

So far, we have

- looked at how to determine the composition by mass of a compound from a formula
- converted from MASS to MOLES (related to the number of atoms/molecules)
- converted from MOLES to MASS

Are we missing anything?

- What about SOLUTIONS, where the desired chemical is not PURE, but found DISSOLVED IN WATER?
- How do we deal with finding the moles of a desired chemical when it's in solution?

MOLAR CONCENTRATION

- unit: MOLARITY (M): moles of dissolved substance per LITER of solution

$$M = \text{molarity} = \frac{\text{moles of SOLUTE}}{\text{L SOLUTION}}$$

$$6.0 \text{ M HCl solution} = \frac{6.0 \text{ mol HCl}}{\text{L}}$$

If you have 0.250 L (250 mL) of 6.0 M HCl, how many moles of HCl do you have?

↳ six molar

$$6.0 \text{ mol HCl} = 1 \text{ L solution}$$

$$0.250 \text{ L solution} \times \frac{6.0 \text{ mol HCl}}{1 \text{ L solution}} = 1.5 \text{ mol HCl}$$

If you need 0.657 moles of hydrochloric acid, how many liters of 0.0555 M HCl do you need to measure out?

$0.0555 \text{ mol HCl} = 1 \text{ L}$

$$0.657 \text{ mol HCl} \times \frac{1 \text{ L}}{0.0555 \text{ mol HCl}} = \boxed{11.8 \text{ L}}$$

↑ This is a large quantity to measure in lab glassware!

What if we used 6.00 M HCl?

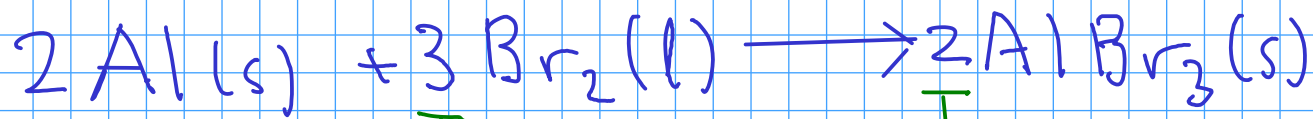
$6.00 \text{ mol HCl} = 1 \text{ L}$

$$0.657 \text{ mol HCl} \times \frac{1 \text{ L}}{6.00 \text{ mol HCl}} = \boxed{0.110 \text{ L}}$$

↑ 110 mL
(easily measured with lab glassware)

CHEMICAL CALCULATIONS CONTINUED: REACTIONS

- Chemical reactions proceed on an ATOMIC basis, NOT a mass basis!
- To calculate with chemical reactions (i.e. use chemical equations), we need everything in terms of ATOMS ... which means MOLES of atoms

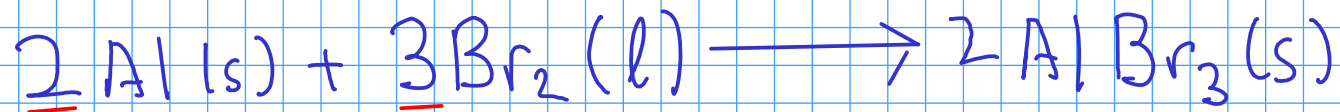


coefficients are in terms of atoms and molecules!

2 atoms Al = 3 molecules Br₂ = 2 formula units AlBr₃

2 mol Al = 3 mol Br₂ = 2 mol AlBr₃

- To do chemical calculations, we need to:
 - Relate the amount of substance we know (mass or volume) to a number of moles
 - Relate the moles of one substance to the moles of another using the equation
 - Convert the moles of the new substance to mass or volume as desired

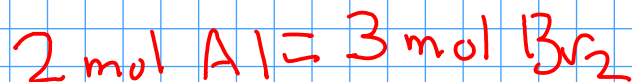


* Given that we have 25.0 g of liquid bromine, how many grams of aluminum would we need to react away all of the bromine? How many grams of aluminum bromide would be produced?

