Qualitative Analysis and Activity Series Chemical Reaction Balancing Tutorial: Fundamentals

To complete and balance many of the reactions in this worksheet requires little more than remembering how one completed the simple redox balancing worksheets, the Chemical Nomenclature Lab exercise and class worksheet and Dimensional Analysis from the Math Primer.

In simple redox, you used half reactions and balanced gain and loss of electrons to obtain the final, balanced reaction.

In chemical nomenclature, you learned how to name compounds and ions … and you learned the charges on many of the ions.

In the Math Primer, you learned that units are just as important as the numerical value.

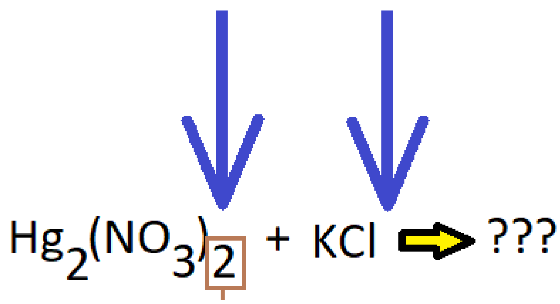
By combining (remembering!) concepts from all three of these exercises, you can comfortably balance the problems in Question 13 in the Qual/Activity worksheet.

Remember, too, what I said about "memorizing to regurgitate" vs "learning to apply". 95% of Chemistry (and Physics) is critical thinking: "learning to apply".

We'll start with a simple reaction: $Hg_2(NO_3)_2 + KCl \rightarrow$??? and take it a step at a time, then bring it all together so you can see the thinking process that, with practice and experience, takes place in milliseconds.

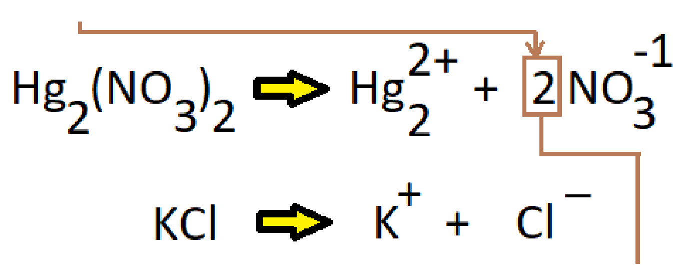
Step 1

In the graphic at slightly upper right, note the very large blue arrows. This is an important observational step: there are NO numbers above the compounds, which means that the compounds have an overall net charge of zero (0), i.e., they're neutral compounds. This also means that the elements and complex ions are, thus far, balanced out. This is really no different than balancing a checkbook.



Step 2

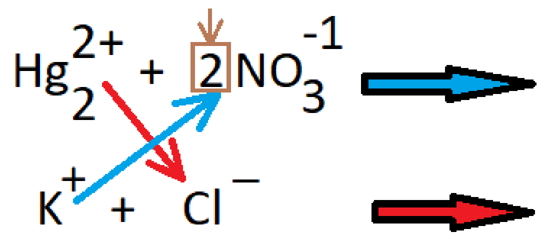
Because you have experience writing out half reactions, simply write out the half reaction for the dissociation (separation) of each of the reactants, image at right. At this stage, the charges still balance at each half reaction, however, the charges are NOT



equivalent between each half reaction. Also, remember from the Chemical Nomenclature Experiment/Worksheet that Hg(I) is a weird ion: it prefers to run around as $Hg^{2+}{}_2$.

