ACIDS & BASES

ACID-BASE NEUTRALIZATION & SALTS

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DR. MIOY T. HUYNH | 2020

What happens when we mix an acid and a base?

So far, we have only considered the aqueous equilibria of acids and bases separately:

$$HA\ (aq) \rightleftharpoons H^+\ (aq) + A^-\ (aq) \qquad BOH\ (aq) \rightleftharpoons B^+\ (aq) + OH^-\ (aq)$$

But we may also consider the chemical reaction that occurs when we *mix* acids and bases together:

$$HA\ (aq) + BOH\ (aq) \rightleftharpoons HOH\ (l) + (B^+)(A^-)\ (aq)$$

–or–

$$HA\ (aq) + BOH\ (aq) \rightleftharpoons H_2O\ (l) + BA\ (aq)$$

acid **base** **water** **salt**

Neutralization: The reaction between an acid and a base to form water and a salt.

The water formed is neutral (pH = 7).

That salt formed may be acidic (pH <7), basic (pH >7), or neutral (pH = 7) depending on how it reacts with water.

Determining the acidity/basicity of salts

We've discussed that there are strong acids and weak acids and strong bases and weak bases. Depending on the strengths of the acid and base mixed, we can form salts of varying acidity/basicity.

Let's take the example of a strong acid (HCl) and a strong base (NaOH):

$$HCl\ (aq) + NaOH\ (aq) \rightarrow H_2O\ (l) + NaCl\ (aq)$$

Note this is not an equilibrium because we have strong acids and strong bases, which dissociate completely.

To determine the acidity/basicity of the salt:

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To determine the acidity/basicity of the salt:

1. We need to consider the reaction of the aqueous salt with water. $NaCl\ (aq) + H_2O\ (l) \rightarrow ???$
2. Write the reaction of the cation/anion of the salt with water.

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To determine the acidity/basicity of the salt:

1. We need to consider the reaction of the aqueous salt with water. $NaCl\ (aq) + H_2O\ (l) \rightarrow ???$
2. Write the reaction of the cation/anion of the salt with water.
    a. The conjugate-acid (Na^+) of a strong base (NaOH) is extremely weak, so Na^+ won't react with H_2O. $Na^+\ (aq) + H_2O\ (l) \rightarrow$ *no reaction*

In other words, NaOH will not form because NaOH is a strong base and will dissociate completely.

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1. We need to consider the reaction of the aqueous salt with water. $NaCl\ (aq) + H_2O\ (l) \rightarrow ???$
2. Write the reaction of the cation/anion of the salt with water.
    a. The conjugate-acid (Na^+) of a strong base (NaOH) is extremely weak, so Na^+ won't react with H_2O. $Na^+\ (aq) + H_2O\ (l) \rightarrow$ *no reaction*
    b. The conjugate-base (Cl^-) of a strong acid (HCl) is extremely weak, so Cl^- won't react with H_2O. $Cl^-\ (aq) + H_2O\ (l) \rightarrow$ *no reaction*

In other words, NaOH will not form because NaOH is a strong base and will dissociate completely.

In other words, HCl will not form because HCl is a strong acid and will dissociate completely.

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$$HCl\ (aq) + NaOH\ (aq) \rightarrow H_2O\ (l) + NaCl\ (aq)$$

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To determine the acidity/basicity of the salt:

1. We need to consider the reaction of the aqueous salt with water.
2. Write the reaction of the cation/anion of the salt with water.
   a. The conjugate-acid (Na^+) of a strong base (NaOH) is extremely weak, so Na^+ won't react with H_2O.
   b. The conjugate-base (Cl^-) of a strong acid (HCl) is extremely weak, so Cl^- won't react with H_2O.
3. Determine acidity/basicity depending on whether the salt produces H^+ (acidic), OH^- (basic), or neither (neutral) in water.

$NaCl\ (aq) + H_2O\ (l) \rightarrow ???$

$Na^+\ (aq) + H_2O\ (l) \rightarrow$ *no reaction*

In other words, NaOH will not form because NaOH is a strong base and will dissociate completely.

$Cl^-\ (aq) + H_2O\ (l) \rightarrow$ *no reaction*

In other words, HCl will not form because HCl is a strong acid and will dissociate completely.

$Na^+\ (aq) + Cl^-\ (aq) + H_2O\ (l) \rightarrow$ *no reaction*

NaCl is a neutral salt.

Kinds of salts

We can generalize this analysis to other combinations of strong and weak acids and bases.

The chart below shows an example of this type of analysis on the four possible combinations.

	STRONG ACID *(e.g. HCl)*	WEAK ACID *(e.g. HClO)*
STRONG BASE *(e.g. NaOH)*	$NaOH + HCl \rightarrow NaCl + H_2O$ • $Na^+ + H_2O \rightarrow$ *no reaction* • $Cl^- + H_2O \rightarrow$ *no reaction* SALT IS NEUTRAL (pH =7)	
WEAK BASE *(e.g. NH_3)*		

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WEAK BASE *(e.g. NH_3)*		

The salt will only be acidic or basic if a weak acid or weak base can be formed. Note that for weak acids and bases, the equilibrium lies toward the side of of the un-dissociated acid or base.

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WEAK BASE *(e.g. NH_3)*	$NH_3 + HCl \rightleftharpoons NH_4Cl$ • $NH_4^+ + H_2O \rightleftharpoons NH_3 + H^+$ • $Cl^- + H_2O \rightarrow$ *no reaction* SALT IS ACIDIC (pH < 7)	

The salt will only be acidic or basic if a weak acid or weak base can be formed. Note that for weak acids and bases, the equilibrium lies toward the side of of the un-dissociated acid or base.

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What about the weak acid and weak base salt?

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In these cases, we need to compare the K_a of the acid (NH_4^+) and the K_b of the base (ClO^-).

$K_a > K_b \rightarrow$ acidic salt
$K_a = K_b \rightarrow$ neutral salt
$K_a < K_b \rightarrow$ basic salt

PRACTICE PROBLEM

Determine whether aqueous solutions of the following salts are acidic, basic, or neutral.

— answer —

	Salt
A.	KBr
B.	$NaHCO_3$
C.	Na_2HPO_4
D.	NH_4F
E.	$CaCl_2$

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For each salt, we can write out the reaction of the salt (its ions) with water to determine if it is acidic, basic, or neutral.

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C.	Na_2HPO_4	$Na^+ + H_2O \rightarrow$ no reaction $HPO_4^{2-} + H_2O \rightleftharpoons H_2PO_4^- + OH^-$	Basic
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D.	NH_4F	$NH_4^+ + H_2O \rightleftharpoons NH_3 + H^+$ $F^- + H_2O \rightleftharpoons HF + OH^-$ $K_a\,(NH_4^+) > K_b\,(F^-)$	Acidic
E.	$CaCl_2$		

$K_a\,(NH_4^+) = 5.68 \times 10^{-10}$
$K_b\,(F^-) = 1.47 \times 10^{-11}$

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E.	$CaCl_2$	$Ca^{2+} + H_2O \rightleftharpoons$ no reaction $Cl^- + H_2O \rightleftharpoons$ no reaction	Neutral

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