Chemistry CP
Chapter 15 Notes

Chapter 15, Section 1

Acids and Bases

ACIDS - Were first recognized for the sour taste they created

BASES – Were first recognized for the bitter taste they created and also for having a slippery feel

Svante Arrhenius- first person to describe the nature of acids and bases

Known as the **Arrhenius Model**.

Acid- produced hydrogen ions in aqueous solution

Example:

$HCl\ (aq) \rightarrow H^+ + Cl^-$

Base- produced hydroxide ions in aqueous solution

Example:

$NaOH\ (aq) \rightarrow Na^+ + OH^-$

Another Model of Acids and Bases was proposed by Johannes Bronsted and Thomas Lowry.

Known as the **Bronsted-Lowry Model**.

Acid- donates/gives up/loses a proton (H^+)

Base- accepts/takes/gains a proton (H^+)

In the Bronsted-Lowry model there are also substances called CONJUGATE ACIDS and CONJUGATE BASES.

Conjugate Acid- the substance (will be on the product side) that accepted the proton

Conjugate Base- the substance (will be on the product side) that is what remains of the original acid

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These acids, bases, conjugate acids and conjugate bases form pairs in an acid base reaction.

Example:

$HCl + H_2O \rightarrow H_3O^+ + Cl^-$

HCl and Cl^- are an acid/conjugate base pair, H_2O and H_3O^+ are a base/conjugate acid pair

The water acts as a Bronsted –Lowry base by accepting the proton from HCl

The conjugate acid formed when water accepts a proton is H_3O^+, which is known as the HYDRONIUM ion.

You should be able to identify these pairs according to the Bronsted-Lowry Model

Practice:

Which of the following represent conjugate acid /base pairs?

A. HF, F^-
B. NH_4^+, NH_3
C. HCl, H_2O

Answer- A and B are both conjugate acid/base pairs because they differ by a proton (H^+)

In A, HF is the acid and F^- is the conjugate base

In B, NH_3 is the base and NH_4^+ is the conjugate acid

You should also be able to write the conjugate acid or base for a given base or acid.

Practice:

Write the conjugate base for the following acids:

A. $HClO_4$ B. H_3PO_4 C. $CH_3NH_3^+$

Answers:

A. ClO_4^- B. $H_2PO_4^-$ C. CH_3NH_2

Remember when removing a hydrogen, you remove a positively charged particle from the molecule, this will either create a negative charge on a neutral compound, reduce the positive charge on a positively charged compound, or increase the negative charge on a negatively charged compound.

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Water as an acid and a base.

Some substances can behave as an acid or as a base.

These substances are known as AMPHOTERIC.

Amphoteric substances are those substances capable of behaving as an acid or a base (they can donate protons or accept them)

Water is the most common amphoteric substance.

Water can actually "react" with itself- this is called IONIZATION OF WATER.

$H_2O + H_2O \rightarrow H_3O^+ + OH^-$

In this special reaction one water molecule acts as an acid and gives up a proton, which is accepted by another water molecule that is acting as a base. This results in the formation of a hydronium ion and a hydroxide ion.

For simplicity, the hydronium ion is often written a just H^+

At 25°C the concentration of the hydronium ion and hydroxide ion is $1x10^{-7}$ M. (remember M = mols/liter)

They are equal in concentration because the ionization reaction produces a 1:1 ratio of hydronium to hydroxide ion.

Three types of Solutions:

In a NEUTRAL solution the concentration of hydronium ion equals the concentration of hydroxide ion.

This is written as: $[H^+] = [OH^-]$ or $[H_3O^+] = [OH^-]$

In an ACIDIC solution the concentration of hydronium ion is greater than the concentration of hydroxide ion.

This is written as: $[H^+] > [OH^-]$ or $[H_3O^+] >[OH^-]$

In a BASIC solution the concentration of hydronium ion is less than the concentration of hydroxide ion.

This is written as: $[H^+] < [OH^-]$ or $[H_3O^+] < [OH^-]$

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Ion Product

For all solutions at 25°C the concentration of hydronium ion multiplied by the concentration of the hydroxide ion will equal $1.0x10^{-14}$.

