Step by Step: Molecular Reactions, Complete Ionic Reactions and Net Ionic Reactions

Solubility Rules

** soluble = **aqueous** marginally/slightly soluble = **solid**

Solubility Table

1. Nitrate (NO_3^{-1}) salts are soluble.
2. Ammonium (NH_4^{+1}) and Group I Alkali metal (Li^{+1}, Na^{+1}, K^{+1}, Cs^{+1}, Rb^{+1}) salts are soluble.
3. Chloride, Bromide, Iodide (Cl^{-1}, Br^{-1}, I^{-1}) salts are soluble, except for salts with Ag^{+1}, Pb^{2+} and Hg_2^{2+}.
4. Sulfate (SO_4^{2-}) salts are soluble, except Ba^{2+}, Ca^{2+}, Pb^{2+}, and Hg_2^{2+}.
5. Soluble Hydroxides are LiOH, NaOH and KOH. Marginally soluble: $Ba(OH)_2$, $Sr(OH)_2$ and $Ca(OH)_2$. The rest are slightly soluble.
6. Carbonates (CO_3^{2-}), Sulfides (S^{2-}), Chromates (CrO_4^{2-}) and Phosphates (PO_4^{3-}) are slightly soluble. (All with ammonium or Group 1 Alkali metals are soluble.)

Ex. 1) Write the **molecular** equation:

$BaCl_{2(aq)} + Na_2SO_{4(aq)} \rightarrow$

Steps: 1) Break compounds apart to their Single ions: Ba^{2+} Cl^{-1} & Na^{+1} SO_4^{2-}

Ba is in the 2nd column, so +2. Cl is in the 17th column, so -1.
Na is in the 1st column, so +1. Sulfate you have memorized is -2.
*Do not worry about the 2 for chlorine; you want only the single ions. Just one Cl. You will fix the amount in step number 4.
*Do not worry about the 2 for sodium; you want only the single ions. Just one Na.

2) Mix ions to make new neutral compounds:

Ba^{2+} & SO_4^{2-} Na^{+1} & Cl^{-1} = $BaSO_4$ + NaCl

Now you need to mix and match to make the new compounds. **Opposites Attract!** So put positive with negative. (Do not reform the compounds you started with; they have already broken up and do not want to go back together.) If necessary, you will need to multiply the ions to make new neutral compounds. But in this case Ba is +2 and SO_4 is -2, a perfect match. Na is +1 and Cl is -1, a perfect match.

For step 3: Look at the solubility rules to see if it is soluble (aq) or not (s).
-Rule 4 says that sulfates are soluble, except for $BaSO_4$. If it is not soluble, then **solid**.
-Rule 2 says that sodium will be soluble (aq) and Rule 2 says that chloride will be soluble (aq), so NaCl is **aqueous.**

$BaCl_{2(aq)} + Na_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + NaCl_{(aq)}$

↑ ↑

3) Solubility Rules from Table: Rule #4 Rule #2,3 **If no rule, then soluble (aq).

For step 4: Balance the equation. This will fix the amounts of elements we ignored in the first step.

4) Balance equation: **$BaCl_{2(aq)} + Na_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + 2\ NaCl_{(aq)}$**

Chem Honors see at the end of these notes for the complete ionic and net ionic!

Ex. 2) Write the molecular equation.

$NaBr_{(aq)} + Pb(NO_3)_{2(aq)} \rightarrow$

Break apart to single ions:

Na is in 1st column, so +1. Br is in 17th column, so -1.

Pb is in the middle and needs a roman numeral, so we will need to find its' charge from the nitrate! Nitrate is -1, but there are 2 nitrates, since there is a 2 outside the parenthesis. If we have 2 nitrates, that are -1 each, we have a -2 charge on the right of the compound. To balance the -2, the Pb on the left side must be +2.

Na^{+1} Br^{-1} & Pb^{2+} NO_3^{-1}

Next we must mix and match. Opposites attract! Do not put them back with who they just broke up with!

*Then we have to make neutral compounds. Na and nitrate are +1 and -1, a perfect match. But Pb is +2 and Br is -1. We need 2 Bromides, so that we have a -2 charge to cancel with the +2 of Pb. The X2 for the Br is written like when we were naming compounds, so the number is on the bottom!

Na^{+1} & NO_3^{-1} Pb^{2+} & Br^{-1} = $NaNO_3$ + $PbBr_2$
X2

Then we look at the solubility rules.

Rule 2 says that sodium is soluble (aq). Rule 1 says that nitrate is soluble (aq). So $NaNO_3$ is aq.

Rule 3 says that bromides are soluble, except for Pb. If it is not soluble, then it is solid (s).

$NaBr_{(aq)} + Pb(NO_3)_{2(aq)} \rightarrow NaNO_{3(aq)} + PbBr_{2(s)}$

↑ Rule #1,2 ↑ Rule #3

Next balance the reaction.

