

CHEMDU · COMMUNITY CHEMISTRY · LEVEL 2 ADVANCED

LECTURE L2-5

Stoichiometry

The Mole in Your Kitchen: Why Pool Chlorine Must Be Measured Exactly

Duration: 75 minutes

Advanced lecture script — pre-requisite: Level 1

HOOK (3 minutes)

Teacher holds up (or shows photos of):

A pool chlorine container with measuring instructions

A medicine dosing cup with mL markings

A baking soda box and vinegar bottle

A recipe card (cookies or pancakes)

Teacher says: "A pool chlorine label says: 'Add 1 pound per 10,000 gallons of water.' If you add 3 pounds instead, someone could get chemical burns. That's stoichiometry — measuring the right amounts for a chemical reaction.

But chemists don't use pounds or gallons. They use the mole — a special counting unit. Why? Because atoms are too small to count one by one.

- Today's question: How do chemists count particles too small to see — and how does that keep you safe? *

By the end of this session, you will be able to:

Explain what a mole is using household analogies

Calculate molar mass from the periodic table

Convert between grams, moles, and number of particles

Identify the limiting reactant in a recipe or chemical reaction

Calculate percent yield (how much product you actually get)"

SEGMENT 1: Review from Level 1 and Previous Level 2 Lectures (5 minutes)

Teacher says: "Before we go deeper, let's recall what you already know."

Review from Level 1 (Stoichiometry - Math-Light)

Level 1 Concept	Definition	Household Example
Stoichiometry	Measuring the right amounts for a chemical reaction	Recipe for cookies
Limiting reactant	The ingredient that runs out first	Eggs in a cookie recipe
Concentration	How much chemical in a given amount of liquid	Strong vs. weak lemonade

Level 1 Concept	Definition	Household Example
Dilution	Adding liquid to make a chemical weaker	Adding water to juice

Review from Level 2-1 (Atomic Mass)

Element	Atomic Mass (from periodic table)	What It Means
Carbon (C)	12.01 amu	One carbon atom weighs 12.01 atomic mass units
Hydrogen (H)	1.008 amu	One hydrogen atom weighs 1.008 amu
Oxygen (O)	16.00 amu	One oxygen atom weighs 16.00 amu

Review from Level 2-4 (Balancing Equations)

Teacher: "Remember the balanced equation for baking soda + vinegar:"

text



Teacher: "This equation tells us that 1 molecule of baking soda reacts with exactly 1 molecule of vinegar. But we can't count molecules one by one. So chemists invented the mole."

Quick check (show of hands / chat): "What is the law of conservation of mass?" (Atoms are neither created nor destroyed) "Why do we need to balance equations?" (Same number of each atom on both sides)

SEGMENT 2: The Mole — Chemist's Counting Unit (12 minutes)

Teacher says: "A mole (mol) is a counting unit — just like a dozen."

Analogies to Understand the Mole

Unit	Number of Items	Example
1 dozen	12	12 eggs
1 gross	144	144 pencils
1 ream	500	500 sheets of paper
1 mole	6.022×10^{23}	602,200,000,000,000,000,000,000 particles

Mole (mol): 6.022×10^{23} particles (atoms, molecules, ions, etc.) This number is called Avogadro's number (a-voh-GAH-droz NUM-ber).

Teacher: *"Why 6.022×10^{23} ? Because that's how many atoms are in exactly 12 grams of carbon-12. It's a huge number because atoms are tiny."*

Visualizing Avogadro's Number

Teacher: "If you had 6.022×10^{23} marbles, they would cover the entire Earth to a depth of 50 miles. If you had that many dollars, you could give every person on Earth \$1 million — and still have money left over."

Why Do Chemists Use Moles?

Without Moles (Impossible for Atoms)	With Moles (Practical)
"Add 1,000,000,000,000,000,000 molecules of baking soda"	"Add 1 mole of baking soda"
"Add 500,000,000,000,000,000,000 atoms of carbon"	"Add 0.83 moles of carbon"

Household connection: "Just as you buy eggs by the dozen (not by the individual egg), chemists work with moles — not individual atoms."

Converting Between Moles and Number of Particles

The conversion factor:

1 mole = 6.022×10^{23} particles

Formula:

Number of particles = Moles $\times 6.022 \times 10^{23}$ Moles = Number of particles $\div 6.022 \times 10^{23}$

Worked Example 1: Moles to Particles

Problem: How many molecules are in 2.5 moles of water (H₂O)?

