STOICHIOMETRY

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STOICHIOMETRY

Elements Measure

Stoichiometry

Calculate quantities of substances in chemical reactions

For a balanced chemical equation, the Coefficients show:

 # formula units that react

mole ratio of reactants & products

(with molar mass) # grams of reactants & products

Let the units drive the solution

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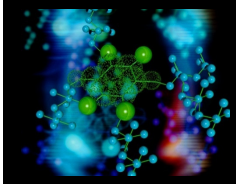
Mole Map (One Chemical Entity)



Avagadro's

$\frac{6.02 \times 10^{23} \text{ fu}}{\text{mole}}$

Molar Mass

$\frac{\text{g}}{\text{mole}}$

Atomic Units | Moles | Grams

Avogadro's Number: From Memory
Molar Mass: Calculated from Periodic Table
Let the Units Drive the Solution!

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Stoichiometry (For Two Chemical Entities)

Think Molar Ratio

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Molecule – Molecule Stoichiometry

$2\ C_2H_6 + 7\ O_2 \rightarrow 4\ CO_2 + 6\ H_2O$

Molecular Interpretation:

2 *molecules* C_2H_6 (ethane) react with 7 *molecules* O_2
to form
4 *molecules* CO_2 & 6 *molecules* H_2O

Burning fossil fuels is major contributor to global warming

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Molecule – Molecule Stoichiometry

$4\ NH_3 + 5\ O_2 \rightarrow 4\ NO + 6\ H_2O$

How many O_2 molecules react with 308 molecules NH_3?

Given (known) = 308 molecules NH_3
Wanted = # molecules O_2

308 molecules NH_3 = # molecules O_2

Need "per" expression (from balanced chemical reaction)
to convert molecules of ammonia to molecules oxygen

$$308\ \text{molecules}\ NH_3 \times \frac{5\ O_2\ \text{molecules}}{4\ NH_3\ \text{molecules}} = 385\ O_2\ \text{molecules}$$

From Coefficients of BALANCED Reaction

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Mole – Mole Stoichiometry

$2\ C_2H_6 + 7\ O_2 \rightarrow 4\ CO_2 + 6\ H_2O$

Molar Interpretation:

2 *moles* C_2H_6 (ethane) react with 7 *moles* O_2
to form
4 *moles* CO_2 & 6 *moles* H_2O

Burning fossil fuels is major contributor to global warming

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Mole – Mole Stoichiometry

$4\ NH_3 + 5\ O_2 \rightarrow 4\ NO + 6\ H_2O$

How many moles H_2O are formed from 4 moles NH_3?

Given (known) = 4 moles NH_3
Wanted = # moles H_2O

Need "per" expression (from balanced chemical reaction)
to convert molecules of ammonia to molecules oxygen

$$4 \text{ mole } NH_3 \times \frac{6\ H_2O \text{ moles}}{4\ NH_3 \text{ moles}} = 6\ H_2O \text{ moles}$$

From Coefficients of BALANCED Reaction

Let the units drive the solution

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Stoichiometry: Per Expressions

$2\ C_2H_6 + 7\ O_2 \rightarrow 4\ CO_2 + 6\ H_2O$

Relating C_2H_6 (ethane) to other components

$\frac{2 \text{ moles } C_2H_6}{7 \text{ moles } O_2}$ $\frac{2 \text{ moles } C_2H_6}{4 \text{ moles } CO_2}$ $\frac{2 \text{ moles } C_2H_6}{6 \text{ moles } H_2O}$

2 moles of C_2H_6 corresponds to:
7 moles O_2
4 moles CO_2
6 moles H_20

Let the units drive the solution

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Stoichiometry: Per Expressions

$2\ C_2H_6 + 7\ O_2 \rightarrow 4\ CO_2 + 6\ H_2O$

"per expressions" (Conversion factors)
based on coefficients of balanced equation

$\frac{2 \text{ moles } C_2H_6}{7 \text{ moles } O_2}$ $\frac{2 \text{ moles } C_2H_6}{6 \text{ moles } H_2O}$ $\frac{2 \text{ moles } C_2H_6}{4 \text{ moles } CO_2}$

$\frac{7 \text{ moles } O_2}{2 \text{ moles } C_2H_6}$ $\frac{7 \text{ moles } O_2}{4 \text{ moles } CO_2}$ $\frac{7 \text{ moles } O_2}{6 \text{ moles } H_2O}$

$\frac{4 \text{ moles } CO_2}{2 \text{ moles } C_2H_6}$ $\frac{4 \text{ moles } CO_2}{7 \text{ moles } O_2}$ $\frac{4 \text{ moles } CO_2}{6 \text{ moles } H_2O}$

$\frac{6 \text{ moles } H_2O}{2 \text{ moles } C_2H_6}$ $\frac{6 \text{ moles } H_2O}{7 \text{ moles } O_2}$ $\frac{6 \text{ moles } H_2O}{4 \text{ moles } CO_2}$

Molar Ratio
Relates Any 2
Chemical Entities

Let the units drive the solution

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Stoichiometry: Per Expressions

