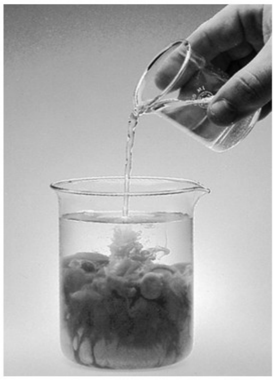


3.5 Net Ionic Equations

- Overall chemical equation

  $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$
- Complete ionic equation
  - strong electrolytes are completely ionized in aqueous solutions **[$NaCl(aq) \rightarrow Na^+(aq), Cl^-(aq)$]**

  $Ag^+(aq) + NO_3^-(aq) + Na^+(aq) + Cl^-(aq) \rightarrow$
  $\rightarrow AgCl(s) + Na^+(aq) + NO_3^-(aq)$

- Spectator ions - present on both sides of the equation (can be canceled)

  $Ag^+(aq) + NO_3^-(aq) + Na^+(aq) + Cl^-(aq) \rightarrow$
  $\rightarrow AgCl(s) + Na^+(aq) + NO_3^-(aq)$
- Net ionic equation - no spectator ions

  $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$
- For simplicity, we can omit **(aq)** after the symbols of all ions in aqueous solutions (assume all ions in solution as aqueous)

  $Ag^+ + Cl^- \rightarrow AgCl(s)$

Example:

- Write the net ionic equation for the precipitation of mercury(I) phosphate from mercury(I) nitrate and potassium phosphate.

  mercury(I) $\rightarrow Hg_2^{2+} \rightarrow Hg_2(NO_3)_2$

$\Rightarrow$Skeletal eq:

$Hg_2(NO_3)_2(aq) + K_3PO_4(aq) \rightarrow$
$\rightarrow (Hg_2)_3(PO_4)_2(s) + KNO_3(aq)$

$\Rightarrow$Overall balanced eq:

$3Hg_2(NO_3)_2(aq) + 2K_3PO_4(aq) \rightarrow$
$\rightarrow (Hg_2)_3(PO_4)_2(s) + 6KNO_3(aq)$

$\Rightarrow$Complete ionic eq:

$3Hg_2^{2+} + 6NO_3^- + 6K^+ + 2PO_4^{3-} \rightarrow$
$\rightarrow (Hg_2)_3(PO_4)_2(s) + 6K^+ + 6NO_3^-$

$\Rightarrow$Net ionic eq:

$3Hg_2^{2+} + 2PO_4^{3-} \rightarrow (Hg_2)_3(PO_4)_2(s)$

3.6 Predicting the outcome of Precipitation Reactions

Table 3.1 Solubility rules for inorganic compounds

Soluble compounds	**Insoluble compounds**
compounds of Group 1 elements	carbonates (CO_3^{2-}), chromates (CrO_4^{2-}), oxalates ($C_2O_4^{2-}$), and phosphates (PO_4^{3-}), **except** those of the Group 1 elements and NH_4^+
ammonium (NH_4^+) compounds	sulfides (S^{2-}), **except** those of the Group 1 and 2 elements and NH_4^+
chlorides (Cl^-), bromides (Br^-), and iodides (I^-), **except** those of Ag^+, Hg_2^{2+}, and Pb^{2+}*	hydroxides (OH^-) and oxides (O^{2-}), **except** those of the Group 1 and 2 elements†
nitrates (NO_3^-), acetates ($CH_3CO_2^-$), chlorates (ClO_3^-), and perchlorates (ClO_4^-)	
sulfates (SO_4^{2-}), **except** those of Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}, Hg_2^{2+}, and Ag^+‡	

*$PbCl_2$ is slightly soluble.
†$Ca(OH)_2$ and $Sr(OH)_2$ are sparingly (slightly) soluble.
‡Ag_2SO_4 is slightly soluble.

Example:

- Predict the outcome of the mixing of silver nitrate and potassium chromate solutions.

⇒Ions present in the solution:

Ag^+, NO_3^-, K^+, CrO_4^{2-}

⇒consider all possible combinations of ions to find if an insoluble product can form:

Ag^+ and CrO_4^{2-} form insoluble Ag_2CrO_4

⇒Net ionic eq: **$2Ag^+ + CrO_4^{2-} \rightarrow Ag_2CrO_4(s)$**

Reactions of Acids and Bases

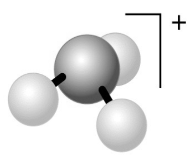
- Acids - sharp, sour taste
- Alkalis (bases) - soapy, bitter taste

3.7 Acids and Bases in Solution

- Arrhenius acids - release hydrogen ions (protons), **$H^+(aq)$**, in water solutions
- Formation of hydronium ions (**H_3O^+**) - transfer of protons from the acid to the water molecules
- The **H_3O^+** ions are strongly hydrated by water molecules → **$H_9O_4^+$**

Example: Hydrogen chloride dissolves in water to form hydrochloric acid solution.

$HCl(g) + H_2O(l) \rightarrow H_3O^+ + Cl^-$



4 Hydronium ion, H_3O^+

- Acidic hydrogen atoms in molecules
  - can be released as H^+ ions
  - formulas normally begin with the acidic Hs

⇒**HCl, H_2SO_4, HCN, ….**

- Carboxyl groups → **–COOH** (contain the acidic Hs in organic acids)

⇒**Acetic acid $C_2H_4O_2$ → 4 H atoms, 1 acidic H**
Formula depicting the acidic H → CH_3COOH

⇒**Benzoic acid → $C_7H_6O_2$ → C_6H_5COOH**

- Arrhenius bases - release hydroxide ions, **HO^-**, in water solutions

Examples:

⇒**NaOH** dissolves in water and dissociates to **Na^+** and **OH^-**.

⇒Ammonia gas, **NH_3**, dissolves in water and produces **NH_4^+** and **OH^-**.

$NH_3(g) + H_2O(l) \rightarrow NH_4^+ + OH^-$

3.8 Strong and Weak Acids

- Strong acid - almost completely ionized in aqueous solutions

⇒**$HBr(g) + H_2O(l) \rightarrow H_3O^+ + Br^-$ (~100% ionized)**

- Weak acids - only partially ionized in aqueous solutions

⇒**$C_6H_5COOH(aq) + H_2O(l) \rightarrow$**
$\rightarrow H_3O^+ + C_6H_5COO^-$ (~1% ionized)

3.8 Strong and Weak Bases

- Strong bases - almost completely ionized in aqueous solutions (oxides and hydroxides of alkali and alkaline earth metals)

⇒**$KOH(s) \rightarrow K^+ + OH^-$** **(~100% ionized)**

⇒**$CaO(s) + H_2O(l) \rightarrow Ca^{2+} + 2OH^-$**

$(O^{2-} + H_2O(l) \rightarrow 2OH^-)$

- Weak bases - only partially ionized in aqueous solutions (ammonia, amines, …)

⇒**$NH_3(aq) + H_2O(l) \rightarrow NH_4^+ + OH^-$** **(~1% ionized)**

Table 3.2 The strong acids and bases in water

Strong acids	Strong bases
hydrobromic acid, $HBr(aq)$	Group 1 hydroxides
hydrochloric acid, $HCl(aq)$	alkaline earth metal hydroxides*
hydroiodic acid, $HI(aq)$	
nitric acid, HNO_3	
perchloric acid, $HClO_4$	
chloric acid, $HClO_3$	
sulfuric acid, H_2SO_4 (to HSO_4^-)	

*$Ca(OH)_2$, $Sr(OH)_2$, $Ba(OH)_2$.