Stoichiometry

Relationships between Reactants and Products

Consistent Process

There are a variety of different problems we face in chemistry that can all be approached with the same process.

Some resources treat these different problems as if they are unique different things, but if we study the *process* that we use to solve these problems, then we just have to learn the few differences between the *application* of the consistent process.

Stoichiometry Problems

For anything we can identify as a stoichiometry problem, we use the same 4 steps to address and solve those problems.

1. Write a balanced chemical equation
2. Determine moles for the "known" species in the process
3. Use the mole-to-mole relationship in the balanced chemical equation to convert "moles of known" to "moles of interest"
4. Determine whatever "quantity of interest" the problem asks for.

1. Balanced chemical equation

This is a whole topic in itself, BUT there are a few specific points here:

- Stoichiometry problems are (somewhat) “self-cleaning”. It (usually) doesn’t matter if you balance using smallest-whole-number coefficients, or fractional coefficients, or multiples of these, you will (usually) come up with the same correct answer
- Full molecular or net ionic equations work equally well for (most) stoichiometry problems.

2. Find moles of known

There are dozens of ways to get to moles.

1. From grams using formula mass
2. From mL using concentration
3. From mL using density & formula mass
4. From mL using gas law relationships
5. From pressure using gas law relationships
6. From temperature using thermochemistry
7. From energy using free energy
8. From energy using specific heat
9. And more, and more, and more…

3. Mole-to-Mole Conversion

Back to the chemical equation. That's why writing and balancing chemical equations is so important, they give us a relationship between reactants and products

4. Moles of interest to ???

There are just as many ways to get *out* of moles as there are ways to get *into* moles.

Think about the *process* when you see one of these problems. You know how to do all the individual steps, it’s just a matter of putting them together.

Types of Stoichiometry Problems

Some of the most common problems:

1. How much Reactant A is needed to react with a specific amount of Reactant B?
2. How much product can be made from a specific amount of Reactant A?
3. How much product can be made from specific amounts of Reactants A & B?
4. How much heat is required/liberated by a specific amount of Reactant A?

Example: Planning a Reaction

You would like to react 35.00mL of 1.024M sodium chloride solution with 1.208M silver(I) nitrate solution to form silver(I) chloride precipitate. How many mL of silver(I) nitrate solution do you need?

Step 1: Balanced Chemical Equation

$$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$$

Net ionic equation also works:

$$Ag^{+1}(aq) + Cl^{-1}(aq) \rightarrow AgCl(s)$$

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$$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$$

$$Ag^{+1}(aq) + Cl^{-1}(aq) \rightarrow AgCl(s)$$

Step 2: Find moles of known

We have enough information to find the moles of sodium chloride (or just chloride ions) in the problem.

$$(35.00mL\ NaCl(aq))\left(\frac{1\ L}{1000\ mL}\right)\left(\frac{1.024mols\ NaCl(aq)}{L\ NaCl(aq)}\right) = 0.03584\text{mols NaCl(aq)}$$

Or if you prefer the net ionic equation:

$$(35.00mL\ Cl^{-1}(aq))\left(\frac{1\ L}{1000\ mL}\right)\left(\frac{1.024mols\ Cl^{-1}(aq)}{L\ Cl^{-1}(aq)}\right) = 0.03584\text{mols Cl}^{-1}\text{(aq)}$$

Both work equally well in this case.

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You would like to react 35.00mL of 1.024M sodium chloride solution with 1.208M silver(I) nitrate solution to form silver(I) chloride precipitate. How many mL of silver(I) nitrate solution do you need?

$$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$$

$$Ag^{+1}(aq) + Cl^{-1}(aq) \rightarrow AgCl(s)$$

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$$(35.00mL\ Cl^{-1}(aq))\left(\frac{1\ L}{1000\ mL}\right)\left(\frac{1.024mols\ Cl^{-1}(aq)}{L\ Cl^{-1}(aq)}\right) = 0.03584\text{mols Cl}^{-1}\text{(aq)}$$

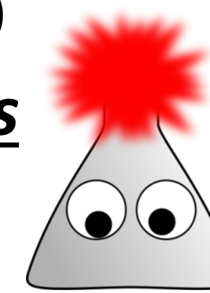
Step 3: Mole-to-mole conversion

For every mole of NaCl(aq) {or Cl^{-1}(aq)} that reacts, we need 1 mole of $AgNO_3$(aq). We use a mol ratio to perform this conversion:

$$(0.03584moL\ NaCl(aq))\left(\frac{1\ mol\ AgNO_3(aq)}{1\ mol\ NaCl(aq)}\right) = 0.03584\text{mols AgNO}_3\text{(aq)}$$

$$(0.03584moL\ Cl^{-1}(aq))\left(\frac{1\ mol\ Ag^{+1}(aq)}{1\ mol\ Cl^{-1}(aq)}\right) = 0.03584\text{mols Ag}^{+1}\text{(aq)}$$

The 1:1 conversion may seem trivial, but ***always*** include this step. It will help you avoid errors!



