Infrared Radiation

CO₂ Molecule
Content

• Molecular Bonds
• Molecular Vibrations
A greenhouse gas

a) Is transparent to visible light.
b) Scatters some of outgoing radiation.

[c] Both a) and b)
Greenhouse Gas

• A greenhouse gas allows energy from the sun (visible, ultraviolet) in.

• A greenhouse gas “scatters’ some of the outgoing radiation (infrared).
How Does The Greenhouse Effect Work

• The greenhouse effect is due to gases (greenhouse gases) that absorb radiation in the infrared but that are transparent to the visible part of the spectrum.
Recap

- Heat released from the Earth’s surface can be absorbed by certain atmospheric molecules.
- These molecules later release the heat in all directions, effectively trapping some of it.
- As a result of human activity the concentration of heat trapping gases in our atmosphere has increased.
- Burning of fossil fuels has increased concentration of \( \text{CO} \) and \( \text{CO}_2 \)
- Nitrogen oxides and methane result from agricultural and industrial processes.
Molecular Polar Bonds

• A bond dipole is a vector that represents the degree of charge separation in the bond.

• The sum of all bond dipole vectors in a molecule is the molecular dipole moment.
Molecular Vibrations

• Monoatomic gases (e.g. He) increase velocity as the temperature is increased.

• Polyatomic gases can vibrate as well as increase velocity when heat energy is added.

• When a molecule absorbs an amount of energy and vibrates, it has gone from its ground state to a vibrational excited state.
Vibrational States

• Vibrational Energy Levels are Quantized.
  ❑ Only specific amounts of energy (E) can be absorbed.
  \[ E = h \frac{c}{\lambda} \]
  - Plank's constant \( h = 6.63 \times 10^{-34} \text{Js} \)
  - Speed of light \( c = 3.00 \times 10^8 \text{ m/s} \)

• Transitions between vibrational energy levels require much less energy than transitions between electronic energy levels.

• For electronic transitions, \( 1/\lambda \) is on the order of \( nm^{-1} \)
• For vibrational transitions \( 1/\lambda \) is in the order of \( cm^{-1} \).
A $CO_2$ molecule has 4 vibrational modes, 2 stretching and 2 bending.

- Symmetric stretch: $1500 \text{ cm}^{-1}$
- Asymmetric stretch: $2400 \text{ cm}^{-1}$
- In plane bending: $700 \text{ cm}^{-1}$
- Out of plane bending: $700 \text{ cm}^{-1}$

Resting state

O $\equiv$ C $\equiv$ O

No resting dipole
$CO_2$ Vibrational Modes

- A $CO_2$ molecule has 4 vibrational modes, 2 stretching and 2 bending.
$CO_2$ Vibrational Modes

Vibrational modes in which the dipole moment is altered are heat absorbing. These are most important for climate.
Greenhouse Gasses Contd.

\[ CO_2 \]

\textit{longer wavelength →}

\textit{CO}_2 \textit{absorbs right at the peak of the blackbody spectrum of the earth!}
A thick metal bucket contains one gallon (1 gal) of gasoline. You ignite the gasoline with a match and count 7 hours until the fuel was exhausted.

What was the power output (assumed to be constant) of the bucket? (The energy density of gasoline is $1.3 \times 10^8 J/gal$)

\[
\begin{align*}
\text{\textbf{ICLICKER QUESTION}} \\
\text{A thick metal bucket contains one gallon (1 gal) of gasoline. You ignite the gasoline with a match and count 7 hours until the fuel was exhausted.} \\
\text{What was the power output (assumed to be constant) of the bucket? (The energy density of gasoline is } 1.3 \times 10^8 J/gal)\\
\end{align*}
\]

\[
\begin{align*}
&\text{a) } 5.2 \text{ kW} \\
&\text{b) } 9.1 \text{ kWh} \\
&\text{c) } 9.1 \times 10^8 J \\
&\text{d) } 18.6 \text{ MW}
\end{align*}
\]
In Class Activity

- **Stefan – Boltzmann Law**: \( I = \sigma T^4 \)

- **Intensity** = \( \frac{\text{Power}}{\text{Area}} \)  
  \( I = \frac{P}{A} \)

- **Stefan – Boltzmann Constant**  
  \( \sigma = 5.67 \times 10^{-8} \ \text{W/m}^2\text{K}^4 \)

- **The solar energy flux that reaches Venus (minus albedo \( \alpha \))**:  
  \( I_{Venus} = \frac{1}{4} I_{Solar} (1 - \alpha) = 447 \ \text{W/m}^2 \)

- **Percent Error**:  
  \( \%\text{error} = \left| \frac{T_{\text{measured}} - T_{\text{actual}}}{T_{\text{actual}}} \right| \times 100\% \)

- **Sun's power output** \( P_{\text{Sun}} = 3.8 \times 10^{26} \)

- **Sun's Mass**: \( M_{\text{Sun}} = 2.0 \times 10^{30} \text{kg} \)