① Convert grams of bromine to moles: Need formula weight Br_2 : $\frac{2 \times 79.90}{159.80}$
 $159.80 \text{ g Br}_2 = 1 \text{ mol Br}_2$

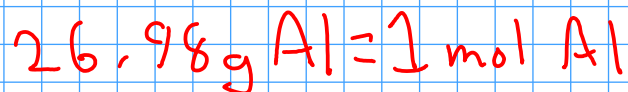
$$25.0 \text{ g Br}_2 \times \frac{1 \text{ mol Br}_2}{159.80 \text{ g Br}_2} = 0.15645 \text{ mol Br}_2$$

② Use the chemical equation to relate moles of bromine to moles of aluminum



$$0.15645 \text{ mol Br}_2 \times \frac{2 \text{ mol Al}}{3 \text{ mol Br}_2} = 0.10430 \text{ mol Al}$$

③ Convert moles aluminum to mass: Need formula weight Al : 26.98



$$0.10430 \text{ mol Al} \times \frac{26.98 \text{ g Al}}{1 \text{ mol Al}} = \boxed{2.81 \text{ g Al}}$$

Aluminum bromide: Use conservation of mass!

$$25.0 \text{ g} + 2.81 \text{ g} = 27.8 \text{ g}$$

You can combine all three steps on one line if you like!

$$25.0 \text{ g Br}_2 \times \frac{1 \text{ mol Br}_2}{159.80 \text{ g Br}_2} \times \frac{2 \text{ mol Al}}{3 \text{ mol Br}_2} \times \frac{26.98 \text{ g Al}}{1 \text{ mol Al}} = 2.81 \text{ g Al}$$

① ② ③

$$\begin{array}{r} 25.0 \text{ g Br}_2 \\ + 2.81 \text{ g Al} \\ \hline 27.8 \text{ g AlBr}_3 \end{array}$$

But ...

...what would you have done to calculate the mass of aluminum bromide IF you had NOT been asked to calculate the mass of aluminum FIRST?

$$25.0 \text{ g Br}_2 \times \frac{1 \text{ mol Br}_2}{159.80 \text{ g Br}_2} \times \frac{2 \text{ mol AlBr}_3}{3 \text{ mol Br}_2} \times \frac{266.694 \text{ g AlBr}_3}{1 \text{ mol AlBr}_3} = 27.8 \text{ g}$$

① ② ③

convert mass
bromine
to moles

convert moles
bromine to
moles aluminum
bromide

convert moles
aluminum
bromide
to mass

Example:

How many milliliters of 6.00M hydrochloric acid is needed to completely react with 25.0 g of sodium carbonate?



- 1 - Convert mass of sodium carbonate to moles using formula weight
 - 2 - Convert moles of sodium carbonate to moles hydrochloric acid using chemical equation
 - 3 - Convert moles of hydrochloric acid to volume using concentration (M = moles/L)
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- Convert mass of sodium carbonate to moles using formula weight

$$\begin{array}{l} \text{Na}_2\text{CO}_3: \text{Na} : 2 \times 22,99 \\ \quad \quad \quad \text{C} : 1 \times 12,01 \\ \quad \quad \quad \text{O} : 3 \times 16,00 \\ \hline \quad \quad \quad 105,99 \end{array}$$

$$105,99 \text{ g Na}_2\text{CO}_3 = 1 \text{ mol Na}_2\text{CO}_3$$

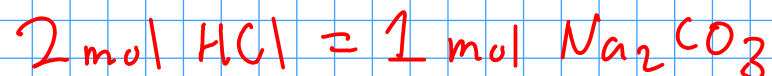
$$25,0 \text{ g Na}_2\text{CO}_3 \times \frac{1 \text{ mol Na}_2\text{CO}_3}{105,99 \text{ g Na}_2\text{CO}_3} = 0,235871 \text{ mol Na}_2\text{CO}_3$$

Example:

How many milliliters of 6.00M hydrochloric acid is needed to completely react with 25.0 g of sodium carbonate?



- Convert moles of sodium carbonate to moles hydrochloric acid using chemical equation



$$0.235871 \text{ mol Na}_2\text{CO}_3 \times \frac{2 \text{ mol HCl}}{1 \text{ mol Na}_2\text{CO}_3} = 0.471743 \text{ mol HCl}$$

- Convert moles of hydrochloric acid to volume using concentration (M = moles/L)

$$6.00 \text{ mol HCl} \approx \underline{1 \text{ L}} \quad \text{mL} \approx 10^{-3} \text{ L}$$

$$0.471743 \text{ mol HCl} \times \frac{1 \text{ L}}{6.00 \text{ mol HCl}} \times \frac{\text{mL}}{10^{-3} \text{ L}} = \boxed{78.6 \text{ mL of } 6.00 \text{ M HCl}}$$

↑ This step converts L to mL,
since the problem statement
asks for mL!