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VCE Chemistry ¾
Gas Calculations & Stoichiometry [1.3]
Workbook

Outline:

Section A: Heat Loss & Energy Efficiency

Sub-Section: Recap

Definition

Change in Enthalpy (ΔH) Values in kJ/mol

- **Definition:** Provides the amount of energy released/absorbed during a chemical reaction **per mole**.
- **SI Units:** kJ/mol
- **Formulae:**

$$\Delta H = \frac{q}{n}$$

  - q – Energy (kJ)
  - n – Moles (mol)
  - ΔH – Change in Enthalpy Value (kJ/mol)
- **Alternative Name: Heat of Combustion** (only if it is a combustion reaction.)

Definition

Change in Enthalpy (ΔH) Values in kJ/g

- **Definition:** Provides the amount of energy released/absorbed during a chemical reaction **per gram**.
- **SI Units:** kJ/g
- **Formulae:**

$$\Delta H = \frac{q}{m}$$

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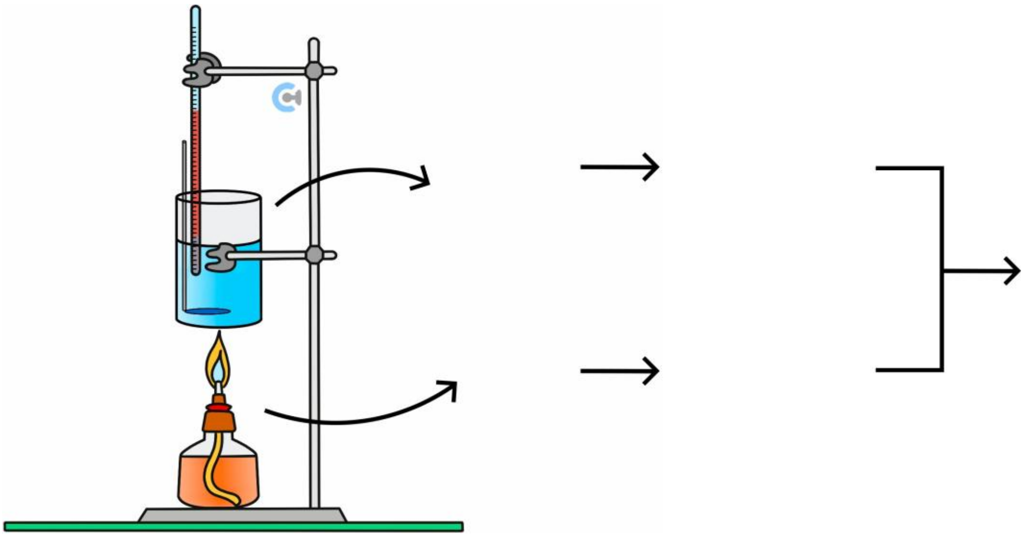
Definition

Calculating ΔH

- **Process:**



Let's look at a question together!

Question 1 (4 marks) **Walkthrough.**

A sample of ethane (C_2H_6) gas undergoes complete combustion in a sealed system. Initially, the container with the ethane weighs $250.45\ g$. After the combustion is complete, the container weighs $248.95\ g$. The heat released is entirely used to heat $400\ mL$ of water at SLC. The water's temperature increases from $25.00°C$ to $60.00°C$.

Calculate the heat of combustion of ethane in kJ/mol.

Question 2 (1 mark)

Snowy is playing with some fuels. She accidentally sets a butane canister that contains 2.20 g of butane on fire. Assuming an excess supply of oxygen, calculate the amount of energy released in kilojoules (kJ).

Question 3 (3 marks)

A sample of ethanol in a spirit burner which initially weighs 100.52 g undergoes complete combustion. After the combustion is complete, it is found that the spirit burner weighs 98.57 g. The heat energy released is used to heat 200 g of water at SLC. The temperature of the water rises to 50.0 C. Calculate the heat of combustion of ethanol in kJ/mol.

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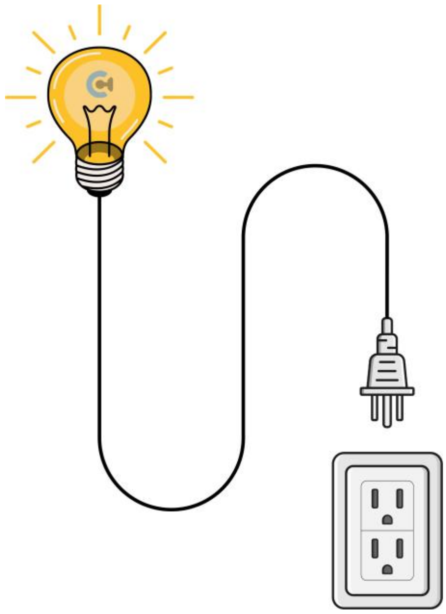
Sub-Section: Energy Efficiency

Context

- Imagine you are trying to light up a light bulb.



- Is this process 100% efficient? Does all the electrical energy from the wall go into the light energy of the light bulb?

[Yes] / [No]

- What other unwanted energy is produced in the meantime? ______________________

NOTE: Energy transformations are not 100% efficient, whereby energy is generally lost as ____________________________ energy.

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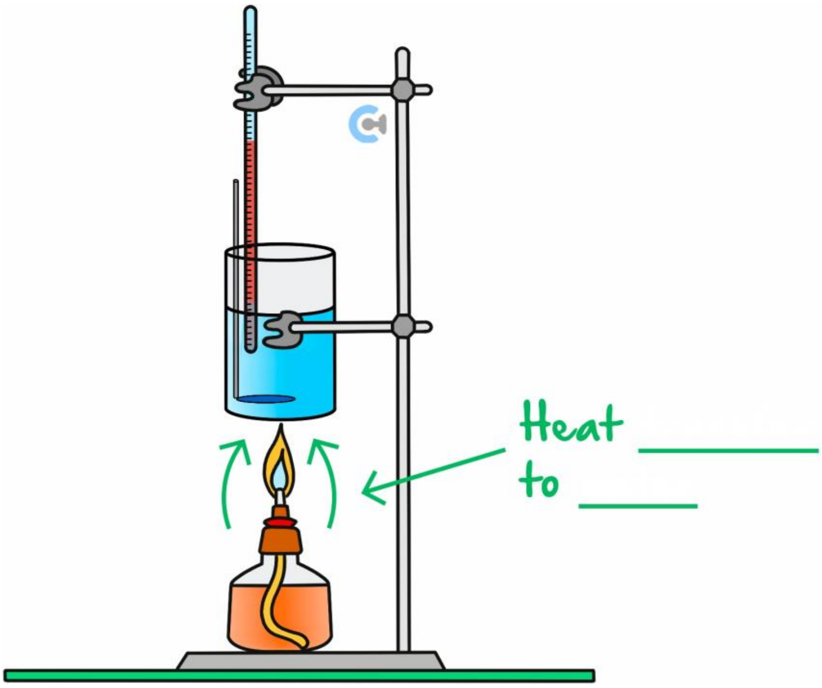
How does this look like when finding ΔH?

