

Combustion stoichiometry

FizziQ activity · Middle and high school · 60 min



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Connected O₂ and CO₂ sensors stream data to FizziQ on a smartphone or tablet while a candle burns in a sealed chamber; students derive the stoichiometric ratio.

Learning objectives

- Measure gas concentrations before and after combustion
- Calculate the O₂ consumed and CO₂ produced
- Determine the experimental stoichiometric ratio
- Compare with the theoretical ratio from the balanced equation
- Understand atom conservation in chemical reactions

Instruments and sensors

O₂ concentration meter · CO₂ concentration meter · O₂ sensor · SCD40 sensor

Materials

- Smartphone or tablet with FizziQ Connect
- SCD40 and O₂ sensors
- M5 Stack module and multiport hub
- Sealed chamber
- Tea light candles
- Note: the protocol remains adaptable to any comparable gas concentration data acquisition tool.

Protocol

1. Set up the experiment: O₂ and SCD40 sensors mounted in the sealed chamber via the multiport hub, connected to the M5 Stack module.
2. Before any combustion, note the initial reference concentrations in ambient air: C_{ini}(O₂) in % and C_{ini}(CO₂) in ppm.
3. Fix a tea light candle to the bottom of the chamber. Set the measurement interval to 250 ms on the M5 Stack.
4. Start recording (REC), light the candle, and quickly close the chamber lid.
5. Let the combustion proceed until the candle goes out. Wait 1-2 more minutes for concentrations to stabilize.
6. Stop the recording (STOP). Note the final concentrations: C_{fin}(O₂) in % and C_{fin}(CO₂) in ppm.
7. Calculate the variations: $\Delta C(\text{O}_2) = C_{\text{fin}}(\text{O}_2) - C_{\text{ini}}(\text{O}_2)$ (negative, O₂ decreases) and $\Delta C(\text{CO}_2) = C_{\text{fin}}(\text{CO}_2) - C_{\text{ini}}(\text{CO}_2)$ (positive, CO₂ increases).
8. Calculate the experimental ratio: $n_{\text{exp}} = -\Delta C(\text{O}_2) \times 10^4 / \Delta C(\text{CO}_2)$. The factor 10⁴ converts % to ppm for consistent units.
9. Open the chamber, ventilate, replace with a fresh candle, and repeat. Perform 6 to 10 trials total for statistical reliability.
10. Calculate the mean n_{exp} after removing any outliers. Compare with the theoretical value n_{att} = 38/25 = 1.52.

Expected results

Typical observed values: O_2 initial $\approx 20.9\%$, O_2 final $\approx 15\text{-}16\%$, giving $\Delta C(O_2) \approx -5\%$. CO_2 initial $\approx 400\text{-}800$ ppm, CO_2 final $\approx 25,000$ ppm, giving $\Delta C(CO_2) \approx 24,000\text{-}25,000$ ppm. The experimental ratio n_{exp} is typically 1.6-2.2, somewhat higher than the theoretical 1.52 due to incomplete combustion.

Questions

- Why is the experimental ratio often higher than the theoretical value of 1.52?
- What products are formed during incomplete combustion?
- Why does the candle go out before all the O_2 is consumed?
- How does atom conservation determine the stoichiometric coefficients?
- What happens to the water produced by the combustion?
- Why do you need multiple trials to get a reliable result?

Going further

- Compare candles of different sizes and verify that the stoichiometric ratio is independent of candle size
- Use a longer or shorter burning time and check if the ratio changes
- Test with different fuels (ethanol lamp, butane lighter) and compare the ratios
- Investigate the effect of initial O_2 concentration by flushing the chamber with O_2 -enriched air
- Calculate the mass of paraffin consumed from the O_2 data and compare with the actual mass loss