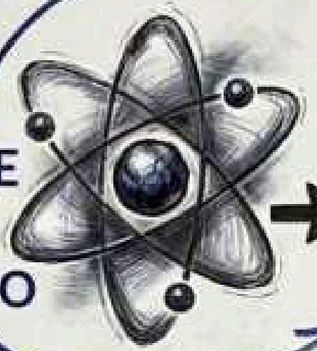
CHEM 101 B - Lecture 4:
The Mole and the Arithmetic of Reactions

¶ 4.1

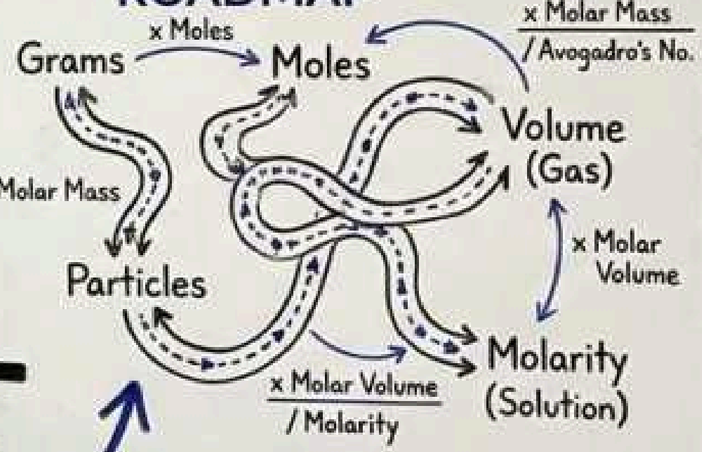


BALANCING EQUATIONS

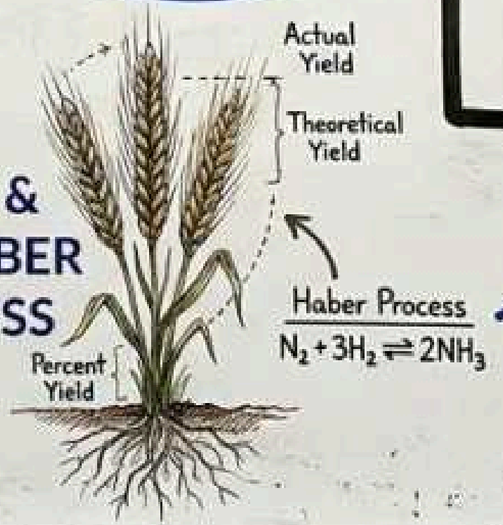
THE MOLE & AVOGADRO



THE STOICHIOMETRY ROADMAP



YIELD & THE HABER PROCESS



Haber Process

$N_2 + 3H_2 \rightleftharpoons 2NH_3$

Bulk Counting Required

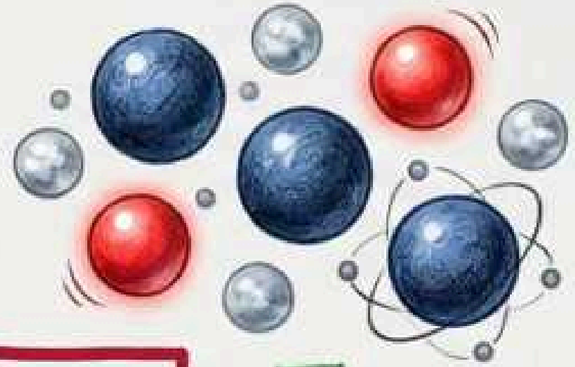
94.2

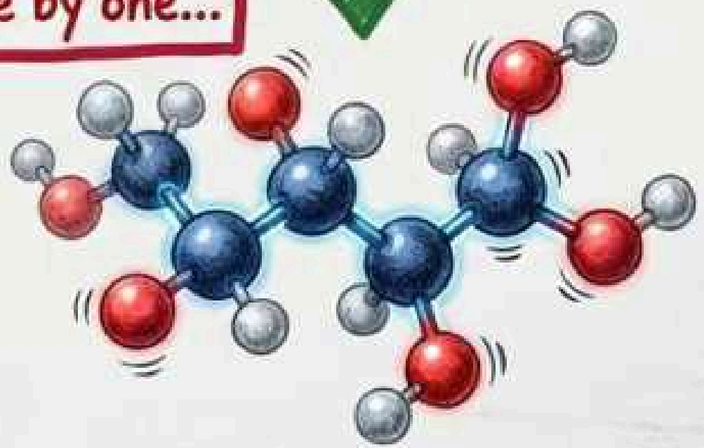
The Recipe





The Chemical Equation



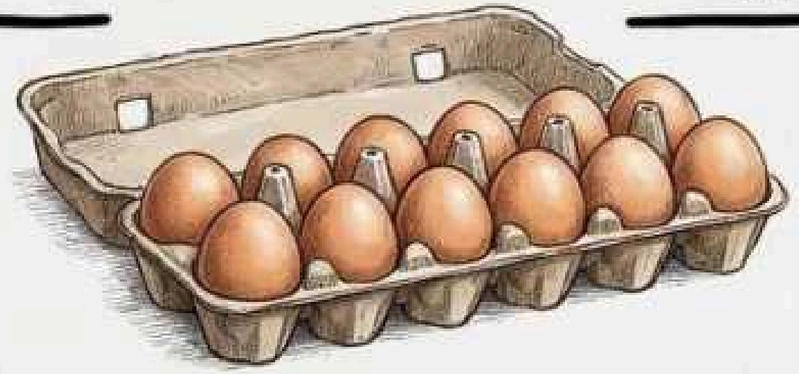


A recipe maps ingredients to food.
An equation maps atoms to molecules.
But atoms are too small to count one by one...