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Example: Planning a Reaction

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$$Ag^{+1}(aq) + Cl^{-1}(aq) \rightarrow AgCl(s)$$

$$(35.00mL\ NaCl(aq))\left(\frac{1\ L}{1000\ mL}\right)\left(\frac{1.024mols\ NaCl(aq)}{L\ NaCl(aq)}\right)\left(\frac{1\ mol\ AgNO_3(aq)}{1\ mol\ NaCl(aq)}\right) = 0.03584\text{mols } AgNO_3(aq)$$

$$(35.00mL\ Cl^{-1}(aq))\left(\frac{1\ L}{1000\ mL}\right)\left(\frac{1.024mols\ Cl^{-1}(aq)}{L\ Cl^{-1}}\right)\left(\frac{1\ mol\ Ag^{+1}(aq)}{1\ mol\ Cl^{-1}(aq)}\right) = 0.03584\text{mols } Ag^{+1}(aq)$$

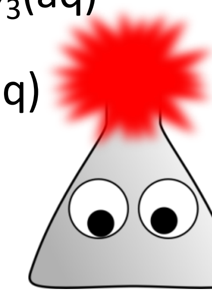
Step 4: Moles to "Quantity of Interest"

Now that we know how many mols of silver(I) nitrate {or Ag^{+1} ions) we need and we know the concentration of this stock solution, we can find the mL of solution needed:

$$(0.03584moL\ AgNO_3(aq))\left(\frac{1\ L\ AgNO_3(aq)}{1.208\ mol\ AgNO_3(aq)}\right)\left(\frac{1000\ mL}{1\ L}\right) = 29.67\text{mL } AgNO_3(aq)$$

$$(0.03584moL\ Ag^{+1}(aq))\left(\frac{1\ L\ Ag^{+1}(aq)}{1.208\ mol\ Ag^{+1}(aq)}\right)\left(\frac{1000\ mL}{1\ L}\right) = 29.67\text{mL } Ag^{+1}(aq)$$

<u>Sig fig note</u>: All inputs had 4 sig figs, this was all multiplication and division, so the result has 4 sig figs.



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Example: Planning a Reaction

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$$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$$

$$Ag^{+1}(aq) + Cl^{-1}(aq) \rightarrow AgCl(s)$$

$$(35.00 mL\ NaCl(aq))\left(\frac{1\ L}{1000\ mL}\right)\left(\frac{1.024 mols\ NaCl(aq)}{L\ NaCl(aq)}\right)\left(\frac{1\ mol\ AgNO_3(aq)}{1\ mol\ NaCl(aq)}\right)\left(\frac{1\ L\ AgNO_3(aq)}{1.208\ mol\ AgNO_3(aq)}\right)\left(\frac{1000\ mL}{1\ L}\right)$$

$$= 29.67 mL\ AgNO_3(aq)$$

$$(35.00 mL\ Cl^{-1}(aq))\left(\frac{1\ L}{1000\ mL}\right)\left(\frac{1.024 mols\ Cl^{-1}(aq)}{L\ Cl^{-1}}\right)\left(\frac{1\ mol\ Ag^{+1}(aq)}{1\ mol\ Cl^{-1}(aq)}\right)\left(\frac{1\ L\ Ag^{+1}(aq)}{1.208\ mol\ Ag^{+1}(aq)}\right)\left(\frac{1000\ mL}{1\ L}\right)$$

$$= 29.67 mL\ Ag^{+1}(aq)$$

Use your units! They will help you avoid errors. If the units don't cancel, then the math will not be correct.

This is also one way to do a limiting reactant problem. If you combine 35.00mL of NaCl(aq) and 35.00mL of $AgNO_3$(aq), the NaCl(aq) will be limiting because you only need 29.67mL of $AgNO_3$(aq) to react with all of the NaCl(aq)

You can do this!

Many “stoichiometry” problems look pretty complex when you first see them. Pick them apart and solve them bit my bit. Always start with a balanced chemical equation. Look for ways to find moles. Be deliberate with your units.

If you do it in 1 long equation, great! If you do it in 4 separate individual steps, also great! There’s no one perfect way, just remember to work through the *process*.