Always has the form:

$$\frac{\text{Moles wanted in next step}}{\text{Moles canceled in previous step}}$$

Relates moles (never grams) chemical entities via coefficients of the balanced chemical reaction

Let the units drive the solution

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Mole – Mole Stoichiometry

How many moles of oxygen are required to burn 2.4 moles ethane?

$$2\ C_2H_6 + 7\ O_2 \rightarrow 4\ CO_2 + 6\ H_2O$$

Given = 2.4 moles ethane

Wanted = moles oxygen

Use "per" expression from the balanced reaction

$$2.4 \text{ moles ethane} \times \frac{7 \text{ moles oxygen}}{2 \text{ moles ethane}} = 8.4 \text{ moles } O_2$$

Just another unit "cancelation"

Let the units drive the solution

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Mole – Mole Stoichiometry

Ammonia is formed from its elements.
How many moles of hydrogen are needed to produce 4.2 moles ammonia?

Write equation: $N_2 + H_2 \rightarrow NH_3$

Balance Equation: $N_2 + 3\ H_2 \rightarrow 2\ NH_3$

Add "per expression" to move from given to wanted:

$$4.2 \text{ moles } NH_3 \times \frac{3 \text{ moles } H_2}{2 \text{ moles } NH_3} = \#\text{ moles } H_2$$

Do the math:

$$4.2 \text{ moles } NH_3 \times \frac{3 \text{ moles } H_2}{2 \text{ moles } NH_3} = 6.3 \text{ moles } H_2$$

Let the units drive the solution

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Mole – Mole Stoichiometry

How many moles of C_2H_4 can be oxidized by 1.35 mol O_2?

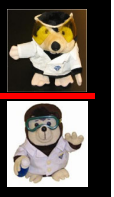
$$C_2H_4 + 3\ O_2 \rightarrow 2\ CO_2 + 2\ H_2O$$

Given = 1.35 moles oxygen
Wanted = moles ethylene

$$1.35 \text{ mol } O_2 = \text{moles } C_2H_4$$

Convert moles given to moles wanted via "per" expression

$$1.35 \text{ mol } O_2 \times \frac{1 \text{ mole } C_2H_4}{3 \text{ mole } O_2} = \text{moles } C_2H_4$$



Units correct; do the math

$$1.35 \text{ mol } O_2 \times \frac{1 \text{ mole}}{3 \text{ mole } O_2} = 0.450 \text{ moles } C_2H_4$$

Let the units drive the solution

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Mass – Mass Stoichiometry

Types of problems that coefficients + molar mass solve:

grams (given) → moles (wanted)
moles (given) → moles (wanted)
moles (given) → grams (wanted)
grams (given) → grams (wanted)

"Per" Expression" (Molar Ratio)

Molar Mass

Grams ➔ Moles ➔ Moles ➔ Grams

Molar Mass

Given Wanted

Just another
What is known?
What is wanted?
How do I get there by "canceling units"?
Type problem

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Mass – Mole Stoichiometry

How many moles of oxygen are needed to form 43.7 g H_2O?

$$C_2H_4 + 3\ O_2 \rightarrow 2\ CO_2 + 2\ H_2O$$

Given = 43.7 grams water
Wanted = moles oxygen

43.7 g H_2O = moles O_2

Molar mass: water: 18.02 g/mole

Set up linear string of per expressions:

$$43.7\ g\ H_2O \times \frac{1\ mole\ H_2O}{18.02\ g} \times \frac{3\ mole\ O_2}{2\ mole\ H_2O} = moles\ O_2$$

Units correct; do the math:

$$43.7\ g\ H_2O \times \frac{1\ mole\ H_2O}{18.02\ g} \times \frac{3\ mole\ O_2}{2\ mole\ H_2O} = 3.64\ moles\ O_2$$

Let the units drive the solution

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Mole – Mass Stoichiometry

How many grams of CO_2 form by burning 0.739 mole C_2H_4?

$$C_2H_4 + 3\,O_2 \rightarrow 2\,CO_2 + 2\,H_2O$$

Given = 0.739 mole ethylene

Wanted = grams carbon dioxide

$0.739 \text{ mol } C_2H_4 = \#\text{ g } CO_2$

Molar Mass carbon dioxide: 44.01 g/mole

Set up linear string of per expressions:

$$0.739 \text{ mol } C_2H_4 \times \frac{2 \text{ mol } CO_2}{1 \text{ mol } C_2H_4} \times \frac{44.01 \text{ g}}{1 \text{ mole } CO_2} = \#\text{ g } CO_2$$

Units correct; do the math:

$$0.739 \text{ mol } C_2H_4 \times \frac{2 \text{ mol } CO_2}{1 \text{ mol } C_2H_4} \times \frac{44.01 \text{ g}}{1 \text{ mole } CO_2} = 65.0 \text{ g } CO_2$$

Let the units drive the solution

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Mass – Mass Stoichiometry

How many grams of oxygen required to burn 155 g ethane?