Step-by-step:

Step	Calculation
Step 1	Use the formula: Particles = Moles \times Avogadro's number
Step 2	Particles = 2.5 mol \times (6.022×10^{23} molecules/mol)
Step 3	Particles = (2.5 \times 6.022) $\times 10^{23}$
Step 4	Particles = 15.055 $\times 10^{23}$
Step 5	Write properly: 1.5055 $\times 10^{24}$ molecules

Answer: 2.5 moles of water contains 1.51×10^{24} molecules.

Worked Example 2: Particles to Moles

Problem: A sample contains 3.011×10^{23} molecules of CO_2 . How many moles is this?

Step-by-step:

Step	Calculation
Step 1	Use the formula: Moles = Particles \div Avogadro's number
Step 2	Moles = $(3.011 \times 10^{23}) \div (6.022 \times 10^{23})$
Step 3	Moles = $3.011 \div 6.022$
Step 4	Moles = 0.500 mol (half a mole)

Answer: 3.011×10^{23} molecules of CO_2 is 0.500 moles.

Partner talk (1 minute): *"Tell your partner: If 1 dozen = 12, and 1 mole = 6.022×10^{23} , how many eggs are in 2.5 dozen? ($2.5 \times 12 = 30$ eggs). How many molecules in 2.5 moles? ($2.5 \times 6.022 \times 10^{23} = 1.51 \times 10^{24}$ molecules)."*

SEGMENT 3: Molar Mass — The Mass of One Mole (15 minutes)

Teacher says: "The periodic table shows atomic mass in atomic mass units (amu). Amazingly, the same number in grams is the mass of one mole of that element."

Molar mass is the mass of one mole of a substance (in grams per mole — g/mol).

Numerically, it equals the atomic/molecular mass in amu.

Molar Mass Examples

Substance	Atomic/Molecular Mass	Molar Mass	What One Mole Weighs
Carbon (C)	12.01 amu	12.01 g/mol	12.01 grams
Hydrogen (H_2)	2.016 amu	2.016 g/mol	2.016 grams
Oxygen (O_2)	32.00 amu	32.00 g/mol	32.00 grams
Water (H_2O)	18.016 amu	18.016 g/mol	18.016 grams
Table salt (NaCl)	58.44 amu	58.44 g/mol	58.44 grams
Baking soda (NaHCO_3)	84.01 amu	84.01 g/mol	84.01 grams

Teacher: *"Notice: One mole of water weighs about 18 grams — about 3-4 teaspoons of water. But that 18 grams contains 6.022×10^{23} water molecules."*

Calculating Molar Mass from the Periodic Table

Step-by-step method:

Step	What to Do
Step 1	Write the chemical formula.
Step 2	Find each element's atomic mass on the periodic table.
Step 3	Multiply each atomic mass by the number of atoms of that element.
Step 4	Add them all together.

Worked Example 1: Water (H₂O)

Element	Atoms	Atomic Mass (g/mol)	Contribution
H	2	× 1.008	= 2.016
O	1	× 16.00	= 16.00
Total			18.016 g/mol

Worked Example 2: Baking Soda (NaHCO₃)

Element	Atoms	Atomic Mass (g/mol)	Contribution
Na	1	× 22.99	= 22.99
H	1	× 1.008	= 1.008
C	1	× 12.01	= 12.01
O	3	× 16.00	= 48.00
Total			84.008 g/mol

Worked Example 3: Table Salt (NaCl)

Element	Atoms	Atomic Mass (g/mol)	Contribution
Na	1	× 22.99	= 22.99
Cl	1	× 35.45	= 35.45
Total			58.44 g/mol

Worked Example 4: Sugar (Sucrose — C₁₂H₂₂O₁₁)

Element	Atoms	Atomic Mass (g/mol)	Contribution
C	12	× 12.01	= 144.12
H	22	× 1.008	= 22.176
O	11	× 16.00	= 176.00
Total			342.296 g/mol

Teacher: "That's why one mole of sugar (342 grams) feels heavier than one mole of water (18 grams) — sugar molecules are much heavier."