Avogadro's Number: The Chemist's Dozen

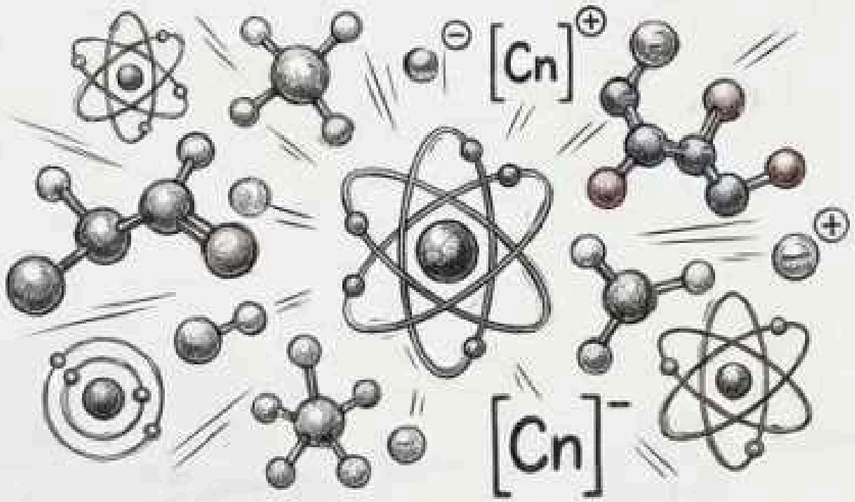
94.3

A Dozen = 12

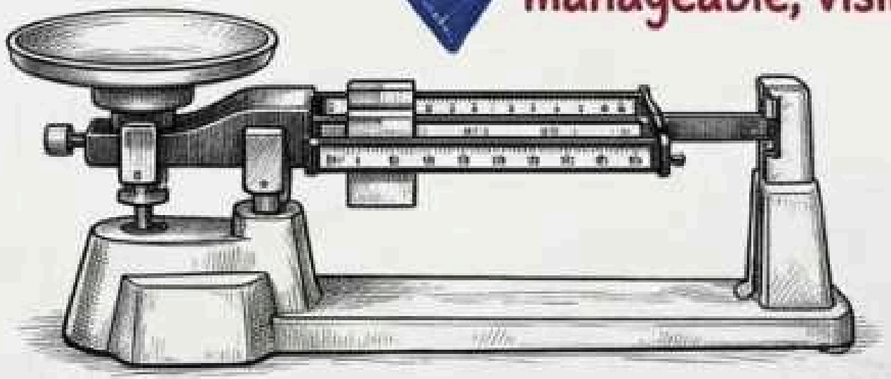




A Mole = 6.022×10^{23}



Links the invisible world of atoms to manageable, visible grams.



Molar Mass: From Periodic Table to the Scale

94.4

Carbon Proof

6
C
12.01

=



Water Proof

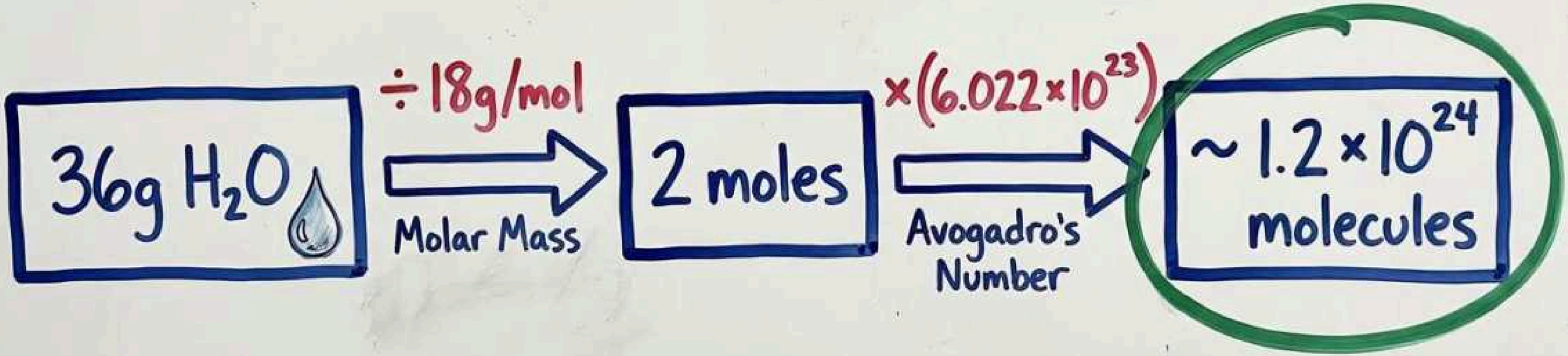
