Writing Chemical Equations

Molecular Equations are written using only neutral elements, compounds and radicals.

a. The equation must be balanced.
b. Each species should include phases in parentheses:

s for solid, ***l*** for liquid, **g** for gas, and **aq** for aqueous (water) solution

Examples:

(1) $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

(2) $Na_2CO_3(aq) + Pb(NO_3)_2(aq) \rightarrow 2\ NaNO_3(aq) + PbCO_3(s)$

(3) $PbCO_3(s) + 2\ HNO_3(aq) \rightarrow Pb(NO_3)_2(aq) + H_2O(l) + CO_2(g)$

Ionic Equations are written using ions for all species which exist in the reaction medium (usually water) primarily as ions.

a. All solids, liquids and gases are written as neutral (not as ions) if they enter, leave, or remain in the reaction medium as such.
b. In aqueous solution only **strong electrolytes are written in ionic form**.
c. Weak electrolytes and non-electrolytes are written as neutral (not as ions).

Examples: (1), (2), and (3) become

(1a) $Na^+ + OH^- + H^+ + Cl^- \rightarrow Na^+ + Cl^- + H_2O(l)$

where all ions are understood to be (aq) unless otherwise indicated

(2a) $2\ Na^+ + CO_3^{2-} + Pb^{2+} + 2\ NO_3^- \rightarrow 2\ Na^+ + 2\ NO_3^- + PbCO_3(s)$

(3a) $PbCO_3(s) + 2\ H^+ + 2\ NO_3^- \rightarrow Pb^{2+} + 2\ NO_3^- + H_2O(l) + CO_2(g)$

Other examples:

(4a) $K^+ + OH^- + HF(aq) \rightarrow K^+ + F^- + H_2O(l)$ (HF is a weak acid, weak electrolyte)

(5a) $Zn^{2+} + 2\ Cl^- + 4\ K^+ + 4\ OH^- \rightarrow 4\ K^+ + 2\ Cl^- + [Zn(OH)_4]^{2-}$

Net Ionic Equations are obtained from ionic equation by canceling those ions on both sides that are identically the same. Ions thus cancelled are called "spectator ions".

Examples: Equations (1a) though (5a) become:

(1b) $OH^- + H^+ \rightarrow H_2O(l)$ or as equilibrium: $OH^- + H^+ \rightleftharpoons H_2O(l)$

(2b) $Pb^{2+} + CO_3^{2-} \rightleftharpoons PbCO_3(s)$

(3b) $PbCO_3(s) + 2\ H^+ \rightarrow Pb^{2+} + H_2O(l) + CO_2(g)$

(4b) $OH^- + HF(aq) \rightarrow + F^- + H_2O(l)$

(5b) $Zn^{2+} + 4\ OH^- \rightleftharpoons [Zn(OH)_4]^{2-}$

Note also:

(6b) $[Zn(OH)_4]^{2-} + 4\ H^+ \rightleftharpoons Zn^{2+} + 4\ H_2O(l)$

Water, precipitates, weak electrolytes and complex ions can be written as separated into component ions on the **reactant side** when they are formed from those ions in the reaction being

written, e.g., (1b), (2b), and (5b). Otherwise they are written in their combined form in ionic equations, e.g., (3a), (3b), (4a), (4b), and (6b).

Water, precipitates, weak electrolytes, and complex ions can be written in their component ions on the **product side** of the equation if that equation is specifically for the purpose of showing equilibrium with the component ions or for the purpose of defining a specific equilibrium constant. Examples:

$H_2O(l) \rightleftharpoons H^+ + OH^-$ (for K_w) $\qquad$ $PbCO_3(s) \rightleftharpoons Pb^{2+} + CO_3^{2-}$ (for K_{sp})

$HF(aq) \rightleftharpoons H^+ + F^-$ (for K_a) $\qquad$ $[Zn(OH)_4]^{2-} \rightleftharpoons Zn^{2+} + 4\ OH^-$ (for K_i)

These equations will not arise naturally as net ionic equations.

All equations should be **balanced** for atoms and charges.

Ions must always **have charges**. It is NEVER correct to leave a charge off of an ion.
OH^- is hydroxide ion. OH is a radical or molecular fragment (not hydroxide).

Do not mix types of equations.
For example: $H^+ + NaOH(aq) \rightarrow H_2O(l) + Na^+$ [a mix of (1), (1a) and (1b)] is confusion.

Write an equation as molecular, OR total ionic, OR net ionic as useful or appropriate, but not as a mix of two or more kinds of equations.

Ion Block Equations are a useful way to represent simultaneous equilibria.

(7) $Cu(OH)_2(s) \rightleftharpoons Cu^{2+} + 2\ OH^-$ and

(8) $Cu^{2+} + 4\ NH_3 \rightleftharpoons [Cu(NH_3)_4]^{2+}$ add together to give

(9) $Cu(OH)_2(s) + 4\ NH_3 \rightleftharpoons [Cu(NH_3)_4]^{2+} + 2\ OH^-$

It is useful at times to put these together into one ionic block equation:

$$Cu(OH)_2(s) \rightleftharpoons \begin{matrix} Cu^{2+} + 2\ OH^- \\ + \\ 4\ NH_3 \\ \Uparrow\Downarrow \\ [Cu(NH_3)_4]^{2+} \end{matrix}$$

The ion block equation specifically shows the hydroxide ions and ammonia molecules in competition for the copper(II) ions in solution. Equation (9) does not specifically show the presence of Cu^{2+} ions, which have an important role in the equilibrium.