Quick check (show of hands): "What is the molar mass of carbon dioxide (CO₂)?" (12.01 + 32.00 = 44.01 g/mol)

SEGMENT 4: Converting Between Grams, Moles, and Particles (12 minutes)

Teacher says: "Now we can move between grams (what we can weigh), moles (the counting unit), and number of particles (what's actually reacting)."

The Conversion Triangle

text

Grams

↑

| (divide by molar mass)

|

Moles ←——→ Particles

(multiply by 6.022×10^{23})

Conversion formulas:

Conversion	Formula
Moles → Grams	Grams = Moles × Molar mass
Grams → Moles	Moles = Grams ÷ Molar mass
Moles → Particles	Particles = Moles × 6.022×10^{23}
Particles → Moles	Moles = Particles ÷ 6.022×10^{23}

Worked Example 1: Moles to Grams

Problem: How many grams are in 0.50 moles of baking soda (NaHCO_3 , molar mass = 84.01 g/mol)?

Step	Calculation
Step 1	Use the formula: Grams = Moles \times Molar mass
Step 2	Grams = 0.50 mol \times 84.01 g/mol
Step 3	Grams = 42.01 grams

Answer: 0.50 moles of baking soda weighs 42.01 grams (about 8-9 teaspoons).

Worked Example 2: Grams to Moles

Problem: You have 10.0 grams of table salt (NaCl , molar mass = 58.44 g/mol). How many moles is that?

Step	Calculation
Step 1	Use the formula: Moles = Grams \div Molar mass
Step 2	Moles = 10.0 g \div 58.44 g/mol
Step 3	Moles = 0.171 mol

Answer: 10.0 grams of table salt is 0.171 moles.

Worked Example 3: Grams to Particles (Two Steps)

Problem: How many molecules of water are in 36.0 grams of water (H_2O , molar mass = 18.016 g/mol)?

Step	Calculation
Step 1	Convert grams to moles: Moles = 36.0 g \div 18.016 g/mol = 2.00 mol
Step 2	Convert moles to particles: Particles = 2.00 mol \times 6.022×10^{23} = 1.204×10^{24} molecules

Answer: 36.0 grams of water contains 1.20×10^{24} molecules.

Household connection: 36 grams of water is about 2 tablespoons — and it contains over a trillion trillion molecules!

Worked Example 4: Particles to Grams (Two Steps)

Problem: A sample contains 3.011×10^{23} molecules of CO_2 . How many grams is this? (Molar mass CO_2 = 44.01 g/mol)

Step	Calculation
Step 1	Convert particles to moles: Moles = $(3.011 \times 10^{23}) \div (6.022 \times 10^{23}) = 0.500 \text{ mol}$
Step 2	Convert moles to grams: Grams = $0.500 \text{ mol} \times 44.01 \text{ g/mol} = 22.01 \text{ grams}$

Answer: 3.011×10^{23} molecules of CO_2 weighs 22.01 grams.

Partner talk (2 minutes): *"You have 5.0 grams of table salt (NaCl, molar mass = 58.44 g/mol). How many moles is that? ($5.0 \div 58.44 = 0.086$ moles)."*

SEGMENT 5: Limiting Reactant — The Ingredient That Runs Out First (12 minutes)

Teacher says: "In Level 1, you learned about limiting reactant using cookies. Now let's do the math."

Limiting reactant (LIM-it-ing ree-AK-tant): The reactant that runs out first. It determines how much product you can make.

Recipe Analogy (Cookies)

Teacher: "A cookie recipe requires:

2 cups flour

1 cup sugar

2 eggs

Makes 24 cookies

You have: 6 cups flour, 3 cups sugar, and 4 eggs. Which runs out first?"

Ingredient	Have	Needed per batch	Maximum batches
Flour	6 cups	2 cups	$6 \div 2 = 3$ batches
Sugar	3 cups	1 cup	$3 \div 1 = 3$ batches
Eggs	4 eggs	2 eggs	$4 \div 2 = 2$ batches (lowest)

Answer: Eggs are the limiting reactant. You can only make 2 batches (48 cookies), even though you have enough flour and sugar for 3 batches.

Chemical Reaction Example: Baking Soda + Vinegar

Balanced equation:

text



Teacher: "1 mole of baking soda reacts with exactly 1 mole of vinegar."

Problem: You have 2.0 moles of baking soda and 1.5 moles of vinegar. Which is limiting? How much CO₂ can you make?