Exploration: Energy Loss when determining the heat of Combustion of Fuels

- Consider the following setup from before:
  - Where does the energy released by the spirit burner go? *(Label Below)*
  - Is all the thermal energy released by the fuel absorbed by the water? [Yes] / [No]
  - What type of energy is this lost as? *(Label Below)*

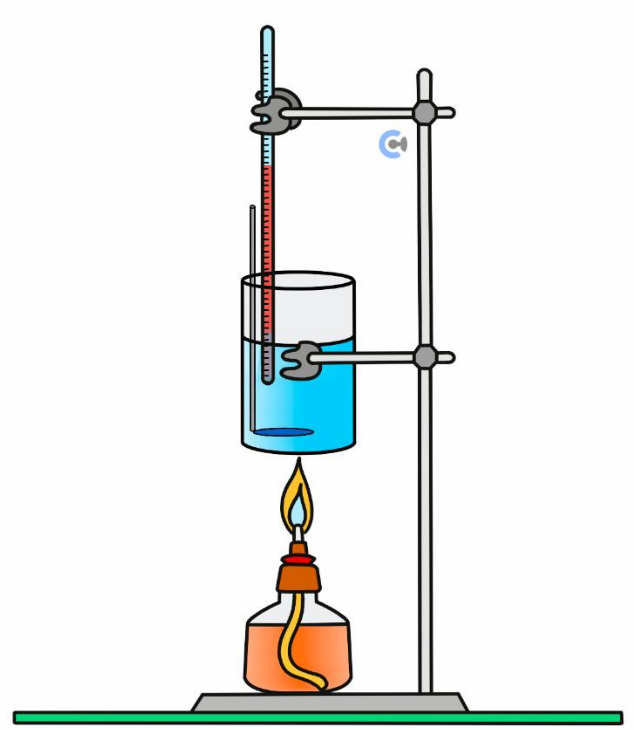


- As the process is not 100% efficient, we can try to calculate this energy efficiency.

Discussion: What is the approximate energy efficiency of this process? (Take a random guess)

Exploration: Calculating Energy Efficiency

- Consider the same setup as before. Given that:
  - Ethanol in the spirit burner releases $50\ kJ$ of energy. *(Label Below)*
  - The water in the beaker absorbs $15\ kJ$ of energy. *(Label Below)*



- **Percentage (%) efficiency:**

- **How did we obtain this percentage?**

REMINDER: Don't forget!

- When converting between decimal and percentage, we need to multiply/divide by 100%.

$$0.75 = 75\%$$

Definition

Percentage Efficiency (%)

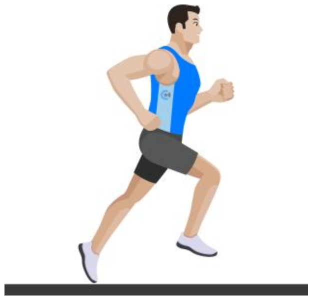
- **Definition:** A measure of how much energy supplied (input), is transformed into the final form of energy (output).
- **Formulae:**

$$\% \, eff = \frac{Experimental}{Theoretical} = \frac{Output}{Input}$$

Your turn!

Question 4

Matthew is an elite athlete and is preparing for a marathon race. To prepare, he consumes an apple, which contains 200 kJ of energy. This turns into 43 kJ of usable movement energy during his race.



a. Find the energy efficiency.

___

b. If he also consumes a pear which contains 130 kJ of energy, how much usable energy is he expected to obtain from this pear?

___

c. On another day, Matthew runs his second marathon, where it is found he requires 840 kJ of usable energy. How much energy in food should he have consumed beforehand?

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NOTE: The human body also requires fuel (food), which will be covered later in this AOS!

Let's link this to calculating ΔH!

Question 5 (5 marks) **Walkthrough.**

A sample of octane is burned completely in a calorimeter. The initial mass of the calorimeter and octane is $300.50\ g$, and after combustion, the mass is $298.30\ g$. The heat released during combustion is used to heat $500\ mL$ of water. The temperature of the water rises from $27.0°C$ to $69.5°C$.

a. Calculate the heat of combustion of octane in kJ/mol. (3 marks)

b. The energy efficiency is then investigated.

i. Find the percentage efficiency of the setup. (1 mark)

ii. Find the percentage of heat loss to the environment. (1 mark)

Your Turn!

Question 6 (5 marks)

The temperature of a $250\ mL$ sample of water increases from $22.5°C$ to $57.0°C$ as a result of the combustion of methanol. The initial combined mass of the calorimeter and methanol is $150.75\ g$, and after the combustion, the mass decreases to $148.83\ g$.

a. Calculate the heat of combustion of methanol in kJ/mol. (3 marks)

b. The energy efficiency is then investigated.

i. Find the percentage efficiency of the setup. (1 mark)

ii. Find the percentage of heat loss to the environment. (1 mark)

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Question 7 (1 mark)

Pentane has a calculated $\Delta H = -800\ kJ/mol$. Given the efficiency of energy transfer is 24.2%, find the theoretical heat of combustion of pentane.

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NOTE: When provided with the amount of energy which was produced at the end (output), the amount of energy that was supplied (input), must have been [higher] / [lower], and as such, we need to [multiply] / [divide] by the percentage instead!

ALSO NOTE: The **equation** can also be **rearranged** to solve for the inputted energy instead!

Question 8 Additional.

In an experiment, the energy absorbed by water is $850\ kJ$ when $0.732\ mol$ of ethanol was combusted. Find the percentage of energy which is lost to the environment.

