Acid-Base Neutralization Reactions

C3WS3K By: Dr. Robert Belford

1. What are acids and bases?

We will cover two definitions, the Arrhenius and Bronstead definitions. First we need to look at the autoionization of water. When two water molecules bump into each other a proton can be transferred from one to the other forming hydronium and hydroxide ions.

$H_2O(l) + H_2O(l) \rightarrow H_3O^+(ag) + OH^-(ag)$

This is a very weak reaction and in neutral water (pH=7) the concentration of hydronium and hydroxide ions both equal10^{-7} moles/liter (one mole is $6.022x10^{23}$ molecules of water). That of the undissociated water is 55.56moles/liter. This means that about one molecule dissociates for every $5.5x10^8$ are dissociated.

Arrhenius Acid:

Increase hydronium concentration to that of neutral water (which also means the hydronium ion concentration is higher than the hydroxide)

ex: $HCl(ag) + H_2O(l) \rightarrow H_3O^+(ag) + Cl^-(ag)$

This is often written with the waters omitted, that is H^+**(ag)** represents hydronium ion and not a proton.

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

Arrhenius Base:

Increase hyrdoxide concentration to that of neutral water (which also means the hydroxide concentration is higher than the hydronium).

ex: $NaOH(ag) \rightarrow Na^+(ag) + OH^-(ag)$

or:

$NH_3(ag) + H_2O(l) \rightarrow NH_4^+(ag) + OHl^-(ag)$

In the later case the ammonia took a proton from the water and this reaction is similar to the autoinoization of water, except that it is an ammonia and not another water molecule that acquires the second proton.

Bronstead Acid:

A Proton Donor. Note the HCl gave a proton to the water molecule in the above example

Bronstead Base:

A Proton Acceptor. Note the ammonia above accepted a proton from the water. The Bronstead definition is a more general definition and the one we will use in this class.

Weak and Strong Electrolytes

Solutions which contain dissolved ions conduct electricity and are called electrolytes. Soluble ionic compounds are electrolytes and insoluble ionic compounds are nonelectrolytes. Strong acids and bases are electrolytes but weak ones are not. The thing is both strong and weak acids and bases can be aqueous..

Strong Acids:

Heavier binary hydrogen halides: HCl, HBr and HI (HF is weak)
Some of the larger oxyacids: H_2SO_4, HNO_3, $HClO_4$, and $HClO_3$

Note, this is not an all-inclusive list but you need to memorize these 7.
All other acids will be called strong or you are to assume they are weak.

Strong Bases: Soluble hydroxides
Alkaline hydroxides: LiOH, ... CsOH
Heavier alkaline earth hydroxides ($Ca(OH)_2$....$Ra(OH)_2$.

1. Indicate in the parenthesis if the following are aqueous or are precipitates and write **E** if an electrolyte and **NE** if a nonelectrolyte:

A. In Class Assignment:

a. HNO_3**(aq)** **E** b. HNO_2**(aq)** **NE** c. $AgClO_4$**(aq)** **E**
d. $AgC_2H_3O_2$**(aq)** **E** e. $HC_2H_3O_2$**(aq)** **NE** f. HF**(aq)** **NE**

B. Take Home Assignment: (write formula if needed)

g. barium nitrate $Ba(NO_3)_2$**(aq)** **E** h. hypochlorous acidHClO**(aq)** **NE**
i. hypoiodous acid HIO**(aq)** **NE** j. iodic acid (strong) HIO_3**(aq)** **E**
k. perbromic acid (strong) $HBrO_4$**(aq)** **E** l. trimethyl ammine $N(CH_3)_3$**(aq)** **NE** (weak soluble base)

II. **Predicting products and balancing acid base neutralization reactions.**

Many of these are a type of double displacement reaction and the same principle of conserving ions should be used in balancing them.

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A. Strong Acids and Strong Bases. Write balanced molecular (i), total ionic (ii) and net ionic (iii) equations for the following reactions.

- **(i)** balanced molecular
- **(ii)** total ionic and
- **(iii)** net ionic equations for the following reactions.

1. In Class Assignment

a.

(i) $2HCl(aq) + Ba(OH)_2(aq) \rightarrow 2H_2O(l) + BaCl_2(aq)$

(ii) $2H^+(aq) + 2Cl^- + Ba^{+2} + 2OH^- \rightarrow 2H_2O(l) + Ba^{+2} + 2Cl^-(aq)$

(iii) $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

b.

(i.) $H_2SO_4(aq) + 2KOH(aq) \rightarrow 2H_2O(l) + K_2SO_4(aq)$

(ii) $2H^+(aq) + SO_4^{-2} + 2K^+ + 2OH^- \rightarrow 2H_2O(l) + SO_4^{-2}(aq) + 2K^+(aq)$

(iii) $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

B. Weak Acids and Strong Bases. For the following chemical equations (a-b)

WRITE the,

- **(i)** balanced molecular
- **(ii)** total ionic and
- **(iii)** net ionic equations for the following reactions

1. In Class Assignment

a.