H_2O



$(2 \times 1g) + (1 \times 16g) = 18g/mol$

¶ 4.5

Converting Mass to Molecules



§4.6

The Anatomy of a Chemical Equation

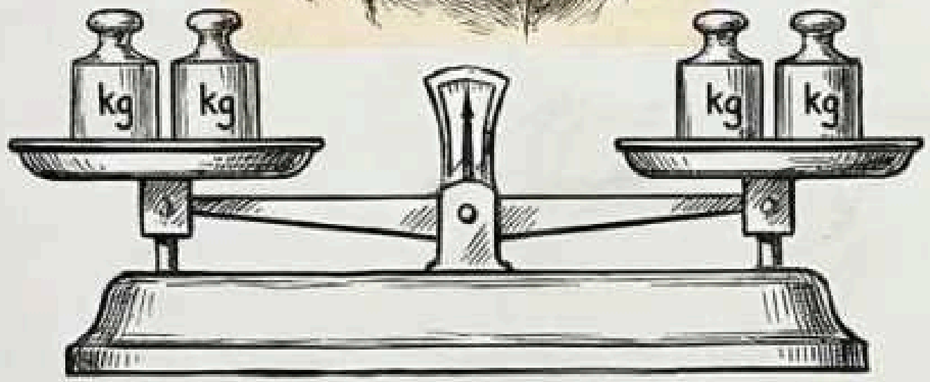


(s) = Solid	(ℓ) = Liquid
(g) = Gas	(aq) = Aqueous (Dissolved in water)

The Law of Conservation of Mass

9.4.7





"Atoms are rearranged, never created or destroyed."