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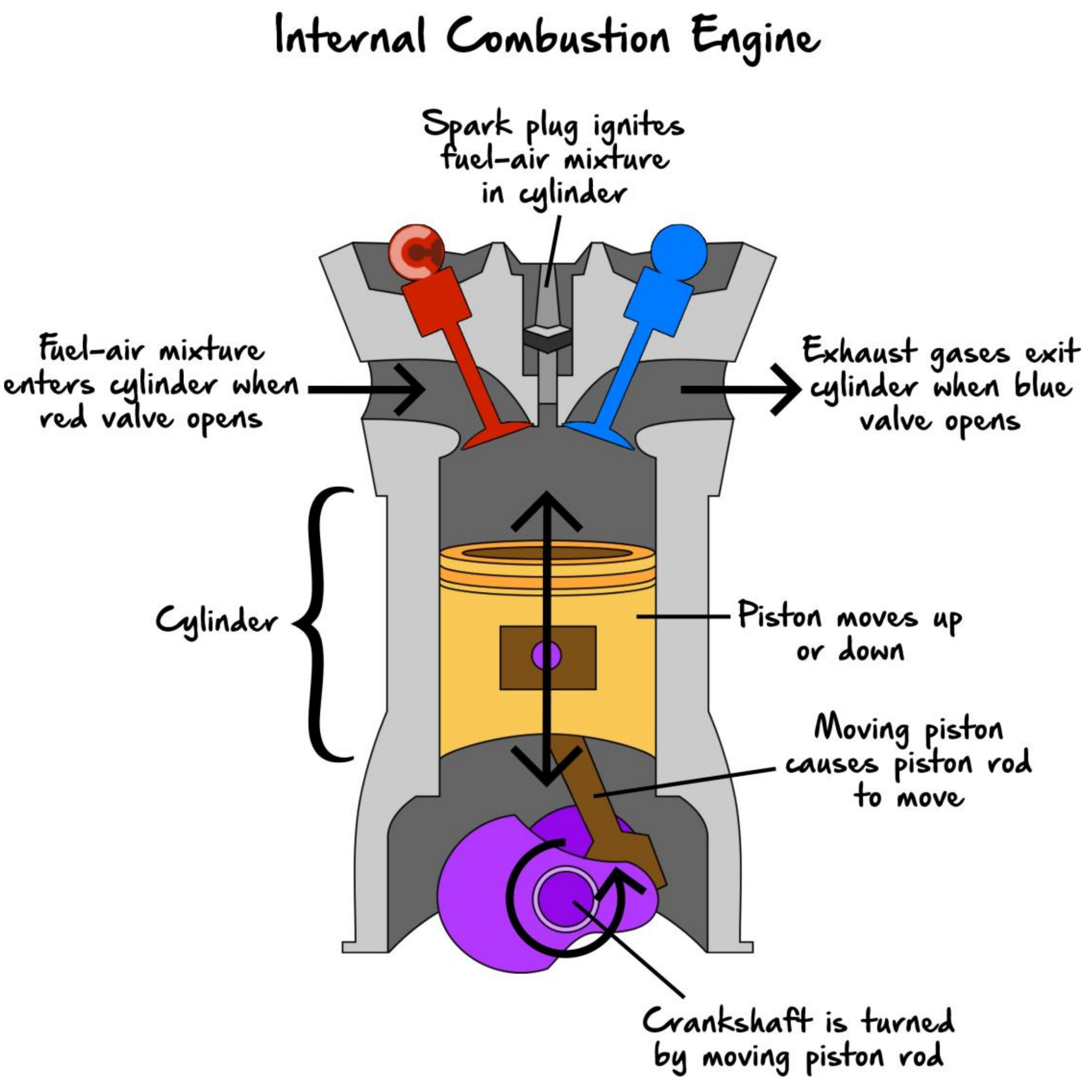
Extension: Energy Transformations in an Internal Combustion Engine

- Cars use fuel to power the internal combustion engine.

- **Simplified the energy transformations:**



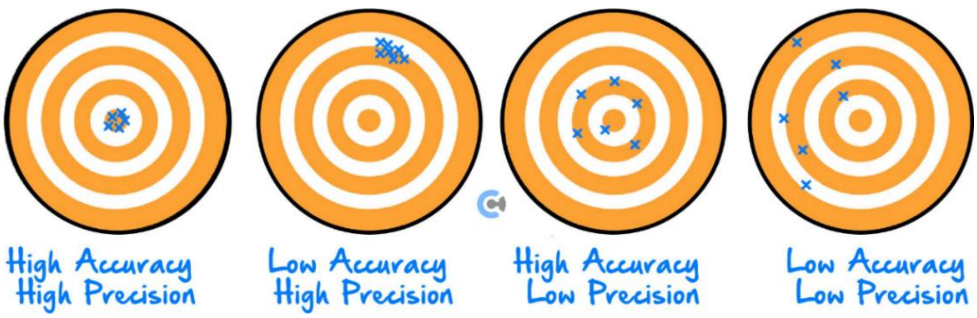
- The actual inner workings along with the energy transformations of an internal combustion engine **will not be tested** on the final exam!

Sub-Section: Accuracy, Precision, & Errors

How do errors relate to heat loss?

Accuracy v/s Precision

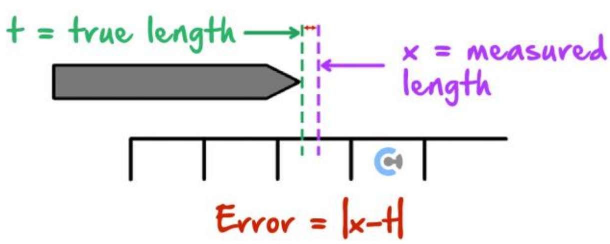
- **Accuracy:** How close a measurement is to the ____________________________.
- **Precision:** How close a measurement is to _________________________.
- **Dartboard Analogy:**



- Accuracy and Precision are _______________________.

Errors

- **Definition**: The **difference** between the **measured** value and the **true** value.



- There are two types of errors:
  - Systematic Error.
  - Random Error.

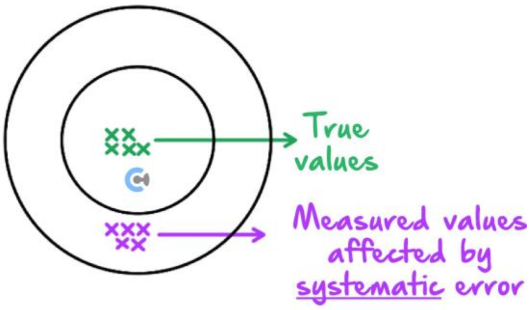
Definition

Systematic Error

- **Definition:** Readings differ from true value in a ____________________ manner. They are consistent in:

Direction & Size

- **Example:** Setting the zero of a weighing scale at $-50\ g$.



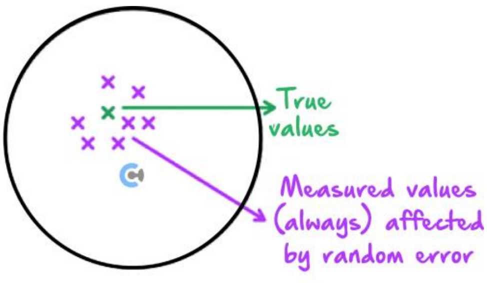
Discussion: Does systematic error affect accuracy or precision?

