Chem 4 example
Ionic Chemical Reactions
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Example:

You should get to the point where it takes about 3 minutes to do a problem like the following:

So you've got a bottle of $AgNO_3$ in solution, and a bottle of Na_3PO_4 in solution.

You mix a little of each in a test tube, to see what happens. We notice that a precipitate forms, but we don't know which ions reacted to form what... If we had the balanced molecular equation, we could know what the precipitate is. So lets try to calculate the balanced molecular formula, from the balanced ionic and net ionic equations. First we'll have to figure out what the balanced ionic equations are...

We know the molecular formula's for $AgNO_3$, and Na_3PO_4 (because we remember the nomenclature rules, or because they're written on the bottles of solution)

So we can immediately write the first half of the *MOLECULAR* equation (but we don't know the molar ratios OR what the products will be, so we'll use some place holder question marks):

$$?AgN0_3(aq)+?Na_3PO_4(aq) \rightarrow ????? \tag{1}$$

So how many moles of $AgNO_3$ and how many moles of Na_3PO_4?

And what's going to be on the right side?

We can investigate if the "silver part" of the first reactant will react with the "phosphate part" of the second reactant, and the "nitrate part" of the first reactant will react with the "sodium part" of the second reactant, we can take a guess and write what we think the second half of the equation (1) in this paper might be. Then equation (1) becomes:

$$?AgNO_3(aq)+?Na_3PO_4(aq) \rightarrow ?Ag_?(PO_4)_?(?)+?Na_?(NO_3)_?(?) \tag{2}$$

Things we don't know for sure yet:

– Are these things on the right side of equation (2) gonna be solids, or aquious?

– How many Ag's will combine with how many PO_4's, and how many Na's will combine with how many NO_3's?

– And how many moles of everything?

So we break down the left side of equation (2) into ions, instead of molecular formula's (you have to know what the charges are, either from memory or looking them up). And we get the following:

$$Ag^{+1} + NO_3^{-1} + 3Na^{+1} + PO_4^{-3} \rightarrow \tag{3}$$

Notice in equation (3) that we have 3 moles of Na^{+1} that's from the subscripted 3 ('$_3$') in the molecular formula in equation (2).

Next we would like to do the same for the right side of equation (2), but we can't because we don't know the subscripts for that side. If we have correctly broken down the left side, we know what the charges are, and we can use those charges to help us come up with the subscripts for the right side of our ionic equation. So lets figure out what the subscripts for the molecules on the right side of equation (2) should be.

Notice (This is huge in understanding this stuff.) that if the Ag^{+1} ions in equation (3) will indeed combine with PO_4^{-3} ions (like we are guessing in equation (2)), then we'll need 3 Ag^{+1}'s to balance the charge of one PO_4^{-3}, and the molecular formula would be $Ag_3(PO_4)$. Also notice that if the Na^{+1} ions will indeed combine with the NO_3^{-1} ions, we'll only need one of each for their charges to cancel. So equation (2) becomes the following:

$$?AgNO_3(aq) + ?Na_3PO_4(aq) \rightarrow ?Ag_3(PO_4)_1(?) + ?Na_1(NO_3)_1(?) \tag{4}$$

But we don't write subcripted 1's. So we get the following:

$$?AgNO_3(aq) + ?Na_3PO_4(aq) \rightarrow ?Ag_3(PO_4)(?) + ?Na(NO_3)(?) \tag{5}$$

So we are slowly replacing the question marks, but equation (5) is still not balanced. And we don't know what's gonna be solid and what's gonna be aquious.

To balance, first notice that their are 3 moles of Ag^{+1} on the right (inside of the $Ag_3(PO_4)$ molecule), and only 1 mole of Ag^{+1} on the left (inside of the $AgNO_3$ molecule). Also, there are 3 moles of Na^{+1} on the left and only 1 mole on the right.

Let's take care of the Ag^{+1}'s first... we can multiply the $AgNO_3$ on the left side by 3, and we get the following:

$$3AgNO_3(aq) + ?Na_3PO_4(aq) \rightarrow ?Ag_3(PO_4)(?) + ?Na(NO_3)(?) \tag{6}$$

Now let's take care of the Na^{+1}'s. We can multiply the $Na(NO_3)$ on the right side by 3, and we get the following:

$$3AgNO_3(aq) + ?Na_3PO_4(aq) \rightarrow ?Ag_3(PO_4)(?) + 3Na(NO_3)(?) \tag{7}$$

Now we've got equal amounts of everything on the left and right sides. (notice how the number of NO_3^{+1}'s went up on both sides when we were taking care of the Ag^{+1}'s and the Na^{+1}'s in the previous two steps, and fortunatly both sides increased the same amount, or else we might have to take more steps to get the equation balanced. As a rule of thumb, most of your equations

will balance after multiplying once or twice... if you need to multiply more times, you might very well have made a mistake).

So, we're done calculating the coefficients(the numbers that go in front of the Molecular formulas) in our Molecular equation. We can replace those remaining place holder question marks with 1's (but again, we don't write 1's in our equation) and we have the following:

$$3AgNO_3(aq) + Na_3PO_4(aq) \rightarrow Ag_3(PO_4)(?) + 3Na(NO_3)(?) \tag{8}$$

Finally we can look up in our list of rules about what is soluble and what's not, and we find that the Ag_3PO_4 is a insoluble.

And in the end we'll get the following molecular equation:

$$3AgN0_3(aq) + Na_3PO_4(aq) \rightarrow Ag_3PO_4(s) + 3NaNO_3(aq) \tag{9}$$

To get the total ionic equation, change the "aq" molecules in equation (8) into ions, as in the following:

$$3Ag^{+1}(aq) + 3NO_3^{-1}(aq) + 3Na^{+1}(aq) + PO_4^{-3} \rightarrow Ag_3PO_4(s) + 3Na^{+1}(aq) + 3NO_3^{+1}(aq) \tag{10}$$

And to get the following net ionic equation, cancel ions that appear on both sides of equation (9). We get the following:

$$3Ag^{+1}(aq) + PO_4^{-3} \rightarrow Ag_3PO_4(s) \tag{11}$$

Practice 1:

Try to repeat this same problem for practice:

$AgNO_3$(aq) reacts with Na_3PO_4(aq) to produce a ppt. Find the balanced Molecular Chemical equation, the Total Ionic equation and the Net Ionic Chemical equation:

Step 1. write the left side like in equation 1:

Step 2. Guess the right side molecules like in equation 2:

Step 3. Break the left side into ions like in equation 3:

Step 4. Write the right side molecules like in equation 5 using the charge info from Step 3:

Step 5. Figure which ions are not balanced and multiply some of the molecules on the left and/or right side, like in equation 6:

Step 6. Repeat step 5 for the other ions until the equation is balanced.

Step 7. Determine which molecules on the right (if any) will be solids/aquious like in equation 9:

Step 8. Determine the Total Ionic equation like in equation 10:

Step 9. Determine the Net Ionic equation like in equation 11:

Practice 2:

Try this for practice:

$Cu(NO_3)_2$(aq) mixed with $NaOH$(aq) to produce a ppt. Find the balanced Molecular Chemical equation, the Total Ionic equation and the Net Ionic Chemical equation:

Step 1-9: same as previous problem

References:

Chem 4 Lab Manual Experiment 4 , UCSD Fall 2006