Whiteboard Rule:

✓ Change Coefficients
(The big numbers in front)

✗ NEVER change Subscripts
(The small numbers inside)

Changes the substance entirely!

Balancing in Action: Burning Methane

§4.8

$$CH_4 + O_2 \longrightarrow CO_2 + 2H_2O$$

Tally Carbon	1 left, 1 right ✓
Tally Hydrogen	4 left, 2 right
Tally Oxygen	2 left, 4 right

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

The Five Reaction Patterns

¶ 4.9

Reaction Type	Visual Representation	Mathematical Formula
Combination		$A + B \rightarrow AB$
Decomposition		$AB \rightarrow A + B$
Single Displacement		$A + BC \rightarrow AC + B$
Double Displacement		$AB + CD \rightarrow AD + CB$
Combustion	$Substance + O_2 \rightarrow$ 	$Substance + O_2 \rightarrow$ [Realistic Flame Sketch] 

Coefficients are Mole Ratios

¶ 4.10

$$1CH_4 + 2O_2 \rightarrow 1CO_2 + 2H_2O$$

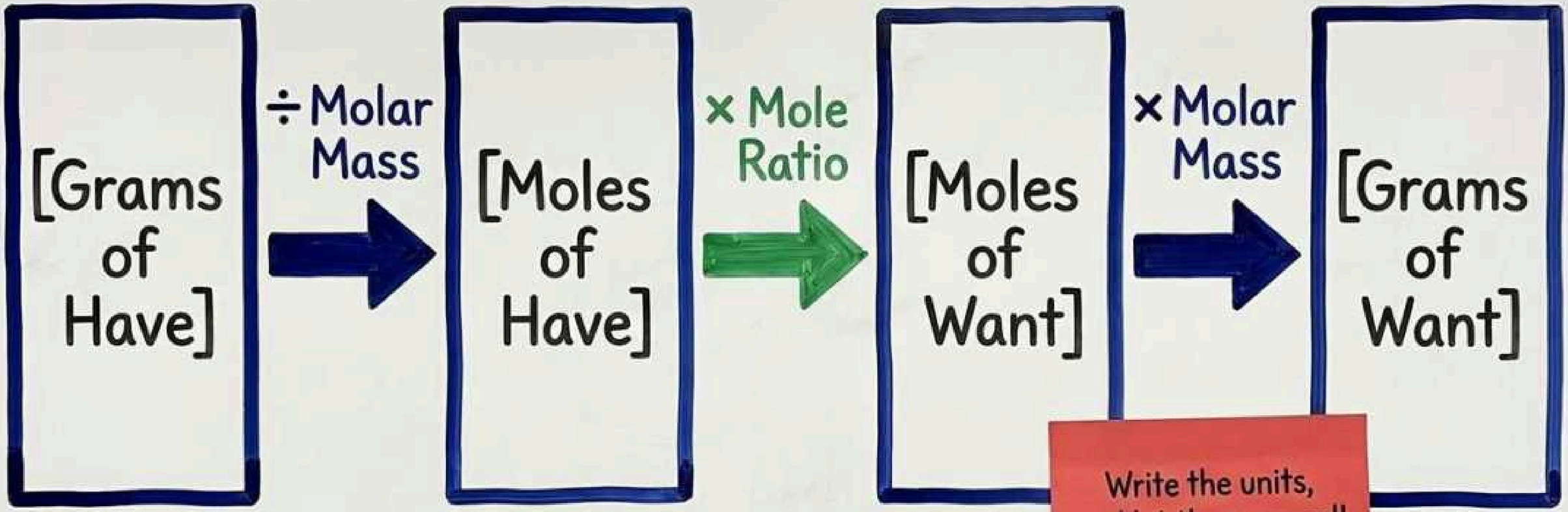
Ratios of Moles, NOT Grams.



