

INFRARED SPECTROSCOPY OF GASES

Introduction:

The infrared spectrometer can be used to detect the presence of various components in a mixture of gases, such as carbon dioxide in breath or in the atmosphere. The IR can detect bonds which are polar covalent. For our purposes, this means two dissimilar atoms (i.e. C=O and C-H bonds can be detected but not N≡N or O=O).

In this experiment infrared spectrophotometry will be used to quantitatively determine the percent of carbon dioxide in one's breath as well as in the atmosphere.

Purpose:

The purpose of this experiment is to quantitatively determine the percentage of carbon dioxide in one's breath and in the atmosphere using an infrared spectrometer.

Equipment / Materials:

FTIR	air source (bicycle pump or compressed air)
balloons (7-9" round)	helium
Dry ice (or another source of CO ₂)	string
meter stick	

Safety:

- Always wear safety glasses and an apron in the lab.

Procedure:

1. Set the FTIR on absorbance mode and the number of scans to 16.
2. Obtain a balloon and fill it with helium. This will serve as the background scan of the balloon since helium will not absorb infrared energy.
3. Using a piece of string, determine the circumference of the balloon.
4. Using the equation for volume of a sphere, determine the volume of the balloon.
5. Take a scan of the helium balloon and save it as the background scan.
6. Fill another balloon with carbon dioxide to approximately the same volume as the balloon containing helium. Determine the circumference of the balloon and record it in the data table. Take a scan of this balloon and save it in A.
7. Subtract the background scan from the scan of the balloon containing carbon dioxide and save it in A. Record the peak(s) of pure carbon dioxide and the absorbance at each peak. Plot the spectrum.
8. Fill another balloon to approximately half the volume of the background balloon with helium. Determine the circumference of the balloon and record it in the data table.
9. Continue to fill the balloon from step 8 to the volume of the background balloon with carbon dioxide. Determine the circumference of the balloon and record it in the data table. Take a scan of this balloon and save it in B.
10. Subtract the background scan from the scan of the balloon containing helium and carbon dioxide and save it in B. Record the peak(s) of carbon dioxide and the absorbance at each peak. Plot the spectrum.
11. Inflate a balloon with your breath to approximately the same volume as the background balloon. Determine the circumference of the balloon and record it in the data table. Take a scan of this balloon and save it in C.

12. Subtract the background scan from the scan of the balloon containing your breath and save it in C. Record the peak(s) of carbon dioxide and the absorbance at each peak. Plot the spectrum.
13. Using a bicycle pump, inflate a balloon with air to approximately the same volume as the background balloon. Determine the circumference of the balloon and record it in the data table. Take a scan of this balloon and save it in A.
14. Subtract the background scan from the scan of the balloon containing air and save it in A. Record the peak(s) of carbon dioxide and the absorbance at each peak. Plot the spectrum.

Name _____

Name _____

Period _____

Date _____

INFRARED SPECTROSCOPY OF GASES

Data Table:

Diameter of helium balloon _____

Volume of helium balloon _____

Diameter of carbon dioxide balloon _____

Volume of carbon dioxide balloon _____

Peak(s) for CO ₂	Absorbance
_____ cm ⁻¹	_____
_____ cm ⁻¹	_____
_____ cm ⁻¹	_____

Diameter of partially filled balloon (He) _____

Volume of partially filled balloon (He) _____

Diameter of He/CO₂ balloon _____

Volume of He/CO₂ balloon _____

Peak(s) for CO ₂	Absorbance
_____ cm ⁻¹	_____
_____ cm ⁻¹	_____
_____ cm ⁻¹	_____

Diameter of balloon containing your breath _____

Volume of balloon containing your breath _____

Peak(s) for CO ₂	Absorbance
_____ cm ⁻¹	_____
_____ cm ⁻¹	_____
_____ cm ⁻¹	_____

Diameter of balloon containing air _____

Volume of balloon containing air _____

Peak(s) for CO ₂	Absorbance
_____ cm ⁻¹	_____
_____ cm ⁻¹	_____
_____ cm ⁻¹	_____

Calculations:

1. Calculate the volume of each balloon and record it in the data table.

2. Correct the absorbance for the volume of the balloon.

$$\frac{\text{Absorbance of unknown}}{\text{Volume of unknown balloon}} = \frac{\text{Corrected absorbance of unknown}}{\text{Volume of pure CO}_2 \text{ balloon}}$$

3. Using the equation, $\frac{\text{Corrected Abs of unknown}}{\text{Abs of pure CO}_2} = \frac{\% \text{ of CO}_2 \text{ in unknown}}{100 \% \text{ (pure CO}_2)}$
- determine the percent of carbon dioxide in the He/CO₂ mixture.

b. determine the percent of carbon dioxide in your breath.

c. determine the percent of carbon dioxide in air.

Substance	Corrected abs	% CO ₂
He/CO ₂ mixture		
breath		
air		

Questions:

- Why was helium used in the background?
- Why was the He/CO₂ mixture analyzed?
- How would the CO₂ content in your breath change under the following conditions?
 - Jog a kilometer?
 - Breathe helium from a helium balloon?
 - Hold your breath as long as possible before filling the balloon?

INFRARED SPECTROSCOPY OF GASES - TEACHER NOTES

Lab Time: 25-30 minutes

Preparations:

Time: 5 minutes

Answers to Questions:

1. Why was helium used in the background?

Helium will not absorb in the infrared region and, thus, only the balloon's scan is obtained.

2. Why was the He/CO₂ mixture analyzed?

In order to test the procedure and make the unknown results more reliable.

3. How would the CO₂ content in your breath change under the following conditions?

- a) Jog a kilometer?

CO₂ content would be increased.

- b) Breathe helium from a helium balloon?

CO₂ content would be decreased.

- c) Hold your breath as long as possible before filling the balloon?

CO₂ content would be increased.

Considerations:

When students interpret the IR spectra, only the left hand side (1500 - 4000 cm⁻¹) is needed. Have the students identify at least one major peak for the pure CO₂ spectrum. This peak(s) should be used throughout the remainder of the experiment. The peaks may shift a few wavenumbers either way from scan to scan. Use the peak(s) closest to the recorded peak(s) for pure CO₂. The color of the balloons should not interfere in the infrared region, however, it is best to use the same sized balloons and brand of balloons throughout the experiment. Carbon dioxide should show an absorbance around 2400 cm⁻¹

An extension of this experiment would be to determine the percent of carbon monoxide in automobile exhaust. This can be accomplished using carbon monoxide in place of carbon dioxide. Be sure adequate ventilation is available if using carbon monoxide. Use a bicycle pump to collect air samples at the exhaust system of a car which is idling.