[Accuracy] / [Precision]

Definition

Random Error

- **Definition:** Affects measurements in __________________ ways.



- Usually occurs due to the _________________________.
- Random errors are __________________________ in measurements.

Discussion: Does random error affect accuracy or precision?

[Accuracy] / [Precision]

TIP: Remember SARP

SARP

Misconception

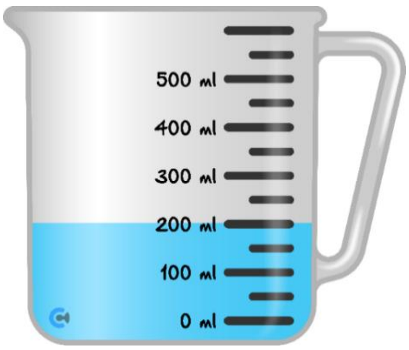
"Temperature fluctuations during the experiment are random errors."

TRUTH: This is not true!

- Temperature fluctuations are ______________________________ which are not controlled!

Exploration: Random Error Example

- Consider filling up a beaker of water to $200\ mL$.



- Is the volume of water exactly $200\ mL$? [Yes] / [No]
- The volume of water could be anywhere between $175\ mL$-$225\ mL$, which is randomly higher or lower!
- **This is a random error!**

Active Recall: What is the difference between accuracy and precision?

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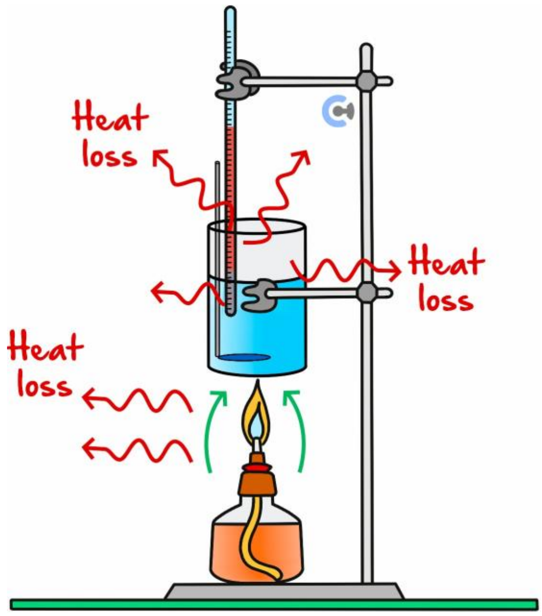
Sub-Section: Minimising Heat Loss

Context

- We've covered how there is energy loss present in the following experimental setup to find the heat of combustion of fuels.



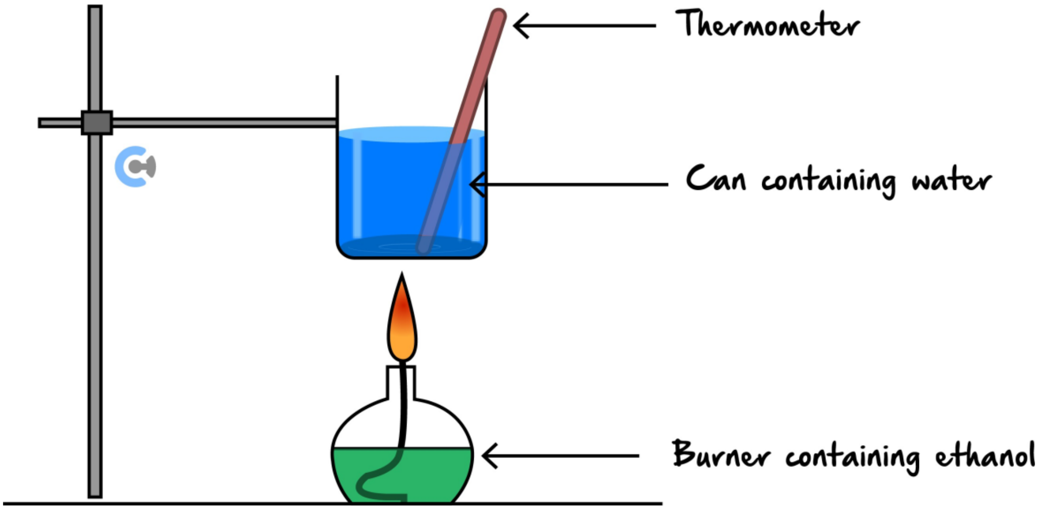
- Now, we'll investigate how to **minimise** the heat loss!

Discussion: What are some ways to reduce energy losses to the environment in this setup?

- ____
- ____
- ____
- ____

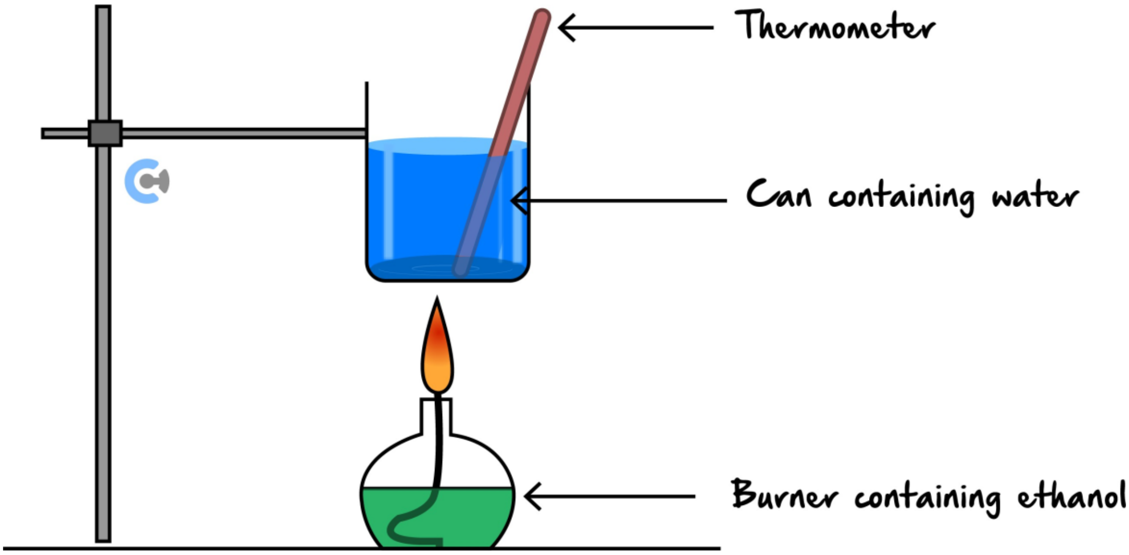
NOTE: The base of the container holding the water should be a heat conductor to allow heat to pass through, but the sides of the container should be an insulator to minimise heat loss from inside the water container to the environment.