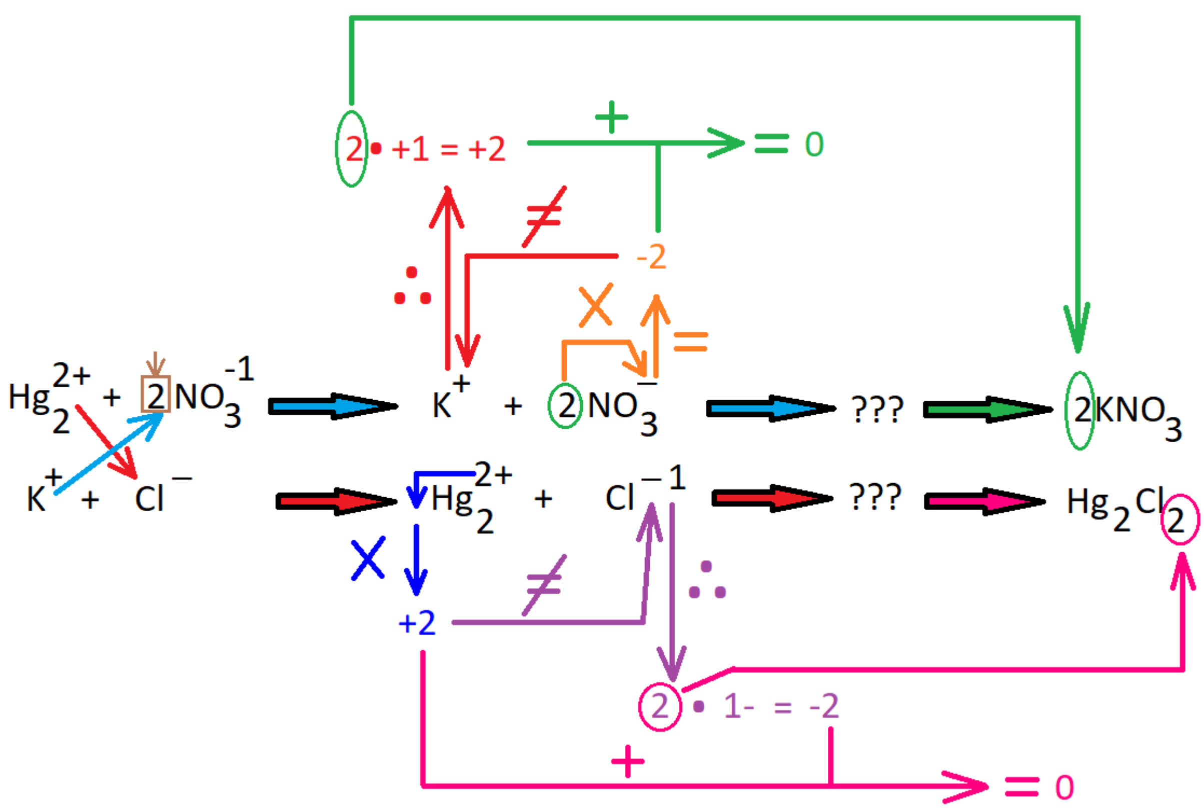
Step 3

Once you have the half reactions written out, simply "cross multiply" (at right) so that you re-align the cations with new anions (this works for these very simple reactions; as we get farther into general chemistry, you'll see there are limitations to this approach – not to worry at this stage) and can begin to see how the new compounds (products) will combine.



Step 4

This step is substantially more involved, below:

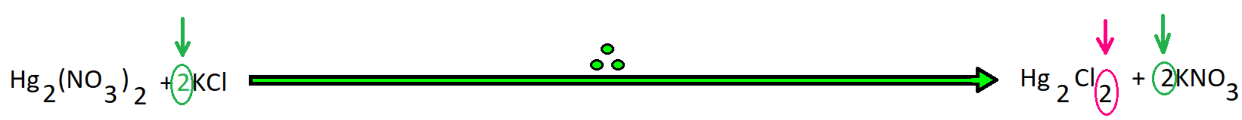


Let's start with the combination between the potassium ion and the nitrate ion (formulas, charges and names are absolutely critical as you learn this new language). Note that there are two (2) nitrate ions. Each nitrate ion has a charge of -1, 1- or just -. Because you have 2 of them, the overall charge on the nitrate is -2 (orange steps). -2 does NOT balance out 1+. In order for the -2 charge to be balanced out, you must double the +1 from the potassium ion to end up with +2 (red steps). Do you note that +2 plus -2 equals zero? Good! As a result, when potassium nitrate is formed, a “2” must be placed in front of the KNO_3 (green steps). Likewise, a “2” will eventually be placed in front of the potassium ion (in the form of KCl). This takes care of the potassium ion combining with the nitrate ion.

Next we look at the combination of the mercurous ion (Hg(I); $Hg^{2+}{}_2$) with the chloride ion. The total charge on the mercurous ion is 2+ (there is a coefficient of “1”; blue steps). The chloride ion has a -1 charge – not enough to balance out the +2 on the mercurous ion (purple steps). The -1 charge, then, needs to be doubled to give an overall charge of -2 on the chloride ion (purple steps). Once that charge balance is determined, a subscript of “2” is placed behind the “Cl” (fuschia steps) in the mercurous chloride (calomel).