$[H^+]$ $[OH^-] = 1.0x10^{-14}$. Or $[H_3O^+]$ $[OH^-]= 1.0x10^{-14}$.

You should be able to calculate hydronium ion concentration if given hydroxide ion concentration or vice versa and also tell if the solution is acidic, basic or neutral base on the concentration information.

Practice:

Calculate the $[H^+]$ or $[OH^-]$ for each of the following solutions at 25°C and state if the solution is acidic, basic or neutral.

A. $1.0x10^{-5}$ M OH^-
B. 1. $0x10^{-7}$ M OH^-
C. 10.0 M H^+

A. $[H^+]$ $[OH^-] = 1.0x10^{-14}$, fill in known concentration- solve for unknown
$[H^+]$ $[1.0x10^{-5}] = 1.0x10^{-14}$
$[H^+] = 1.0x10^{-14} \div 1.0x10^{-5}$
$[H^+] = 1x10^{-9}$M

$1x10^{-9}$M $H^+ <$ $1.0x10^{-5}$ M OH^-
$[H^+] < [OH^-]$, so this is a basic solution

B. $[H^+] = 1x10^{-7}$
$[H^+] = [OH^-]$, so this is a neutral solution

C. $[OH^-] = 1x10^{-15}$
$[H^+] > [OH^-]$, so this is an acidic solution

These concepts set up the basis of the pH Scale

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The pH Scale

The pH Scale is a logarithmic scale (base 10).

The pH Scale is a convenient way to represent solution acidity by taking the very small hydronium ion concentrations and using the logarithm making them much larger numbers

$pH = -\log [H^+]$

There is also a pOH scale which represents the hydroxide ion concentration.

$pOH = -\log [OH^-]$

IMPORTANT: $pH + pOH = 14$

Practice:

Calculate the pH and pOH for each of the following solutions at 25°C.

A. 1.0×10^{-3} M OH^-
B. 1.0 M H^+

Answers:

A. $-\log [OH^-] = pOH$, $-\log 1 \times 10^{-3} = 3 = pOH$
   pOH + pH = 14, 14-pOH = pH, 14-3 = 11

   pOH = 3, pH = 11

B. $-\log [H^+] = pH$, $-\log 1 = 0 = pH$
   pOH + pH = 14, 14-pH = pOH, 14-0 = 14
   pOH = 14, pH = 0

You can also calculate $[H^+]$ and $[OH^-]$ from pH and pOH using the antilog function.
For most calculators this is a second function of the log key. It will look like 10^x. Check with Ms. Neiman to make sure you know how to do this on your calculator.

When calculating $[H^+]$ from pH you take 10 to the negative power of the pH value.

Practice:

Calculate the $[H^+]$ of the following solutions from the given pH values:

A. pH = 7.41
B. pH = 11.56

Answers:

A. $10^{-7.41} = 3.89 \times 10^{-8}$

B. $10^{-11.56} = 2.75 \times 10^{-12}$

The same is done to calculate $[OH^-]$ from pOH.

Practice:

A. pOH = 6.59
B. pOH= 12.80

Answer:

A. $10^{-6.59} = 2.57 \times 10^{-7}$
B. $10^{-12.80} = 1.58 \times 10^{-13}$

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Calculating the pH of a Strong Acid or Strong Base solution.

When strong acids or strong bases dissociate in water they dissociate completely.

This makes calculating the pH of these solutions fairly easy because the concentration of the acid or base, is the same as the concentration of the ions in solution.

Example:

A 1.0 M solution of HCl is really a solution with 1.0 M H^+ ions and 1.0 M Cl^- ions.

Because we are able to determine the amount of H^+ ion, we can calculate the pH.

$pH = -\log [H^+]$

$pH = -\log 1$

$pH = 0$

Remember for a strong base it will be the OH^- that will be used to calculate pOH and pH will have to be a secondary calculation.

Example:

A 1.0 M solution of NaOH is really a solution of 1.0 M Na^+ ions and 1.0 M OH^- ions.

$pOH = -\log [OH^-]$

$pOH = -\log 1$

$pOH = 0$

$pH + pOH = 14$

$pH = 14 - pOH$

$pH = 14 - 0$

$pH = 14$