Discussion: When determining the heat of combustion using the following setup, is heat loss considered to be a systematic error or a random error?



[Systematic] / [Random] Error

Exploration: Errors in Heat Loss



- When heat is absorbed by water, how does it compare to actual heat released?

  ____

- What type of error is this? [Systematic] / [Random] Error
- How can we improve accuracy? ________________________

Heat Loss Errors

- Heat Loss is consistent in direction and size, so it is primarily **systematic error.**
- Amount of heat loss is random each time, so there are **elements of random error.**
- To improve accuracy, reduce heat loss.

Discussion: If we use an 'electric thermometer', does this improve accuracy or precision?

[Accuracy] / [Precision]

NOTE: An electric thermometer improves the instrumentation used, which reduces ____________________________, thereby improving _______________________.

Active Recall: What are some ways to minimise heat loss? (Only list 2)

- ____
- ____

Sample Response: Adding a Lid (Improving Accuracy)

1. To improve the accuracy of the setup, *insert change made*.
2. This reduces the amount of *explain how it minimises heat loss*, thereby **minimising heat loss**.
3. This decreases the effect of **systematic error**, which thereby increases the **accuracy** of the experiment.

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Sub-Section: Factors which change the Heat of Combustion

Context

- Sometimes, you're asked how a change in the setup will alter the change in enthalpy (ΔH) value.
- For these questions, it is important to use ______________________________ and link those proportionalities to the formulas provided.

What are proportionalities?

Proportionality

- **Definition:** Proportionalities basically show how a variable will change if another were to also change.

Exploration: Proportionalities

- Proportionality:

$$x = \frac{y}{z}$$

- In the above equation:
  - ______________________________
  - ______________________________
- Direct Proportionality:
  - For instance, if y is doubled, x would also be ___________________.
  - If y was halved, x would also __________________.
- Inverse Proportionality:
  - For instance, if z is doubled, x would ________________. If z is halved, x would ___________________.

Proportionality

- **Definition:** Proportionalities basically show how a variable will change if another were to also change.

$$x = \frac{y}{z}$$

- Direct Proportionality: $x \propto y$
  - If x doubles, y doubles.
- Inverse Proportionality: $x \propto \frac{1}{z}$
  - If x doubles, z halves.

NOTE: Proportionalities are not officially in the Chemistry study design, but they can help identify what happens when a change is made!

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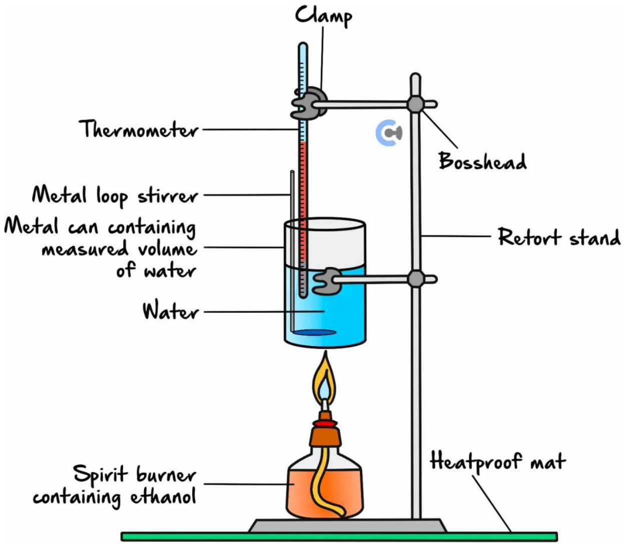
Let's try some questions together!

Question 9 (4 marks) **Walkthrough.**

The change in enthalpy value for ethanol fuel was determined through the setup below, where 100 g of water is placed on top of a spirit burner.



a. It turns out that the spirit burner was located too far from the beaker, and as such, the change in enthalpy value for the fuel is determined again but now with the flame moved closer to the beaker of water.

Describe and explain the effect that this has on the calculated ΔH value compared to the first ΔH value obtained. (2 marks)

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b. It also turns out that the mass of water used was measured incorrectly as the weighing scale was not zeroed beforehand, resulting in the mass reading of the water to have been 20 g higher than the actual mass of water.

Describe and explain the effect this has on the calculated ΔH value. (2 marks)

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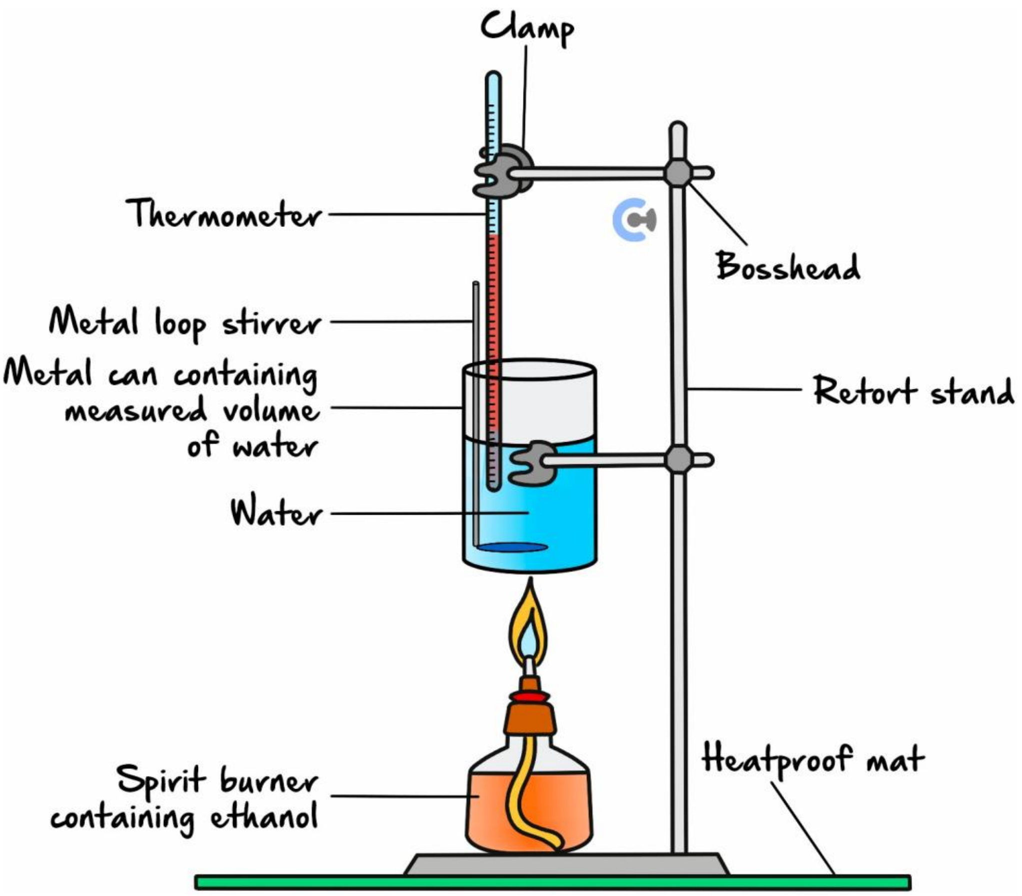
Your turn!