The ratio holds for any amount, just like doubling a recipe.

The Stoichiometry Roadmap

¶ 4.11



Write the units, and let them cancel!

$\frac{\cancel{\text{mol}}}{\cancel{\text{mol}}} = 1$ (dimensionless)

Putting the Roadmap to Work

¶ 4.12

$16g\ CH_4 \div 16g/mol = 1\ mole\ CH_4$

↓

1:1 ratio → $1\ mole\ CO_2$

↓

$1\ mole\ CO_2 \times 44g/mol = \boxed{44g\ CO_2}$

Lavoisier's Check (Conservation of Mass)

Reactants: 16g (Methane) + 64g (Oxygen) = 80g

Products: 44g (Carbon Dioxide) + 36g (Water) = 80g



The Limiting Reagent

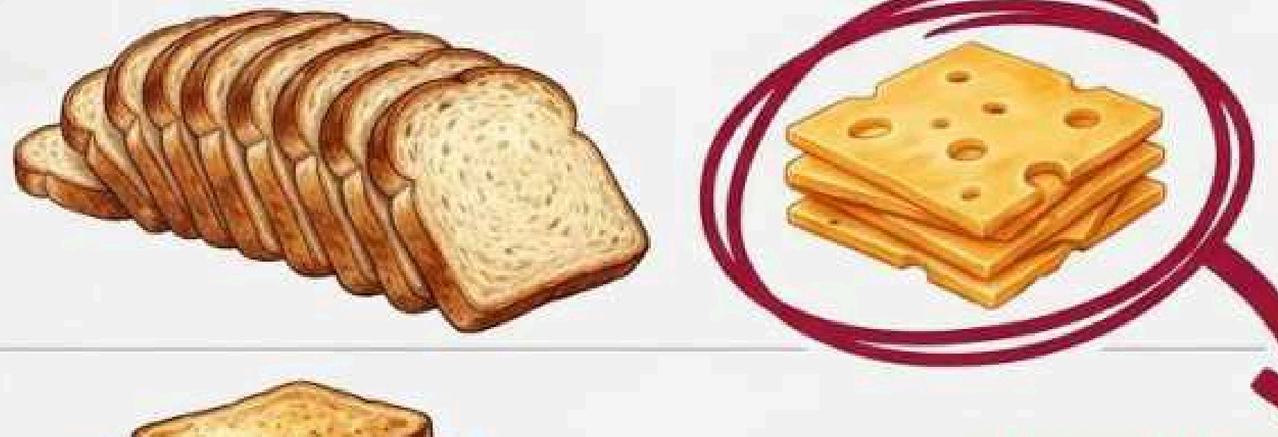
¶ 4.13

The Recipe



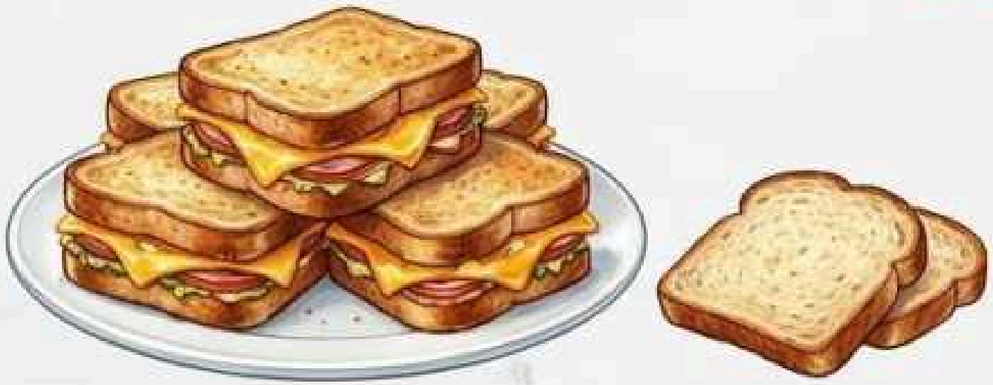
2 slices bread + 1 slice cheese = 1 sandwich

