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Project 3

So we are given 50.00 mL of 0.123 M $Mn(NO_3)_5$. This is mixed with 25.00 mL of 0.100 M K_2S. Strangely enough, grey precipitate forms after the reaction. It is found to have a 72% yield. The exact reaction is as followed:

$$2\,Mn(NO_3)_5(aq) + 5\,K_2S(aq) \rightarrow Mn_2S_5(s) + 10\,KNO_3(aq)$$

As we can see, on the left side of the reaction, two moles of aqueous $Mn(NO_3)_5$ is mixed with five mols of aqueous K_2S. The reaction turns these into an aqueous solution and a solid. The aqueous solution is ten mols of KNO_3, and the solid, Mn_2S_5, is the precipitate. However, why is Mn_2S_5 a solid if we mixed two aqueous solutions? We know that according to the law of conservation of matter, the matter at the beginning of the reaction is equal to the matter at the end of the reaction. Knowing this, we know that the solid had to come from *somewhere*.

Once two aqueous solutions are mixed, the positively charged ions essentially swap spaces. In this case, the positively charged ions are Mn and K_2. These ions swap places and bond with the other non-metal. Even though they bond with each other, they do not necessarily still form a soluble solution. We know that any ion bonded with Nitrate is a soluble solution, which means it remains aqueous. However, a Sulfide ion is only soluble when bonded with a Group 1 ion, or Ammonium. In our case, the Sulfide ion is bonded with Mn, which is not a Group 1 ion. This means that the compound becomes insoluble, and it precipitates into a solid.

However, now we have to ask ourselves, how would we find the number of grams of Mn_2S_5 produced by this reaction?

So to begin, let's name all of the things we know about this reaction:

- There is 50.00 mL of 0.123 M $Mn(NO_3)_5$ that is aqueous
- There is 25.00 mL of 0.100 M K_2S that is also aqueous
- Once the reaction occurs we are left with Mn_2S_5, a solid, and KNO_3, an aqueous solution.

To find the amount of precipitate, we have to separately utilize the reactants. Following the equation:

$$0.050\,L\,Mn\left(NO_3\right)_5 \frac{0.123\,mol\,Mn\left(NO_3\right)_5}{L} \frac{1\,mol\,Mn_2S_5}{2\,mol\,Mn\left(NO_3\right)_5} \frac{270.2\,g\,Mn_2S_5}{mol} \frac{72\,g\,actual}{100\,g\,theoretical} = 0.598\,g\,Mn_2S_5$$

To start, we turn the first reactant, $Mn(NO_3)_5$, from mL to L. This conversion is merely dividing the mL by 1000 to turn it into L. Next, we know that 50.00 mL of $Mn(NO_3)_5$ has a molarity of 0.123 per L. This is signified by the first fraction. Next, we know we have to convert the number of moles of $Mn(NO_3)_5$ to mols of Mn_2S_5. This is shown in the second fraction. From there, we have to convert the mols of Mn_2S_5 to its molar mass, which is just 270.2 grams. This is shown in the third fraction. Lastly, we were told that this reaction has a 72% yield; this means that for every 100 grams of theoretical yield, we get 72 grams. This is the last fraction. Then we are left with 0.598 g Mn_2S_5. Now that we found the yield from the first reactant, we must do the same for the second reactant.

$$0.025\,L\,K_2S\,\frac{0.100\,mol\,K_2S}{L}\,\frac{1\,mol\,Mn_2S_5}{5\,mol\,K_2S}\,\frac{270.2\,g\,Mn_2S_5}{mol}\,\frac{72\,g\,actual}{100\,g\,theoretical}=0.0973\,g\,Mn_2S_5$$

Again, we are converting L to mL by dividing by 1000. Then we know that there is 0.100 mol of K_2S per liter of solution. Then the mol ratio between Mn_2S_5 and K_2S is 1:5, which is shown in the reaction. Again, like the previous equation, we use the molar mass of Mn_2S_5 to find the grams of the precipitate, then apply the 72% yield to get 0.0973 g Mn_2S_5.

Notice how by using each reactant, we find different values for the number of grams of Mn_2S_5. Which one should we keep? Essentially, we have to choose the smaller of the two. This is called the limiting reagent. To best explain this concept. Imagine if there are ten hamburger buns but only eight hamburgers. How many complete hamburgers can be made? There would be eight complete burgers and two leftover buns. This same concept applies here. You can only make 0.0973 g Mn_2S_5 with 25.00 mL of K_2S regardless of how much more $Mn(NO_3)_5$ you have.