Solubility Guidelines for Compounds in Aqueous Solutions

- *It is very important that you know these guidelines and how to apply them in reactions.*

1) Common inorganic acids and low-molecular-weight organic acids are water soluble.
2) All common compounds of the Group IA metal ions and the ammonium ion are water soluble.
   - **Li^+**, **Na^+**, **K^+**, **Rb^+**, **Cs^+**, and **NH_4^+**

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3) Common nitrates, acetates, chlorates, and perchlorates are water soluble.
   - **NO_3^-**, **CH_3COO^-**, **ClO_3^-**, and **ClO_4^-**
4) Common chlorides are water soluble.
   - Exceptions – **AgCl**, **Hg_2Cl_2**, & **$PbCl_2$**
   - Common bromides and iodides behave similarly to chlorides.
   - Common fluorides are water soluble.
     - Exceptions – **MgF_2**, **CaF_2**, **SrF_2**, **BaF_2**, and **PbF_2**

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5) Common sulfates are water soluble.
   - Exceptions – **$PbSO_4$**, **$BaSO_4$**, & **$HgSO_4$**
   - Moderately soluble – **$CaSO_4$**, **$SrSO_4$**, & **Ag_2SO_4**
6) Common metal hydroxides are water **insoluble**.
   - Exceptions – **LiOH, NaOH, KOH, RbOH** & **CsOH**
   - Common bromides and iodides behave similarly to chlorides.
   - Common fluorides are water soluble.
     - Exceptions – **MgF_2, CaF_2, SrF_2, BaF_2, and PbF_2**

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7) Common carbonates, phosphates, and arsenates are water **insoluble**.
   - **CO_3^{2-}**, **PO_4^{3-}**, & **AsO_4^{3-}**
   - Exceptions- **IA metals** and **NH_4^+** plus **Ca to Ba**
   - Moderately soluble – **$MgCO_3$**
8) Common sulfides are water **insoluble**.
   - Exceptions – **IA metals** and **NH_4^+** plus **IIA metals**

Ionic Equations

- There are three ways to write reactions in aqueous solutions.

1. **Molecular equation**
   - Show all reactants & products in molecular or ionic form

$$Zn_{(s)} + CuSO_{4(aq)} \rightarrow ZnSO_{4(aq)} + Cu_{(s)}$$

2. **Total ionic equation**
   - Show the ions and molecules as they exist in solution

$$Zn_{(s)} + Cu^{2+}_{(aq)} + SO^{2-}_{4(aq)} \rightarrow Zn^{2+}_{(aq)} + SO^{2-}_{4(aq)} + Cu_{(s)}$$

Ionic Equations

3. **Net ionic equation**
   - Shows ions that participate in reaction and removes spectator ions.
- Spectator ions do not participate in the reaction. Spectator ions in < >'s.

$$Zn_{(s)} + Cu^{2+}_{(aq)} + \left\langle SO^{2-}_{4(aq)} \right\rangle \rightarrow Zn^{2+}_{(aq)} + \left\langle SO^{2-}_{4(aq)} \right\rangle + Cu_{(s)}$$

$$Zn_{(s)} + Cu^{2+}_{(aq)} \rightarrow Zn^{2+}_{(aq)} + Cu_{(s)}$$

- **Molecular equation**

$$2\,HCl_{(aq)} + Na_2SO_{3(aq)} \rightarrow 2\,NaCl_{(aq)} + H_2O_{(\ell)} + SO_{2(g)}$$

- **Total ionic reaction**

$$2\,H^{1+}_{(aq)} + 2\,Cl^{1-}_{(aq)} + 2\,Na^{1+}_{(aq)} + SO^{2-}_{3(aq)} \rightarrow$$

$$2\,Na^{1+}_{(aq)} + 2\,Cl^{1-}_{(aq)} + H_2O_{(\ell)} + SO_{2(g)}$$

- **Net ionic reaction**

$$2\,H^{1+}_{(aq)} + SO^{2-}_{3(aq)} \rightarrow H_2O_{(\ell)} + SO_{2(g)}$$

- **Molecular equation**

$$Ca(OH)_{2(aq)} + 2\,HNO_{3(aq)} \rightarrow Ca(NO_3)_{2(aq)} + 2\,H_2O_{(\ell)}$$