(i.) $HC_2H_3O_2(aq) + LiOH(aq) \rightarrow H_2O(l) + LiC_2H_3O_2(aq)$

(ii) $HC_2H_3O_2(aq) + Li^+(aq) + OH^-(aq) \rightarrow H_2O(l) + Li^+(aq) + C_2H_3O_2^-(aq)$

(iii) $HC_2H_3O_2(aq) + OH^-(aq) \rightarrow H_2O(l) + C_2H_3O_2^-(aq)$

b.

(i.) $2HF(aq) + Ba(OH)_2(aq) \rightarrow 2H_2O(l) + BaF_2(s)$
(***NOTE***: $BaF_2(s)$ came from the original solubility rules)

(ii) $2HF(aq) + Ba^{+2} + 2OH^{-} \rightarrow 2H_2O(l) + BaF_2(s)$

(iii) $2HF(aq) + Ba^{+2} + 2OH^{-} \rightarrow 2H_2O(l) + BaF_2(s)$

C. Strong Acids and Weak Bases. For the following chemical equations (a-b)

WRITE the,

(i) balanced molecular
(ii) total ionic and
(iii) net ionic equations for the following reactions

1. In Class Assignment

a.

(i.) $HCl(aq) + NH_3(aq) \rightarrow$ $\mathbf{NH_4Cl(aq)}$

(ii) $H^{+}(aq) + Cl^{-}(aq) + NH_{3(ag)} \rightarrow NH_4^{+}(aq) + Cl^{-}(aq)$

(iii) $H^{+}(aq) + NH_3(aq) \rightarrow NH_4^{+}(aq)$

b.

(i.) $HNO_3(aq) + C_5H_5N(aq) \rightarrow$ $\mathbf{NO_3^{-} + HC_5H_5N^{+}(aq)}$
(***NOTE***: $C_5H_5N(aq)$ is pyridine, a weak base)

(ii) $H^{+}(aq) + NO_3^{-}(aq) + C_5H_5N \rightarrow NO_3^{-}(aq) + HC_5H_5N^{+}(aq)$

(iii) $H^{+}(aq) + C_5H_5N(aq) \rightarrow HC_5H_5N^{+}(aq)$

D. Weak Acids and Weak Bases. For the following chemical equations (a-b)

Write the,

(i) balanced molecular
(ii) total ionic and
(iii) net ionic equations for the following reactions

1. In Class Assignment

a.

(i.) $HF(aq) + NH_3(aq) \rightarrow$ $\mathbf{NH_4F(aq)}$

(ii) $HF(aq) + NH_3(aq) \rightarrow NH_4^{+}(aq) + F^{-}(aq)$

(iii) $HF(aq) + NH_3(aq) \rightarrow NH_4^{+}(aq) + F^{-}(aq)$

III. Mixtures of Acids, Bases and Salts.

Write the,

(i) Predict products
(ii) balanced molecular
(iii) total ionic and
(iv) net ionic equations for the following reactions

a.

(i) $Na_2SO_4(aq) + 2KOH(aq) \rightarrow$ **$2NaOH(aq) + K_2SO_4(aq)$**

(ii) **$2Na^+(aq) + SO_4^{-2}(aq) + 2K^+(aq)+2OH^-(aq)$**
$\rightarrow 2K^+(aq) + SO_4^{-2}(aq) + 2Na^+(aq) + 2OH_-(aq)$

(iii) **No RXN**

b.

(i.) $H_2SO_4(aq) + Ba(OH)_2(aq) \rightarrow$ **$2H_2O_{(l)}$ + Ba $SO_4(s)$**

(ii) **$2H_+(aq) + SO_4^{-2}(aq) + Ba^{+2} + 2OH^- (aq) \rightarrow 2H_2O(l) + Ba\ SO_4(s)$**

(iii) **$2H_+(aq) + SO_4^{-2}(aq) + Ba^{+2} + 2OH^- (aq) \rightarrow 2H_2O(l) + Ba\ SO_4(s)$**

Take Home Problems: Write Net Ionic Equations for the following:

a.

(i) $AgCH_3CO_2(aq) + HCl(aq)$
$Ag^+(aq)+ CH_3CO_2^-(aq) + H^+(aq)+ Cl^-(aq) \rightarrow AgCl(s) + HCH_3CO_2\ (aq)$

b.

(ii) $H_2SO_4(aq) + Pb(NO_3)_2(aq)$
$Pb^{+2}(aq) + SO_4^{-2}(aq) \rightarrow Pb\ SO_4(s)$

c.

(iii) $H_2SO_3(aq) + AgNO_3(aq)$
$H_2SO_3(ag) + 2Ag^+(aq) \rightarrow Ag_2SO_3(s) + 2H^+(aq)$