$$2\,C_2H_6 + 7\,O_2 \rightarrow 4\,CO_2 + 6\,H_2O$$

Molar masses: ethane: 30.07 g/mole ; oxygen: 32.00 g/mole

Start with given (g) and convert to moles using molar mass:

$$155 \text{ g } C_2H_6 \times \frac{1 \text{ mole } C_2H_6}{30.07 \text{ g}} = \#\text{ g } O_2$$

Convert moles known to moles wanted with "per expression"

$$155 \text{ g } C_2H_6 \times \frac{1 \text{ mole } C_2H_6}{30.07 \text{ g}} \times \frac{7 \text{ Moles } O_2}{2 \text{ Moles } C_2H_6} = \#\text{ g } O_2$$

Convert moles oxygen to grams oxygen using molar mass:

$$155 \text{ g } C_2H_6 \times \frac{1 \text{ mol } C_2H_6}{30.07 \text{ g}} \times \frac{7 \text{ Mol } O_2}{2 \text{ Mol } C_2H_6} \times \frac{32.00 \text{ g}}{1 \text{ mol}} = \#\text{ g } O_2$$

Units correct; do the math:

$$155 \text{ g } C_2H_6 \times \frac{1 \text{ mol } C_2H_6}{30.07 \text{ g}} \times \frac{7 \text{ Mol } O_2}{2 \text{ Mol } C_2H_6} \times \frac{32.00 \text{ g}}{1 \text{ mol}} = 577 \text{ g } O_2$$

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Mass – Mass Stoichiometry

How many grams of Al must react with O_2 to form 43.6 grams of Al_2O_3?

$$4\ Al + 3\ O_2 \rightarrow 2\ Al_2O_3$$

Given = 43.6 grams Al_2O_3

Wanted = grams Al

Molar masses: Al = 26.98 g/mole; Al_2O_3 = 101.96 g/mole

Set up linear string of per expressions:

$$43.6\text{ g } Al_2O_3 \times \frac{1\text{ mole } Al_2O_3}{101.96\text{ g}} \times \frac{4\text{ moles Al}}{2\text{ moles } Al_2O_3} \times \frac{26.98\text{ g Al}}{1\text{ mole}} = \#\text{ g Al}$$

Units correct; do the math:

$$43.6\text{ g } Al_2O_3 \times \frac{1\text{ mole } Al_2O_3}{101.96\text{ g}} \times \frac{4\text{ moles Al}}{2\text{ moles } Al_2O_3} \times \frac{26.98\text{ g Al}}{1\text{ mole}} = 23.1\text{ g Al}$$

Let the units drive the solution

LPT

If the density of water is 1.00 g/mL, how many mL of H_2O are produced when 6.70 moles of HNO_3 reacts with KOH?

$$HNO_{3(aq)} + KOH_{(aq)} \rightarrow KNO_{3(aq)} + H_2O_{(l)}$$

$$6.70\text{ mol } HNO_3 \times \frac{1\text{ mol } H_2O}{1\text{ mol } HNO_3} \times \frac{18.02\text{ g } H_2O}{1\text{ mol } H_2O} \times \frac{1\text{ mL } H_2O}{1.00\text{ g } H_2O} = 121\text{ mL}$$

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Generalized Pathway

"Per" Expression" (Molar Ratio)

Molar Mass

Grams ➔ Moles ➔ Moles ➔ Grams

Molar Mass

Given Wanted

Entry & Exit Points Depend On

- Given
- Wanted

Let the units drive the solution

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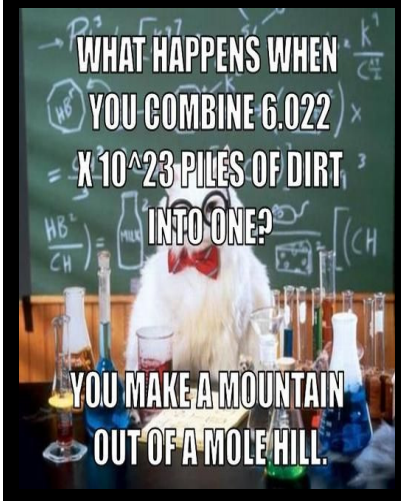

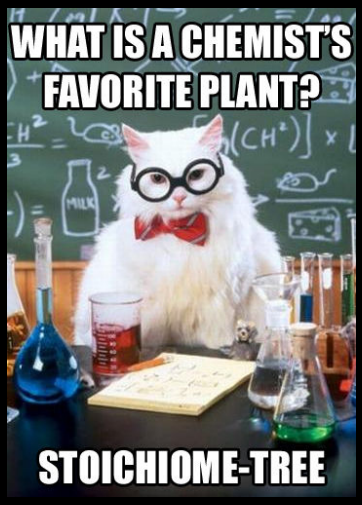

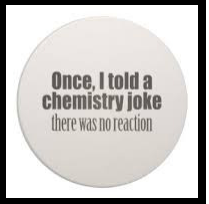

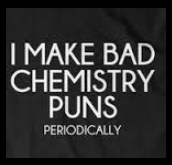

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