- **Total ionic equation**

$$Ca^{2+}_{(aq)} + 2\,OH^{-}_{(aq)} + 2\,H^{+}_{(aq)} + 2\,NO^{-}_{3(aq)} \rightarrow Ca^{2+}_{(aq)} + 2\,NO^{-}_{3(aq)} + 2\,H_2O_{(\ell)}$$

- **Net ionic equation**

$$2\,OH^{-}_{(aq)} + 2\,H^{+}_{(aq)} \rightarrow 2\,H_2O_{(\ell)}$$

or better

$$OH^{-}_{(aq)} + H^{+}_{(aq)} \rightarrow H_2O_{(\ell)}$$

- **Molecular equation**

$$Ca(NO_3)_{2(aq)} + K_2CO_{3(aq)} \rightarrow 2\,KNO_{3(aq)} + CaCO_{3(s)}$$

- **Total ionic reaction**

$$Ca^{2+}_{(aq)} + 2\,NO^{-}_{3(aq)} + 2\,K^{+}_{(aq)} + CO^{2-}_{3(aq)} \rightarrow$$

$$2\,K^{+}_{(aq)} + 2\,NO^{-}_{3(aq)} + CaCO_{3(s)}$$

- **Net ionic reaction**

$$Ca^{2+}_{(aq)} + CO^{2-}_{3(aq)} \rightarrow CaCO_{3(s)}$$

- **Molecular equation**

$$3\,CaCl_{2(aq)} + 2\,Na_3PO_{4(aq)} \rightarrow 6\,NaCl_{(aq)} + Ca_3(PO_4)_{2(s)}$$

- **Total ionic reaction**

$$3\,Ca^{2+}_{(aq)} + 6\,Cl^{1-}_{(aq)} + 6\,Na^{1+}_{(aq)} + 2\,PO^{3-}_{4(aq)} \rightarrow$$

$$6\,Na^{1+}_{(aq)} + 6\,Cl^{1-}_{(aq)} + Ca_3(PO_4)_{2(s)}$$

- **Net ionic reaction**

$$3\,Ca^{2+}_{(aq)} + 2\,PO^{3-}_{4(aq)} \rightarrow Ca_3(PO_4)_{2(s)}$$

Oxidation Numbers

- **Guidelines for assigning oxidation numbers.**

1. The oxidation number of any free, uncombined element is zero.
2. The oxidation number of an element in a simple (monatomic) ion is the charge on the ion.
3. In the formula for any compound, the *sum* of the oxidation numbers of all elements in the compound is zero.
4. In a polyatomic ion, the *sum* of the oxidation numbers of the constituent elements is equal to the charge on the ion.

Oxidation Numbers

5. Fluorine has an oxidation number of –1 in its compounds.
6. Hydrogen, H, has an oxidation number of +1 unless it is combined with metals, where it has the oxidation number -1.
   - Examples – LiH, BaH_2
7. Oxygen usually has the oxidation number -2.
   - Exceptions:
   - In peroxides O has oxidation number of –1.
     - Examples - H_2O_2, CaO_2, Na_2O_2
   - In OF_2: O has oxidation number of +2.

Oxidation Numbers

8. Use the periodic table to help with assigning oxidation numbers of other elements.
   a. IA metals have oxidation numbers of +1.
   b. IIA metals have oxidation numbers of +2.
   c. IIIA metals have oxidation numbers of +3.
      - There are a few rare exceptions.
   d. VA elements have oxidation numbers of –3 in ***binary*** compounds with H, metals or NH_4^+.
   e. VIA elements below O have oxidation numbers of –2 in ***binary*** compounds with H, metals or NH_4^+.

Assign oxidation numbers to the element specified in each group of compounds

- N in $NaNO_3$
- Sn in $K_2Sn(OH)_6$
- P in H_3PO_4
- S in SO_3^{2-}
- Cr in $Cr_2O_7^{2-}$

Assign oxidation numbers to the element specified in each group of compounds

- N in NH_3
- O in Na_2O_2
- Fe
- N in N_2O_4

Assign oxidation numbers to the element specified in each group of compounds

- P in $H_4P_2O_7$
- Hg in Hg_2Cl_2
- Li in LiH
- S in $S_4O_6^{2-}$