Question 10 (7 marks)

The following setup was used to calculate the heat of combustion (ΔH) of ethanol fuel, where the mass of the spirit burner containing ethanol was intially measured to be $2.510\ g$, and the final mass was measured to be $2.160\ g$. $150\ mL$ of water was placed $3\ cm$ above the spirit burner and the change in temperature was measured to go from 30.00°C to 41.20°C.



a. The electronic balance was not calibrated properly, and it turns out that the final mass of the spirit burner containing ethanol was higher than the actual final mass of the spirit burner.

State and explain the effect a higher final mass reading of the spirit burner will have on the calculated heat of combustion of the ethanol. (2 marks)

b. It turns out that the density of water at 30.00°C is actually $0.996\ g/mL$.

Explain what effect using this density of water will have on the calculated heat of combustion. (2 marks)

Key Takeaways

- Percentage Efficiency:

$$\%\ eff = \frac{Experimental}{Theoretical} = \frac{Output}{Input}$$

- When finding theoretical ΔH from experimental ΔH, divide by percentage efficiency.
- Systematic error links to accuracy is how close to true value.
- Random error links to precision which is how spread the data is.
- To minimise heat loss:
  - Place the beaker closer to the spirit burner
  - Add a lid.
  - Use an insulator on the outside of the can.
  - Use heat shield to wrap the spirit burner – beaker.

$$x = \frac{y}{z}$$

- Direct Proportionality: $x \propto y$
  - If x doubles, y doubles.
- Inverse Proportionality: $x \propto \frac{1}{z}$
  - If x doubles, z halves.

Section B: Gas Laws

Sub-Section: Stoichiometry

Context

- As a combustion reaction occurs, a fire is produced.

- As this reaction occurs, gases are produced!

Discussion: What gases are produced during a combustion reaction?

- ______________________________.
- ______________________________.

How do we find the amount of gas produced during a combustion reaction?

Exploration: Calculating Amount of Gas Produced During Combustion

- Consider the following reaction:

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

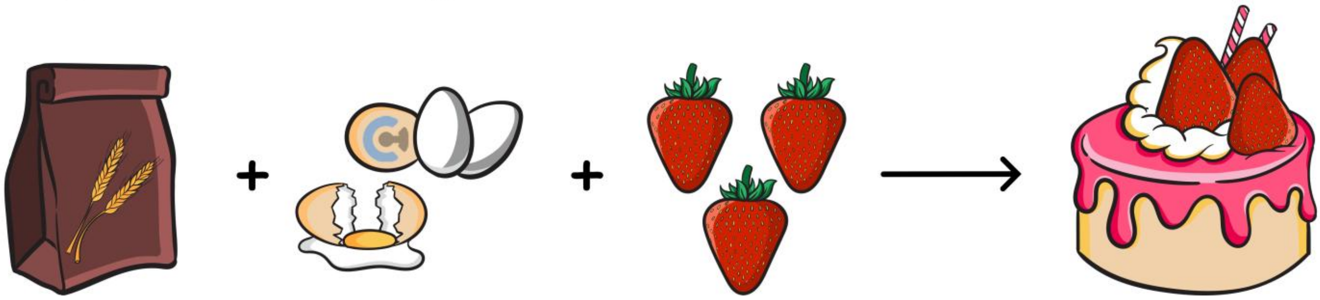
- **Scenario**: $10.0\ g$ of ethane (C_2H_6) combusting.
- How do we find the amount of carbon dioxide gas produced? ________________________

How do we find the amount of gas produced during combustion?

Analogy: Cake Recipe

- Consider the following recipe:

1 Bag of Flour + 4 Eggs + 3 Strawberries → 1 Strawberry Cake



- If **one strawberry cake was made**, how many strawberries were used? ________________
- If **three strawberry cakes were made**, how many eggs were used? ________________
- If there are $4.00\ kg$ of eggs, how many strawberry cakes can we make? ________________

Stoichiometric Ratios

- **Definition**: Use coefficients in the chemical equation to indicate the ________________ of two substances in a reaction!
- **Use**: ________________.
- Method:

$$\frac{Unknown}{Known}$$

Space for Personal Notes

Let's look at a question together!

Question 11 Walkthrough.

During the combustion of ethane, the following reaction takes place:

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

a. Given that there are 3.82 mol of oxygen reacting, what is the amount of water vapour which is produced?

---

b. In another scenario, there is 10.0 g of ethane (C_2H_6) combusting, calculate the mass of carbon dioxide gas which is produced.

REMINDER: Always look out for significant figures when doing questions!

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Your Turn!

Question 12

Vanessa decides to combust some butane (C_4H_{10}) that she found in a fuel tank in her garage.

a. Write the thermochemical equation for the complete combustion of butane.

____

b. Her friend, Phoebe, brings along her fuel tank as well, and together, they find that they have 21.8 g of butane. Find the mass of carbon dioxide which will be produced, assuming that complete combustion has occurred.

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Question 13 Additional Question.

The combustion of pentanol is shown below.

$$C_5H_{11}OH + \frac{15}{2}O_2(g) \rightarrow 5CO_2(g) + 6H_2O(l)$$

If 7.12 g of oxygen gas is combusted, find the mass of water produced.

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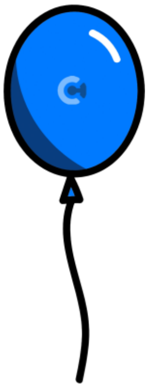
Sub-Section: Volume of Gases

Context

- Gases have volume, just like any other substance in another state of matter!



Discussion: What affects how much volume a gas will occupy?

- ______________________________.
- ______________________________.
- ______________________________.

NOTE: The mass/size of the molecules themselves ____________ affect the volume it occupies, due to ideal gas behaviour, which is a Chemistry ½ concept which is not tested in Chemistry ¾ !

Active Recall: What were the conditions of temperature at pressure at SLC (Standard Laboratory Conditions)?

- Temperature: ____________________________________.
- Pressure: ____________________________________.

Exploration: Volume Occupied by Gases

- In Chemistry ¾, the volume occupied by gases is only calculated at **SLC**!
- What is the only factor remaining which will affect volume of gas occupied?