$2\ NaBr_{(aq)} + Pb(NO_3)_{2(aq)} \rightarrow 2\ NaNO_{3(aq)} + PbBr_{2(s)}$

Ex. 3) Write the molecular equation.

$Na_2CO_{3(aq)} + AlI_{3(aq)} \rightarrow$

Na is in the 1st column, so +1. Carbonate you have memorized, so -2. Aluminum is memorized as +3 or you can figure it out. (Since Al is with 3 iodines, which are each -1 because they are in column #17, then Al must be +3 to balance the -3 charge of the iodines.)

Na^{+1} CO_3^{2-} & Al^{3+} I^{-1}

Mix and match the ions. Opposites attract!
*Make neutral compounds. Na is +1, Cl is -1, so a perfect match.
But Al is +3 and carbonate is -2. Multiply so we have +6 and -6. Multiply Al by 2 and carbonate by 3. Write the X2 and X3 as numbers on the bottom, so it looks like a compound.

Na^{+1} & I^{-1} Al^{3+} & CO_3^{2-} $= NaI + Al_2(CO_3)_3$
X2 X3

Solubility Rule 2 says that sodium is soluble (aq) and Rule 3 says that iodine is soluble (aq). Rule 6 says that carbonates are marginally or slightly soluble, meaning that some will dissolve, but that will leave some solid (s). So it will be solid.

$Na_2CO_{3(aq)} + AlI_{3(aq)} \rightarrow NaI_{(aq)} + Al_2(CO_3)_{3(s)}$
↑ Rule #2,3 ↑ Rule #6

Balance the reaction.

$3\ Na_2CO_{3(aq)} + 2\ AlI_{3(aq)} \rightarrow 6\ NaI_{(aq)} + Al_2(CO_3)_{3(s)}$

Only for Chem Honors:

Ex. 1b) Write the **complete ionic** equation:
$BaCl_{2(aq)} + Na_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + 2\ NaCl_{(aq)}$

Break all compounds apart to their elements, except for solids and liquids.
Reactant side: Cl_2, so 2 chloride ions. Na_2, so 2 sodium ions.
Product side: 2 NaCl, so 2 sodium ions and 2 chlorine ions.

Step 5) Solids and liquids stay together and don't break apart to their ions.
$Ba^{2+}_{(aq)} + 2\ Cl^{-1}_{(aq)} + 2\ Na^{+1}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow BaSO_{4(s)} + 2\ Na^{+1}_{(aq)} + 2\ Cl^{-1}_{(aq)}$

Ex. 1c) Write the **net ionic** equation:

Cancel all ions. The 2 Cl^{-1} and 2 Na^{+1} cancel from both sides. When these cancel, they should cancel completely. The amounts should be the same on the reactant and product sides. If not, something is wrong!

Step 6) Cancel ions.
$Ba^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow BaSO_{4(s)}$

*****Make sure you are writing all ions with their charges and all ions/compounds with their (aq) or (s)!!!**

Ex. 2) $2\ NaBr_{(aq)} + Pb(NO_3)_{2(aq)} \rightarrow 2\ NaNO_{3(aq)} + PbBr_{2(s)}$

Break the compounds apart, except for solids and liquids:
2 NaBr, so 2 sodium ions and 2 bromide ions. $(NO_3)_2$ so **2** nitrates!
2 $NaNO_3$, so 2 sodium ions and 2 nitrate ions.
$2\ Na^{+1}_{(aq)} + 2\ Br^{-1}_{(aq)} + Pb^{2+}_{(aq)} + 2\ NO_3^{-1}{}_{(aq)} \rightarrow 2\ Na^{+1}_{(aq)} + 2\ NO_3^{-1}{}_{(aq)} + PbBr_{2(s)}$

Cancel the 2 sodium ions and the 2 nitrate ions.

$2\ Br^{-1}_{(aq)} + Pb^{2+}_{(aq))} \rightarrow PbBr_{2(s)}$

Ex. 3) $3\ Na_2CO_{3(aq)} + 2\ AlI_{3(aq)} \rightarrow 6\ NaI_{(aq)} + Al_2(CO_3)_{3(s)}$

3 Na_2CO_3, so 6 sodium ions. 3 Na_2CO_3, so 3 carbonates.
2 AlI_3, so 2 aluminum ions. 2 AlI_3, so 6 iodide ions.
6 NaI, so 6 sodiums and 6 iodides.

$6\ Na^{+1}_{(aq)} + 3\ CO_3^{2-}{}_{(aq)} + 2\ Al^{3+}{}_{(aq)} + 6\ I^{-1}_{(aq)} \rightarrow 6\ Na^{+1}_{(aq)} + 6\ I^{-1}_{(aq)} + Al_2(CO_3)_{3(s)}$

Cancel the sodiums and iodides.

$3\ CO_3^{2-}{}_{(aq)} + 2\ Al^{3+}{}_{(aq))} \rightarrow Al_2(CO_3)_{3(s)}$

End of Notes