Calculating Yields

Terms:

Theoretical Yield:
Amount of product formed from *complete* conversion of a given amount of reactant to product

Actual Yield:
Amount of product obtained in an experiment

% Yield:
Actual yield expressed as a percentage of the theoretical yield

$$\% \text{ Yield} = \frac{\text{actual}}{\text{theoretical}} \times 100\%$$

Theoretical vs. Actual

Theoretical Yield	Actual Yield
Calculated	Measured
Larger	Smaller
"predicted" on paper	obtained in the laboratory
may be supplied (given) OR calculated from g(A) → g(B)	must be supplied (given)

Calculate a Percent Yield from experimental data:

A combustion reaction produced 45.2 grams of CO_2. If the theoretical yield was 57.3 grams of , what is the percent yield?

Given: actual yield = 45.2 g carbon dioxide
theoretical yield = 57.3 g carbon dioxide
Wanted: percent yield

% Yield = actual / theoretical x 100

$$\% \text{ Yield} = \frac{45.2 \text{ g}}{57.3 \text{ g}} \times 100 = 78.8831 \rightarrow 78.9$$

Calculate the percent yield if 70.6 grams of water were obtained when 52.5 grams of C_3H_8 were burned in oxygen.

Given: actual yield = 70.6 g water
starting material = 52.5 g propane
Wanted: percent yield

Since grams given, must determine molar mass:
water: 18.02 g/mole; propane = 44.10 g/mole

Set-up conversion string for theoretical yield of water

$$52.5\text{ g} \times \frac{1\text{ mole}}{44.10\text{ g}} \times \frac{4\text{ mole } H_2O}{1\text{ mole } C_3H_8} \times \frac{18.02\text{ g}}{1\text{ mole}} = 85.8\text{ g}$$

% Yield – actual/theory x 100

$$\%\text{ Yield} = \frac{70.6\text{ g}}{85.8\text{ g}} \times 100 = 82.3$$

Magnesium Oxide plus water yields magnesium hydroxide. If this process yields 81.3 % of the hydroxide, how much magnesium oxide should be used to make 800 kg of the hydroxide?

Write Equation, then balance:
$MgO + H_2O \rightarrow Mg(OH)_2$

Since stoichiometry is based on theoretical yield:

$$800\text{ kg (actual)} \times \frac{100\text{ kg (theory)}}{81.3\text{ kg (actual)}} = 984\text{ kg (theory)}$$

Like empirical formula calculations, percentage can be converted to 100 (units)

Given: 984 kg $Mg(OH)_2$
Wanted: kg MgO

Since kilograms given, must determine molar mass:
MgO = 40.34 ; $Mg(OH)_2$ = 58.32

Use "per" expressions based on the reaction:

$$984\text{ kg } Mg(OH)_2 \times \frac{1\text{ kmole}}{58.32\text{ kg}} \times \frac{1\text{ kmole MgO}}{1\text{ kmole } Mg(OH)_2} \times \frac{40.34\text{ kg (MgO)}}{1\text{ kmole}} = 680\text{ kg MgO}$$

Sodium sulfate is prepared from the reaction of sulfur, oxygen and sodium hydroxide. If this process yields 79.8 % sodium sulfate, how many grams can be prepared from 36.9 g of sodium hydroxide?

Write Equation for this neutralization reaction, then balance:

$$2\ S + 3\ O_2 + 4\ NaOH \rightarrow 2\ Na_2SO_4 + 2\ H_2O$$

Given: 36.9 g NaOH
Wanted: actual Na_2SO_4

Since kilograms given, must determine molar mass:
NaOH = 40.00; Na_2SO_4 = 142.05

Use "per" expressions in linear string of conversions

$$36.9\ g\ NaOH \times \frac{1\ mole\ (NaOH)}{39.99\ g}$$

Now have moles NaOH, next convert to equivalent moles Na_2SO_4

$$36.9\ g\ NaOH \times \frac{1\ mole\ (NaOH)}{40.00\ g} \times \frac{2\ moles\ (Na_2SO_4)}{4\ moles\ (NaOH)}$$

Now have moles Na_2SO_4 , next convert to grams Na_2SO_4

$$36.9\ g\ NaOH \times \frac{1\ mole\ (NaOH)}{40.00\ g} \times \frac{2\ moles\ (Na_2SO_4)}{4\ moles\ (NaOH)} \times \frac{142.05\ g\ (Na_2SO_4)}{1\ mole} = 65.5\ g$$

65.5 g Na_2SO_4 is theoretical yield … actual would be

$$79.8 = \frac{actual}{theory} \times 100$$

actual = 79.8 (65.5 g) / 100
actual = 52.3 g

Lead (II) nitrate reacts with sodium iodide to form lead(II) iodide and sodium nitrate. What is the theoretical yield of lead (II) iodide if 138.820 g of sodium iodide are reacted with an excess amount of Lead(II) nitrate?

Write the balanced reaction: $Pb(NO_3)_{2\ (aq)} + 2\ NaI_{\ (aq)} \rightarrow PbI_{2\ (s)} + 2\ NaNO_{3\ (aq)}$

Molar Mass NaI = 149.89 g/mole; molar mass PbI_2 = 460.99 g/mole

Setting up the linear string starting with given mass of NaI:

$$138.820\ g \times \frac{1\ mole\ NaI}{149.89\ g} \times \frac{1\ mole\ PbI_2}{2\ moles\ NaI} \times \frac{460.99\ g}{mole\ PbI_2} = 213.472\ g$$

If 197.5 grams were isolated, what is the experimental yield?

$$\frac{197.5 \text{ g}}{213.472 \text{ g}} \times 100 = 92.5180 \rightarrow 92.52\ \%$$

Most chemical processes yield less than 100%

This becomes a severe problem for multiple-step operations
Say 90% yield for each step, then after 5 steps:

$(0.90)^5$ = ~ 59% of wanted product: rest may be useless

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Chemical manufacturing (and lab research)
centers around
Increasing % yields
Separating wanted products from reactants & unwanted products

Assignment

Continue Taking Unit 7 Practice Test
Blackboard only records highest score
Take until multiple 100's have been scored (questions are variable)
(Gives sense of test exam format and content)

The Practice Quiz is very similar to the Unit Exam
Success on Unit exam is directly related to practice exam experiences