Exploration: Molar Volume of Gas at Standard Laboratory Conditions (SLC)

- At (SLC), one mole of **any** gas occupies: ____________.
- **Constant:**
  - Name: ____________________.
  - Value: $V_m = 24.8\ L/mol$.
- At SLC,
  - $1\ mol$ of gas → $24.8\ L$.
  - How much volume does $2\ mol$ of gas occupy? ____________________
- **Operations:**
- **Formula:**
- **Formula Rearranged:**

$$n = \frac{V}{V_m}$$

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Definition

Molar Volume (V_m)

- **Definition:** A **constant** which indicates the volume occupied by one mole of any gas at a particular temperature and pressure.
- **Data Book:** Page 3 and 4.

SI Units	Formulae	Value (at SLC):
L/mol	$n = \frac{V}{V_m}$	$V_m = 24.8 \frac{L}{mol}$

- **Steps:**

1. Find the amount (mol) of the gas present.
2. Use the molar volume formula and the molar volume constant at SLC.

Extension: Universal Gas Law

- The Universal Gas Law is only covered in Chemistry ½ and the old Chemistry ¾ Study Design, but is not covered in this study design for Chemistry ¾!
- **Formulae:**

$$pV = nRT$$

- At Standard Laboratory Conditions (SLC):
  - Temperature $(T) = 25°C$
  - Pressure $(p) = 100\ kPa$

- Rearranging formula for the moles (n):

$$n = \frac{pV}{RT}$$

$$n = \frac{100\ kPa \times V}{8.31 \frac{J}{mol\ K} \times 298K}$$

$$n = \frac{V}{24.8\ L/mol} = \frac{V}{V_m}$$

Recall!

<u>Active Recall:</u> What is the molar volume formula, and what is the value of the molar volume constant?

Let's look at some questions together!

Question 14 Walkthrough.

James is trying to figure out the properties of some gases. To do so, he investigates the ethene gas (C_2H_4).

He finds that he has 30.0 g of ethene gas. Find the volume that this gas will occupy at SLC.

TIP: Usually, this rearranged version is used:

$$V = n \times V_m$$

Your turn!

Question 15

For the following two scenarios, assume everything occurs at SLC.

a. Find the amount (mol) of 5.00 L of hydrogen chlorine gas (HCl).

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b. Find the volume that 18.20 g of carbon dioxide (CO_2) occupies.

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<u>Active Recall:</u> Which equation is used to find the energy released from a fuel, if the amount (mol) of fuel is provided?

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Space for Personal Notes

Question 16

A balloon containing 22500 mL of methane is completely combusted. Find the amount of energy which is released at SLC.

TIP: Whenever we need to find the energy released by the fuel, first find the mass (g) or the amount (mol), before linking to energy by using the relevant ΔH value (kJ/g and kJ/mol respectively).

REMINDER: Don't forget!

- The SI unit for volume is litres (L)!

Question 17 Additional Question.

In a 13.8 L sample of nitrogen gas, find the mass of nitrogen present.

Space for Personal Notes

Sub-Section: Mass-Volume Stoichiometry

Context

- Sometimes, the mass of one substance is given, and the question asks for the volume of another substance!
- This is where we need to use mass-volume stoichiometry!

Mass-Volume Stoichiometry Steps

1. Find the moles of substance using ________________________.
2. Find the moles of other substance using ____________________________.
3. Find the volume of other substance using ______________________.

Let's look at an example together!

Question 18 Walkthrough.

James now takes the ethene gas (C_2H_4) and combusts it, whereby the following reaction takes place:

$$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$$

Find the volume of carbon dioxide that will be produced, if 20.0 g of ethene gas is combusted at SLC.

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Your turn!

Question 19

The following equation takes place when acid is dropped on some stone statues which some sodium (Na):

$$2HCl(aq) + 2Na(s) \rightarrow 2NaCl(aq) + H_2(g)$$

Given that 5.00 g of sodium metal has excess hydrochloric acid added, find the volume of gases which are produced at SLC.

Question 20

Mia is investigating hydrogen gas and how it can be combusted at Standard Laboratory Conditions (SLC).

a. Write the thermochemical equation for the complete combustion of hydrogen gas.

b. Given that 500 kJ of energy is produced, find the volume of hydrogen gas which has been combusted at SLC.

c. Find the volume of water vapour which is formed at SLC, given that 5.20 g of hydrogen gas is combusted.

Question 21 Additional Question.

The combustion of ethene gas is shown below.

$$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$$

Find the mass of carbon dioxide produced, if 9.60 L of oxygen gas was reacted at SLC.

Space for Personal Notes

Sub-Section: Volume-Volume Stoichiometry

Context

- Sometimes, the volume of one substance is provided, and the volume of the other substance is asked to be found.

Let's have a look at together!

Exploration: Volume Stoichiometry Example

- Consider the following:

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

- $50\ mL$ of methane was burnt. Calculate the volume of $O_2(g)$ required for complete combustion to occur at SLC.

Method 1:

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____

____

- Operations Undertaken:

- What steps can be cancelled out? *(Label Above)*

- What's the quicker way to do it?

Method 2:

____

____

Why does this work?

Exploration: Proportionality Within Moles and Volume

- In the following equation:

$$n = \frac{V}{V_m}$$

  - What is the constant? *(Highlight Above)*
  - If moles are doubled, what happens to volume? ________________

- Proportionality:

- Consider the following reaction:

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

- If $1.00\ mol$ of methane is present, how much (mol) of oxygen is required? ____________
- If $24.8\ L$ of methane is present, how much volume (L) of oxygen is required? ____________

Volume-Volume Stoichiometry

- **Conditions to execute:**
  - ________________________________.
  - ________________________________.
  - ________________________________.
- **How to use**: Do stoichiometry directly with volume!

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<u>Extension:</u> Can the same be done for mass?

[Yes] / [No]

Proof:

$$\mathbf{CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)}$$

- Consider 50 g of methane (CH_4) which completely combusts. What mass of O_2 is required?

$$n(CH_4) = \frac{m}{Mr} = \frac{50}{16} = 0.3125\ mol$$

$$n(O_2) = 2 \times n(CH_4) = 0.625\ mol$$

$$m(O_2) = n \times Mr = 0.625 \times 32 = 200\ g$$

- Why/why not?

Let's look at some questions together!

Question 22 Walkthrough.

The following equation occurs when ethanol is combusted:

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$

At a pressure of 120 kPa at a temperature of 30°C, 72.8 L of oxygen gas is reacted. Given that the pressure and temperature are kept constant throughout the reaction, find the volume of carbon dioxide produced in litres.

Your turn!

