0.131\text{ M NaBrO}$$

$$2.94\text{ g NaClO} \times \frac{1\text{ mole NaClO}}{74.44\text{ g NaClO}} = \frac{0.3949\text{ mole}}{0.300\text{ L}} = 0.132\text{ M NaClO}$$

Will the solutions be acidic or basic?

Identify each ion in the two salts.

$NaBrO \rightarrow Na^+ \quad BrO^-$

$NaClO \rightarrow Na^+ \quad ClO^-$

Write out the chemical equation of each ion in water.

$$Na^+ + H_2O \rightleftharpoons Na^+ + H_2O$$

$$BrO^- + H_2O \rightleftharpoons HBrO + OH^-$$

$$ClO^- + H_2O \rightleftharpoons HClO + OH^-$$

Based on these chemical equations, will the solutions be acidic or basic?

Since both BrO^- and ClO^- are conjugate bases, they will pull H^+ from water generating weak acids. The byproduct will be OH^-, thus both solutions would be ~~acidic~~. basic
(Na+ does not react w/ water in either case, no effect on pH)

Based on your decision of acidic or basic, now compare the two solutions. Hypothesize which is stronger? Draw molecular structures to support your statements.

$H-Br-O$ ↑ less EN ↑ weaker acid

∴ BrO^- wants to become $HBrO$

$H-Cl-O$ ↑ more EN ↑ stronger acid

∴ ClO^- is less likely to become $HClO$

Since HBro is weaker than HClO the HBro is more favored. More BrO^- will go to HBro than, ClO^- to HClO. So more OH^- in BrO^- case.

Consider that a K_b of 5.0×10^{-6} is associated with salt A, while a K_b of 3.4×10^{-7} is associated with salt B.

What is the pH of solution A?

$$k_b = \frac{[HBrO][OH^-]}{[BrO^-]}$$

	BrO^-	OH^-	$HBrO$
I	0.131	0	0
C	$-x$	$+x$	$+x$
E	$0.131-x$	x	x

$$5.0\times10^{-6} = \frac{(x)(x)}{0.131-x}$$ assume small

$x = 8.09\times10^{-14} = [OH^-]$

$pOH = -\log(8.09\times10^{-14})$

$pOH = 3.1$

$pH = 10.9$

What is the pH of solution B?

$$K_b = \frac{[HClO][OH^-]}{[ClO^-]}$$

	ClO^-	OH^-	$HClO$
I	0.132	0	0
C	$-x$	$+x$	$+x$
E	$0.132-x$	x	x

$$3.4\times10^{-7} = \frac{(x)(x)}{0.132-x}$$ assume small

$x = 2.12\times10^{-4} = [OH^-]$

$pOH = 3.67$

$pH = 10.3$

Do the two calculated pH values match your prediction of acidic or basic?

Yes! Both salts are basic $pH > 7$

Do the two calculated pH values match your prediction of which salt was stronger?

Yes! The pH of the NaBrO solution is higher than the NaClO solution.

Let's try a few more example! Using the problem-solving method from above determine the pH of the three solutions below…you will need to look up K_a/K_b information.

X. 2.43 g of NH_4Cl in 300.0 mL of pure water.
Y. 1.54 g of KCl in 300.0 mL of pure water.
Z. 4.01 g of NH_4HCO_2 in 300.0 mL of pure water.

SALT X

$$2.43\text{ g } NH_4Cl \left| \frac{1\text{ mole } NH_4Cl}{53.491\text{ g } NH_4Cl} \right. = \frac{0.0454\text{ moles } NH_4Cl}{0.300\text{ L}} = 0.151\text{ M}$$

$NH_4Cl \rightarrow NH_4^+ \; Cl^-$

$NH_4^+{}_{(aq)} + H_2O_{(l)} \rightleftharpoons NH_{3(aq)} + H_3O^+{}_{(aq)}$ [Affects pH]

$Cl^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons Cl^-{}_{(aq)} + H_2O_{(l)}$ [Does not affect pH]

$$K_a = \frac{[NH_3][H_3O^+]}{[NH_4^+]}$$

	NH_4^+	NH_3	H_3O^+
I	0.151	0	0
C	$-x$	x	x
E	$0.151-x$	x	x

Look up NH_3 $K_b \rightarrow 1.8\times10^{-5}$

$1.0\times10^{-14} = K_a(1.8\times10^{-5})$

$K_a = 5.56\times10^{-10}$

$$5.56\times10^{-10} = \frac{x^2}{0.151-x}$$ ignore x, $K_a < 10^{-5}$

$8.396\times10^{-11} = x^2$

$9.16\times10^{-6} = x = [H_3O^+]$

$pH = -\log(9.16\times10^{-6})$
$= 5.04$

SALT Y

$$1.54\text{ g KCl} \left| \frac{1\text{ mole KCl}}{74.55\text{ g KCl}} \right. = \frac{0.0206\text{ moles KCl}}{0.3\text{ L}} = 0.0687\text{ M KCl}$$

$KCl \rightarrow K^+ \; Cl^-$

$K^+{}_{(aq)} + H_2O_{(l)} \rightleftharpoons K^+ + H_2O_{(l)}$

$Cl^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons Cl^-{}_{(aq)} + H_2O_{(l)}$ [Neither affect pH]

$pH = 7$

SALT Z

$$4.01\text{g } NH_4HCO_2 \left| \frac{1 \text{ mole } NH_4HCO_2}{63.0559 \text{ g } NH_4HCO_2} \right. = \frac{0.0636 \text{ mole } NH_4HCO_2}{0.300 \text{ L}}$$

$$= 0.212 \text{ M } NH_4HCO_2$$

$NH_4HCO_2 \rightarrow NH_4^+ \quad HCO_2^-$

$NH_4^+{}_{(aq)} + H_2O_{(l)} \rightleftharpoons NH_3{}_{(aq)} + H_3O^+{}_{(aq)}$ [Affects pH]

$HCO_2^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons H_2CO_2{}_{(aq)} + OH^-{}_{(aq)}$ [Affects pH]

$K_a \; NH_4^+ \quad 5.56 \times 10^{-10}$

$K_b \; HCO_2^- \quad K_b = \frac{K_w}{K_a} \quad K_b = \frac{1.0 \times 10^{-14}}{2.1 \times 10^{-4}} = 4.76 \times 10^{-11}$

formic acid

$K_a \; NH_4^+ > K_b \; HCO_2^- \quad \therefore$ solution $pH < 7$

(For this class a salt that acts as an acid and a base, you only need to be able to state pH generally, not exactly)