Reactant	Have	Needed per reaction	Maximum reactions
Baking soda	2.0 mol	1 mol	$2.0 \div 1 = 2.0$
Vinegar	1.5 mol	1 mol	$1.5 \div 1 = 1.5$ (lowest)

Step-by-step:

Step	Calculation
Step 1	Vinegar is limiting (1.5 mol available, needs 1 mol per reaction)
Step 2	The reaction produces 1 mole of CO ₂ per 1 mole of vinegar
Step 3	CO ₂ produced = 1.5 mol

Answer: Limiting reactant = vinegar. You can make 1.5 moles of CO₂.

Worked Example: Grams to Limiting Reactant

Problem: You have 10.0 grams of baking soda (NaHCO₃, molar mass = 84.01 g/mol) and 10.0 grams of vinegar (assume pure acetic acid — HC₂H₃O₂, molar mass = 60.05 g/mol for calculation). Which is limiting? How much CO₂ (molar mass = 44.01 g/mol) can you make?

Step 1: Convert grams to moles for both reactants

Reactant	Grams	Molar Mass	Moles
Baking soda	10.0 g	÷ 84.01 g/mol	= 0.119 mol
Vinegar (acetic acid)	10.0 g	÷ 60.05 g/mol	= 0.166 mol

Step 2: Compare using balanced equation (1:1 ratio)

Reactant	Moles available	Needed per reaction	Maximum reactions
Baking soda	0.119 mol	1 mol	$0.119 \div 1 = 0.119$ (lower)
Vinegar	0.166 mol	1 mol	$0.166 \div 1 = 0.166$

Step 3: Identify limiting reactant

Answer: Baking soda is limiting (0.119 mol < 0.166 mol).

Step 4: Calculate CO₂ produced

The reaction produces 1 mole of CO₂ per 1 mole of baking soda. Moles CO₂ = 0.119 mol

Step 5: Convert moles CO₂ to grams

Step	Calculation
Grams CO ₂ = 0.119 mol × 44.01 g/mol	= 5.24 grams

Final answer: Baking soda is limiting. You can make 5.24 grams of CO₂ gas (the fizz).

Household Safety Connection: Pool Chlorine

Teacher: "Pool chlorine products often contain calcium hypochlorite (Ca(ClO)₂). If you add more than the recommended amount, chlorine becomes the excess reactant — and that excess chlorine can burn swimmers' skin and lungs."

Scenario	Limiting Reactant	Excess Reactant	Safety Result
Correct dose	Contaminants in water	None (balanced)	Safe
Too much chlorine	Contaminants	Chlorine	Chemical burns

Teacher: "That's why you never 'eyeball' pool chemicals. The math keeps people safe."

SEGMENT 6: Percent Yield — How Much You Actually Get (10 minutes)

Teacher says: "In theory, reactions produce a certain amount of product — the theoretical yield (thee-uh-RET-i-kul yeeld). In real life, you almost always get less — the actual yield. The percent yield tells you how efficient the reaction was."

Percent yield = (Actual yield ÷ Theoretical yield) × 100%

Why you get less than 100%:

Reason	Household Example
Some product sticks to container	Batter stuck to the bowl
Reaction doesn't go to completion	Fizzing stops before vinegar is gone
Side reactions occur	Some sugar burns instead of caramelizing
Product is lost during transfer	Spilling flour while measuring

Worked Example: Baking Soda + Vinegar

Problem: In the previous example, you should have made 5.24 grams of CO₂ (theoretical yield). But when you do the experiment, you only collect 4.50 grams. What is your percent yield?

Step	Calculation
Step 1	Percent yield = (Actual ÷ Theoretical) × 100%
Step 2	Percent yield = (4.50 g ÷ 5.24 g) × 100%
Step 3	Percent yield = 0.8588 × 100%
Step 4	Percent yield = 85.9%

Answer: The reaction was about 86% efficient.

Worked Example: Burning Methane (Your Stove)

Problem: You burn 16.0 grams of methane (CH₄ — 1 mole). The theoretical yield of CO₂ is 44.0 grams. If your stove produces 40.0 grams of CO₂, what is the percent yield?