Question 23

At high temperatures, such as those in a car engine during operation, atmospheric nitrogen burns to produce the pollutant nitrogen dioxide, according to the equation:

$$N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$$

a. Assuming that the temperature and pressure stay constant if 20 mL of nitrogen is oxidised, calculate the volume of oxygen needed to produce the pollutant.

b. What is the initial volume of reactants in this combustion reaction?

c. What is the final volume of products in this reaction?

d. Is there an overall increase or decrease in the volume of gases on completion of the reaction?

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Question 24 Additional Question.

If 15.0 cm^3 of sulphur trioxide (SO_3) was formed according to:

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

What volumes of sulphur dioxide (SO_2) and oxygen gas (O_2) must have reacted? (All volumes measured at SLC.)

____

____

____

Key Takeaways

- Gas Law at SLC: $n = \frac{V}{V_m}$.
- Molar Volume at SLC Value: $24.8\ L/mol$.
- Stoichiometry calculations are done using the coefficients as $\frac{\text{unknown}}{\text{known}}$.
- Mass-Volume Stoichiometry Steps:
  1. Find the moles of substance using: $n = \frac{m}{Mr}$.
  2. Find the moles of other substance using stoichiometric ratios.
  3. Find the volume of other substance using $V = V \times V_m$.
- Volume-Volume Stoichiometry Conditions:
  - Constant temperature.
  - Constant pressure.
  - Both substances are gas.

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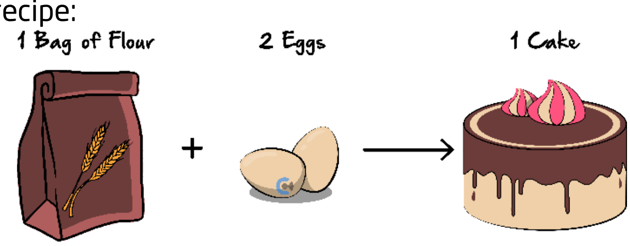
Section C: Limiting Reagents

Exploration: Limiting Reagents Example

- Consider the following recipe:



- If there are 2 bags of flour and 3 eggs, what is maximum amount of cake made? ____________

- What is the limiting reagent? ____________

Limiting Reagents

- Finding limiting reagent steps:

1.

2.

3.

- When finding the amount of products formed, the amount (in mol) of the **[limiting reagent] / [excess reagent]** is used.

- Amount of excess reagent left over:

1.

2.

Let's look at some questions together!

Question 25 (6 marks) **Walkthrough.**

Propane gas undergoes complete combustion according to the following equation:

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$$

A sample of 10.0 g of propane is mixed with 25.0 L of oxygen gas at SLC.

a. Find the limiting reagent. (2 marks)

b. Calculate the maximum volume of carbon dioxide gas which can be produced. (2 marks)

c. Calculate the mass of excess reagent left over. (2 marks)

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Your turn!

Question 26 (5 marks)

Butanol undergoes complete combustion according to the following equation:

$$C_4H_9OH(l) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$$

12.0 g of butanol mixes with 20.0 L of oxygen gas in the air at SLC.

a. Find the limiting reagent. (2 marks)

b. Calculate the mass of water produced. (1 mark)

c. Calculate the mass of excess reagent left over. (2 marks)

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Question 27 (5 marks) **Additional.**

Given the following reaction:

$$FeCl_3(aq) + 3NaOH(aq) \rightarrow Fe(OH)_3(s) + 3NaCl(aq)$$

A sample of 20.0 g of the iron (III) chloride is mixed with 25.0 g of sodium hydroxide.

a. Find the excess reagent. (2 marks)

b. Find the amount, in moles, of excess reagent left over at the end of the reaction. (2 marks)

c. Find the mass of sodium chloride produced, in grams. (1 mark)

Space for Personal Notes

Contour Check

Learning Objective: [1.3.1] – Identify changes to minimise heat loss & calculate percentage efficiency

Study Design

Energy from fuels and food:
Calculation of energy transformation efficiency during combustion as a percentage of chemical energy converted to useful energy

Key Takeaways

- Percentage Efficiency:

$$\% \, \boldsymbol{eff} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

- When finding theoretical ΔH from experimental ΔH, **[multiply] / [divide]** by percentage efficiency.
- Systematic error links to **[accuracy] / [precision]** is how ______________________________.
- Random error links to **[accuracy] / [precision]** which is how ______________________________.
- To minimise heat loss:
  - ____.
  - ____.
  - ____.
  - ____.

$$\boldsymbol{x} = \frac{\boldsymbol{y}}{\boldsymbol{z}}$$

- Direct Proportionality: $x \propto y$
  - If x doubles, y ____________.
- Inverse Proportionality: $x \propto \frac{1}{z}$
  - If x doubles, z __________________.

Learning Objective: [1.3.2] - Apply $n = \frac{V}{V_m}$ to calculate volumes of gas at SLC

Study Design

Calculations related to the application of stoichiometry to reactions involving the combustion of fuels, including mass-mass, mass-volume and volume-volume stoichiometry, to determine heat energy released, reactant and product amounts and net volume or mass of major greenhouse gases (CO_2, CH_4 and H_2O), limited to standard laboratory conditions (SLC) at 25°C and 100 kPa

Key Takeaways

- [ ] Gas Law at SLC Equation/Formula: ____________________
- [ ] Molar Volume at SLC Value: ________________________

Learning Objective: [1.3.3] - Apply m - m, m - v, v-v stoichiometry to calculation questions with equations

Study Design

Calculations related to the application of stoichiometry to reactions involving the combustion of fuels, including mass-mass, mass-volume and volume-volume stoichiometry, to determine heat energy released, reactant and product amounts and net volume or mass of major greenhouse gases (CO_2, CH_4 and H_2O), limited to standard laboratory conditions (SLC) at 25°C and 100 kPa

Key Takeaways

- [ ] Stoichiometry calculations are done using the coefficients as ____________________________.
- [ ] Mass-Volume Stoichiometry Steps:
  1. Find the moles of substance using: ____________________________.
  2. Find the moles of other substance using ____________________________.
  3. Find the volume of other substance using ____________________________.
- [ ] Volume-Volume Stoichiometry Conditions:
  - ______________________________.
  - ______________________________.
  - ______________________________.

Learning Objective: [1.3.4] - Identify limiting reagents

Study Design

Determination of limiting reactants or reagents in chemical reactions

Key Takeaways

- [ ] Finding limiting reagents steps:

  1. ________________________________.

  2. ________________________________.

  3. ________________________________.

- [ ] When finding amount of products formed, the amount (in moles) of the [limiting reagent] / [excess reagent] is used.

- [ ] Amount of excess reagent left over: