Teacher's Tools® Chemistry

Chemical Reactions : Acid Base Reactions: Student Review Notes

Reactions of Acidic and Basic Solutions

Strong acid solution mixed with a strong base solution

Strong acids and strong bases completely dissociate into H^+ and OH^-. The net ionic equation that occurs is therefore the formation of water $H^+_{(aq)}$ and $OH^-_{(aq)} \rightarrow H_2O$

Strong acid solution mixed with a weak base solution

Strong acids completely dissociate into H^+ and the associated anion. H^+ is a very reactive species and will react completely with the weak base. In general, the reaction will result in the formation of the conjugate acid of the weak base. For example: $H^+_{(aq)}$ and $NH_3 \rightarrow NH_4{}^+_{(aq)}$ or in the case of an acid anion: $H^+_{(aq)}$ and $F^-_{(aq)} \rightarrow HF$

Strong base solution mixed with a weak acid solution

Strong bases completely dissociate into OH^- and the associated cation. OH^- is a very reactive species and will react completely with the weak acid. In general, the reaction will result in the formation of the conjugate base of the weak acid and water. For example: $OH^-_{(aq)} + HF \rightarrow F^-_{(aq)} + H_2O$.

Weak base solution mixed with a weak acid solution

The weak acid will be a proton donor and the weak base will be a proton acceptor.

For example: $NH_{3(aq)} + CH_3COOH_{(aq)} \rightarrow NH_4{}^+_{(aq)} + CH_3COO^-_{(aq)}$

Acidic and Basic Salts

Salts that contain the anion of a weak acid will form basic solutions. These are basic salts. The acid anion will react with water to form the weak acid and hydroxide. Salts that contain the ammonium cation, a weak acid, will dissociate and form an acidic solution. For example:

$PO_4{}^{3-}_{(aq)} + H_2O \rightarrow H_2PO_4{}^-_{(aq)} + OH^-_{(aq)}$ (basic phosphate salts)

$SO_3{}^{2-}_{(aq)} + H_2O \rightarrow HSO_3{}^-_{(aq)} + OH^-_{(aq)}$ (basic sulfite salts)

$F^-_{(aq)} + H_2O \rightarrow HF + 4\ OH^-_{(aq)}$ (basic fluoride salts), and so on for the anion of any weak acid.

$NH_4{}^+_{(aq)} + H_2O \rightarrow NH_3 + H^+_{(aq)}$ (acidic ammonium salts)

Metals in H_2O form Basic Solutions

Many metals are strong enough reducing agents to reduce water. The result of this redox reaction is a **basic solution**. The reduction of water is $2\ H_2O \rightarrow H_2 + OH^-$ with $E_{red} = -.828$ V. Any metal with an oxidation potential larger than .828 V will reduce H_2O. For example, take a look at these reactions:

Group IA Alkali metals: $2\ M_{(s)} + 2\ H_2O \rightarrow 2\ M^+ + 2\ OH^- + H_{2(g)}$

$2\ Li_{(s)} + 2\ H_2O \rightarrow 2\ Li^+_{(aq)} + 2\ OH^-_{(aq)} + H_{2(g)}$

$2\ Na_{(s)} + 2\ H_2O \rightarrow 2\ Na^+_{(aq)} + 2\ OH^-_{(aq)} + H_{2(g)}$

$2\ K_{(s)} + 2\ H_2O \rightarrow 2\ K^+_{(aq)} + 2\ OH^-_{(aq)} + H_{2(g)}$

$2\ Rb_{(s)} + 2\ H_2O \rightarrow 2\ Rb^+_{(aq)} + 2\ OH^-_{(aq)} + H_{2(g)}$

$2\ Cs_{(s)} + 2\ H_2O \rightarrow 2\ Cs^+_{(aq)} + 2\ OH^-_{(aq)} + H_{2(g)}$

$2\ Fr_{(s)} + 2\ H_2O \rightarrow 2\ Fr^+_{(aq)} + 2\ OH^-_{(aq)} + H_{2(g)}$

Large Group IIA metals: $M_{(s)} + 2\ H_2O \rightarrow M^{2+}_{(aq)} + 2\ OH^-_{(aq)} + H_{2(g)}$

$Ca_{(s)} + 2\ H_2O \rightarrow Ca^{2+}_{(aq)} + 2\ OH^-_{(aq)} + H_{2(g)}$

$Sr_{(s)} + 2\ H_2O \rightarrow Sr^{2+}_{(aq)} + 2\ OH^-_{(aq)} + H_{2(g)}$

$Ba_{(s)} + 2\ H_2O \rightarrow Ba^{2+}_{(aq)} + 2\ OH^-_{(aq)} + H_{2(g)}$

Aluminum: $2\ Al_{(s)} + 6\ H_2O \rightarrow 2\ Al^{3+}_{(aq)} + 6\ OH^-_{(aq)} + 3H_{2(g)}$

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Metal Oxides in Water form Basic Solutions

Group IA metal oxides and Group IIA metal oxides react with water to form basic solutions.

Group IA metal oxides: $M_2O_{(s)} + H_2O \rightarrow M^+_{(aq)} + 2\ OH^-_{(aq)} + H_{2(g)}$

Group IIA metal oxides: $MO_{(s)} + H_2O \rightarrow M^{2+}_{(aq)} + 2\ OH^-_{(aq)} + H_{2(g)}$

Metal Hydrides in Water for Basic Solutions

Metal hydrides are formed when molecular hydrogen reacts with a Group IA metal or a Group IIA metal. Note that the hydride anion in these compounds has an oxidation state of -1. H^- is a very strong Bronsted base (it wants to accept a proton) and this makes sense because $H^- + H^+ \rightarrow H_2$. Metal hydrides therefore react with water to form basic solutions according to the general reactions:

Group IA metal hydrides: $MH_{(s)} + H_2O \rightarrow M^+_{(aq)} + 2\ OH^-_{(aq)} + H_2$

Group IIA metal hydrides: $MH_{2\,(s)} + H_2O \rightarrow M^{2+}_{(aq)} + 2\ OH^-_{(aq)} + H_2$

Nonmetallic Oxides in Water form Acidic Solutions

Many nonmetal oxides react with water to form acids. These compounds are referred to as acid anhydrides. The acids that are formed in turn dissociate and the solution becomes acidic.

Know these examples (not balanced):

$SO_3 + H_2O \rightarrow H_2SO_4 \rightarrow H^+_{(aq)} + SO_4{}^{2-}{}_{(aq)}$

$P_2O_5 + H_2O \rightarrow H_3PO_4 \rightarrow H^+_{(aq)} + H_2PO_4{}^-{}_{(aq)}$

$P_4O_{10} + H_2O \rightarrow H_3PO_4 \rightarrow H^+_{(aq)} + H_2PO_4{}^{2-}{}_{(aq)}$

$Cl_2O_7 + H_2O \rightarrow HClO_4 \rightarrow H^+_{(aq)} + ClO_4{}^-{}_{(aq)}$

$N_2O_3 + H_2O \rightarrow HNO_2 \rightarrow H^+_{(aq)} + NO_2{}^-{}_{(aq)}$ (nitrogen in the +3 oxidation state)

$N_2O_5 + H_2O \rightarrow HNO_3 \rightarrow H^+_{(aq)} + NO_3{}^-{}_{(aq)}$ (nitrogen in the +3 oxidation state)

Nonmetal Halides in Water

Nonmetal halides can react with water to form acidic solutions. Know the following:

$PCl_3 + H_2O \rightarrow H^+_{(aq)} + H_2PO_4{}^{2-}{}_{(aq)}$

$PI_3 + H_2O \rightarrow H^+_{(aq)} + H_2PO_4{}^{2-}{}_{(aq)}$

$PBr_3 + H_2O \rightarrow H^+_{(aq)} + H_2PO_4{}^{2-}{}_{(aq)}$

Lewis Acids and Bases

Transition metals can behave like Lewis Acids (electron pair acceptors) in the formation of **complex ions**.

The molecules or ions that surround the metal in a complex ion are called **ligands**. The ligands act like a Lewis Base in that they donate a pair of electrons. A ligand must therefore have at least one unshared pair of electrons. The type of bond between the metal and the ligand is a **coordinate covalent bond**. In a coordinate covalent bond, one of the bonding atoms supplies both of the electrons.

For example, in the following reaction silver ion is acting as a Lewis Acid (electron pair acceptor) and ammonia is acting as a Lewis base (electron pair donor): $Ag^+_{(aq)} + NH_{3(aq)} \rightarrow Ag(NH_3)_2{}^+{}_{(aq)}$

Boron trifluoride—an octet rule exception can be a Lewis Acid

For example, in the following reaction boron trifluoride is acting as a Lewis Acid (electron pair acceptor) and ammonia is acting as a Lewis base (electron pair donor): $BF_3 + NH_3 \rightarrow BF_3NH_3$