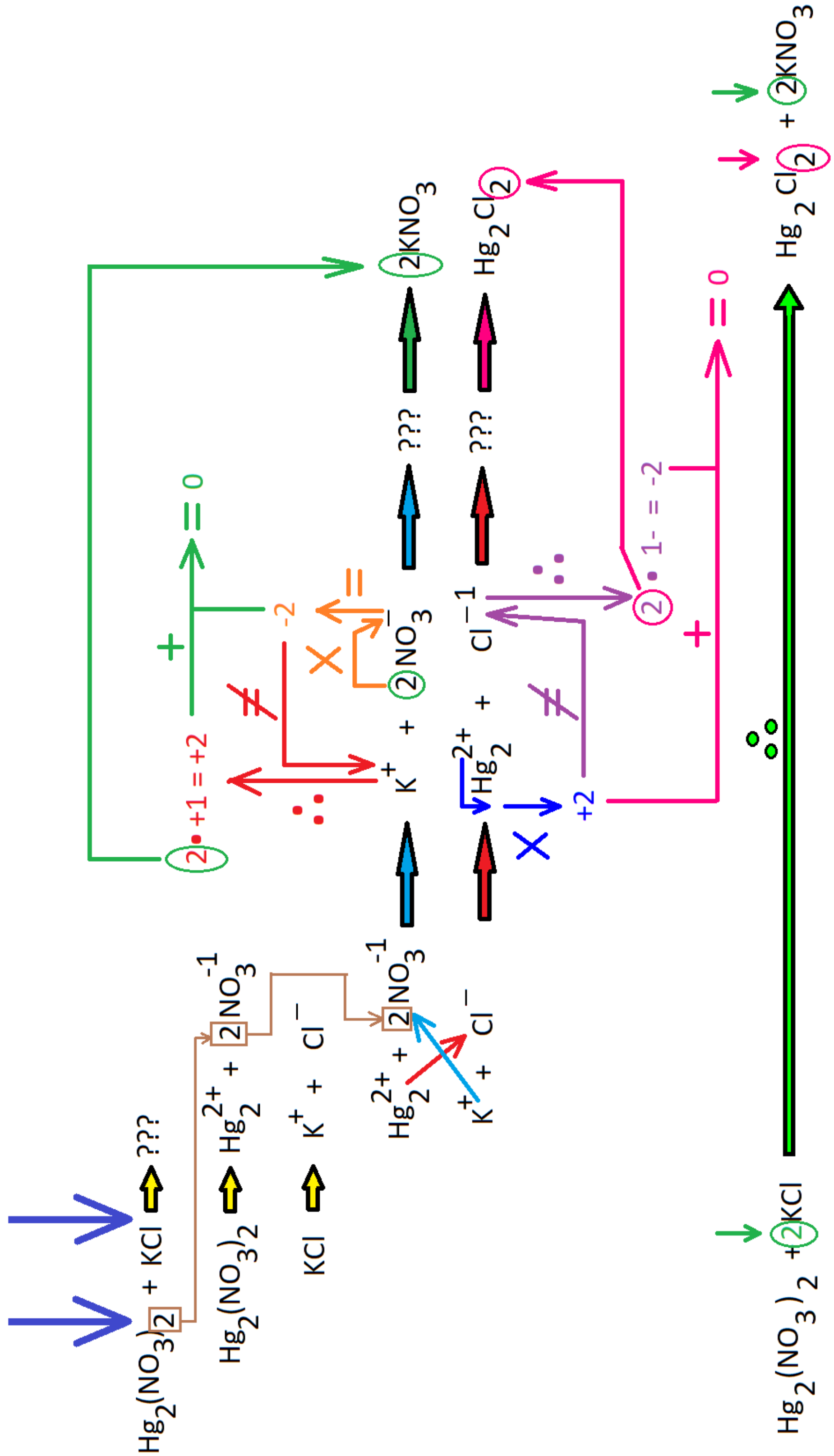
> Note: coefficients apply to everything that follows behind it, e.g., 3NaCl says that there are 3 sodium ions and 3 chloride ions in sodium chloride as “balanced” for this example. Subscripts apply ONLY to the entity that it immediately follows, e.g., $MgCl_2$ says that there is 1 magnesium ion and 2 chlorides in magnesium chloride. When coupling coefficients with subscripts, it’s a little more complex, albeit very doable, e.g., $3Na_3PO_4$ says that for this example there are are 9 sodiums, 3 phosphorus’ and 12 oxygens in the sodium phosphate. In addition, in the case of the mercurous nitrate formed in this reaction, the subscript “2” after the nitrate says there are two nitrates or 2 nitrogens and 6 oxygens in the compound.

Now that we’ve reached the step of comprehending charge balancing, we can balance the complete reaction:



Note the “2” coefficient in front of the potassium chloride on the reactant side of the reaction (left side) and the “2” coefficient in front of the potassium nitrate on the product side (right side) of the reaction (green circles and arrows). Note, too, the subscripted “2” behind the chloride in the calomel on the product side (right side) of the reaction (fuschia circle and arrow). Observe, likewise, that there are two mercury’s, two nitrates, two potassiums and two chlorides on the reactant side of the reaction … and two mercury’s, two chlorides, two potassiums and two nitrates on the product side of the reaction. Balanced just like a checkbook!

The following page illustrates the complete thought process in balancing this sort of reaction: it will get you through this worksheet comfortably … and it will take a lot of paper until you have it down cold. “Learn to Apply”.


Hg2(NO3)2 + KCl → ???
Hg2(NO3)2 → Hg2 2+ + 2NO3 -1
KCl → K+ + Cl−
Hg2 2+ + 2NO3 -1 + K+ + Cl−
K+ + 2NO3−
Hg2 2+ + Cl−1
2 • +1 = +2
-2
+2
2 • 1- = -2
= 0
= 0
??? → 2KNO3
??? → Hg2Cl2
Hg2(NO3)2 + 2KCl → Hg2Cl2 + 2KNO3