The Inventory



The Outcome

=



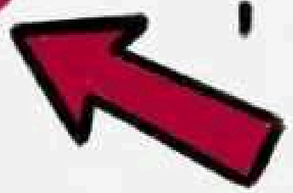
Limiting Reagent: Controls how much product can form.

Limiting Reagent in Chemistry

¶ 4.14

$$N_2 + 3H_2 \rightarrow 2NH_3$$

What We HAVE (Inventory)	What We NEED (Recipe)
28g N_2 (1 mole)	1 mole N_2 specifically requires 3 moles H_2.
4g H_2 (2 moles)	



Only have 2 moles. Hydrogen runs out first.
Hydrogen is LIMITING.

Calculating from the Limiting Reagent

¶ 4.15

$$2 \text{ moles } H_2 \times \left(\frac{2}{3} \text{ ratio}\right) = 1.33 \text{ moles } NH_3$$

$$1.33 \text{ moles} \times 17 g/mol = \boxed{22.7 g\ NH_3}$$

Theoretical Yield

CRITICAL RULE: Always work from the limiting reagent, never from the one in excess. About 0.33 moles of Nitrogen is left over unused.

Theoretical vs. Percent Yield

¶ 4.16

$$\text{Percent Yield} = \left(\frac{\text{Actual}}{\text{Theoretical}}\right) \times 100$$

Side reactions

Incomplete reactions

Losses in handling

$$\frac{20\text{g}}{22.7\text{g}} \times 100 = 88\%$$

Real-World Consequences: The Haber Process

¶ 4.17

Feeds billions.
Profit vs. Waste.



Feeds billions.
Profit vs. Waste.

The Three Golden Rules for Troubleshooting

- ☐ Is the equation balanced?
- ☐ Are the units cancelling?
- ☐ Is the answer sensible?

¶ 4.18

Lecture Question

Task 1: Balance the equation for burning Hydrogen (H_2) to make Water (H_2O).

Task 2: Calculate how many grams of Water you get from 4 grams of Hydrogen.

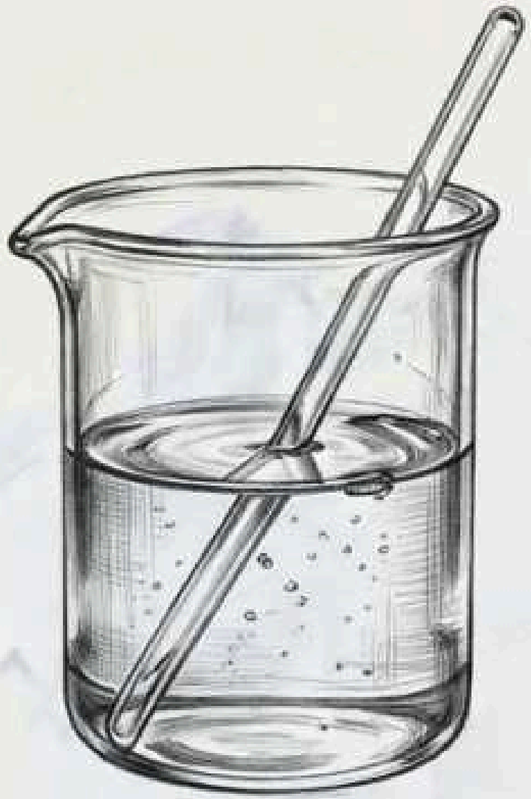
Task 3: Write down each step using the roadmap.



Next Time: Lecture 5

¶ 4.19





Applying stoichiometry to gases and solutions, and observing how reactions behave in water.