Step	Calculation
Step 1	Percent yield = (40.0 g ÷ 44.0 g) × 100%
Step 2	Percent yield = 0.909 × 100%
Step 3	Percent yield = 90.9%

Teacher: "The missing CO₂ is due to incomplete combustion — some methane might produce carbon monoxide (CO) instead of CO₂. That's why you need good ventilation and a CO detector."

Partner talk (1 minute): "Tell your partner: If a reaction has a theoretical yield of 10 grams and you actually get 8 grams, what is the percent yield?" (80%)

SEGMENT 7: Putting It All Together — A Complete Stoichiometry Problem (6 minutes)

Teacher says: "Let's do one complete problem that uses everything from today's lecture."

Problem: You want to make carbon dioxide (CO₂) using the reaction:

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You start with 25.0 grams of baking soda (NaHCO₃). The reaction produces 10.0 grams of CO₂. Calculate:

The molar mass of baking soda

How many moles of baking soda you have

The theoretical yield of CO₂ in grams

The percent yield

Step 1: Molar mass of baking soda (same as earlier)

Element	Atoms	Atomic Mass	Contribution
Na	1	× 22.99	= 22.99
H	1	× 1.008	= 1.008
C	1	× 12.01	= 12.01
O	3	× 16.00	= 48.00
Total			84.008 g/mol

Step 2: Moles of baking soda

Step	Calculation
Moles = 25.0 g ÷ 84.008 g/mol	= 0.2976 mol

Step 3: Theoretical yield of CO₂

From balanced equation: 1 mole baking soda → 1 mole CO₂ Moles CO₂ = 0.2976 mol

Molar mass of CO₂ = 44.01 g/mol Theoretical yield = 0.2976 mol × 44.01 g/mol = 13.10 grams

Step 4: Percent yield

Step	Calculation
Percent yield = (10.0 g ÷ 13.10 g) × 100%	= 76.3%

Final answers:

Molar mass = 84.01 g/mol

Moles baking soda = 0.298 mol

Theoretical yield CO₂ = 13.10 g

Percent yield = 76.3%

CLOSING — The 60-Second Challenge (5 minutes)

Teacher says: "Pair up. Person A: 60 seconds — explain what a mole is and why chemists use it (use a dozen as analogy). Person B: 60 seconds — calculate the molar mass of carbon dioxide (CO₂) and then how many moles are in 22.0 grams of CO₂."

Answer for Person B: Molar mass $\text{CO}_2 = 44.01 \text{ g/mol}$; Moles = $22.0 \text{ g} \div 44.01 \text{ g/mol} = 0.500 \text{ mol}$.

Final takeaway table (show on screen / read aloud):

You learned...	Household Example
1 mole = 6.022×10^{23} particles (Avogadro's number)	Like a dozen (12) — but much bigger
Molar mass = mass of 1 mole (in g/mol)	Water = 18.016 g/mol; NaCl = 58.44 g/mol
Grams → Moles = divide by molar mass	10 g salt = 0.171 mol
Moles → Grams = multiply by molar mass	0.5 mol water = 9.0 g
Limiting reactant = the one that runs out first	Eggs limiting cookies, baking soda limiting CO_2
Theoretical yield = what you should get	13.1 g CO_2 from 25 g baking soda
Percent yield = $(\text{actual} \div \text{theoretical}) \times 100\%$	$(10.0 \text{ g} \div 13.1 \text{ g}) = 76\%$
Never eyeball pool chemicals	Excess chlorine = chemical burns

Final line (preview of L2-6): "Next session: Solutions & Solubility (Advanced) — calculating concentration (molarity), diluting bleach safely, and predicting whether a reaction will produce a solid (precipitate). See you then."

SUPPLEMENTARY MATERIALS FOR L2-5 (No Grade)

Resource	Household Connection	Description	How to Find It
PhET "Moles and Molar Mass" simulation	Interactive conversion practice	Drag and calculate	Search "PhET molar mass"
Avogadro's number visualizations	YouTube	How big is 6.022×10^{23} ?	Search "Avogadro's number visualized"
Limiting reactant kitchen activity	Cookie recipe	Hands-on stoichiometry	Search "limiting reactant cookies activity"
Percent yield in cooking	Recipes	Why you never get 100%	Search "percent yield cooking examples"

"This week, look at a nutrition label. Find the serving size in grams. That's the mass of one serving. If you knew the molar mass, you could calculate how many moles are in that serving — but for food, grams are more practical. Next time, tell us: what food did you look at?"