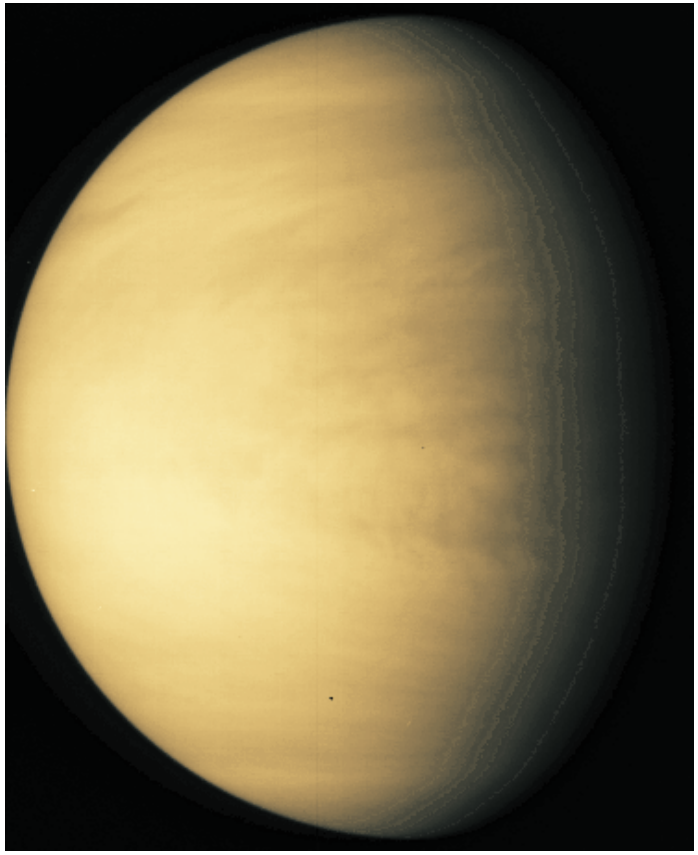
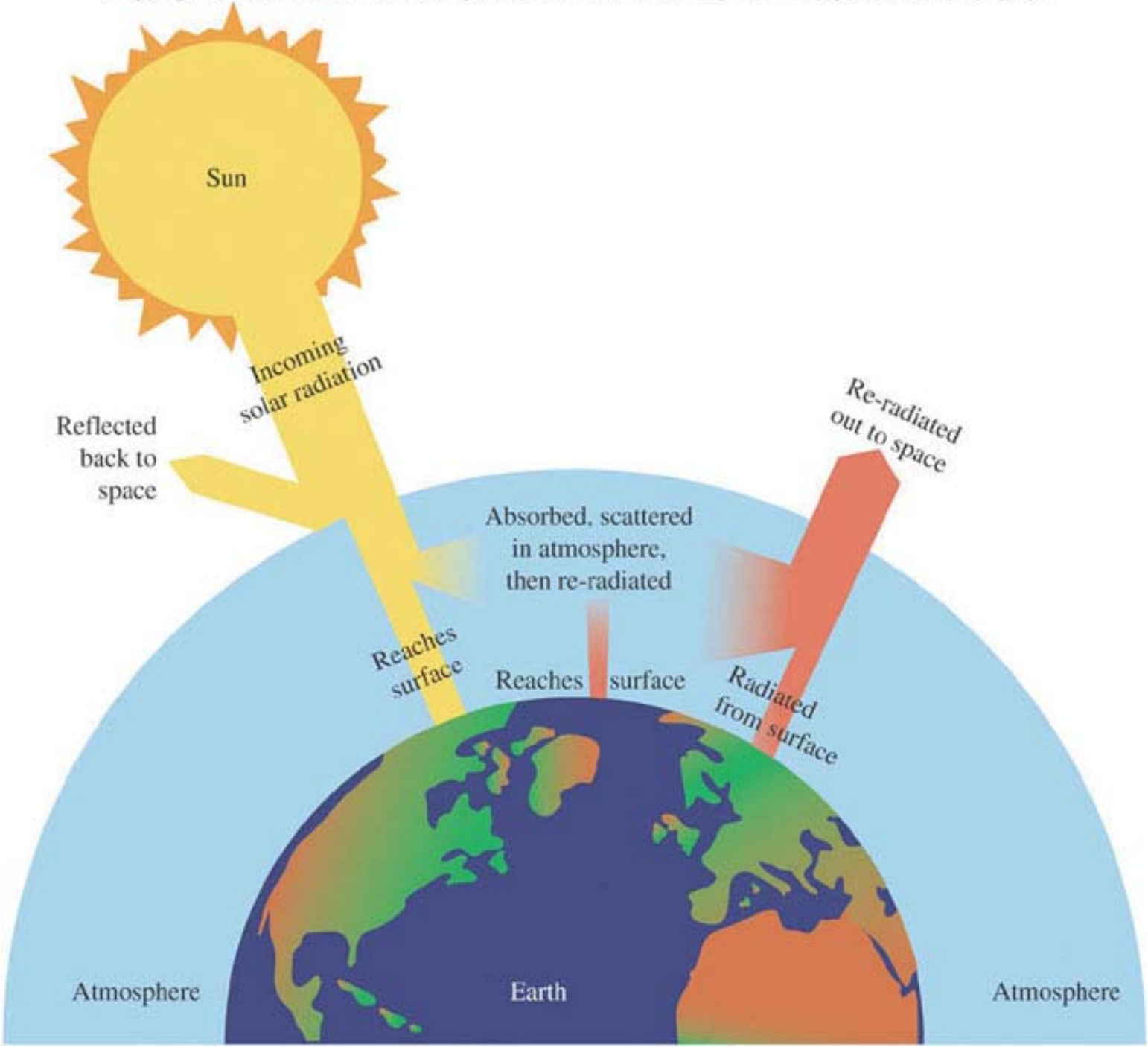
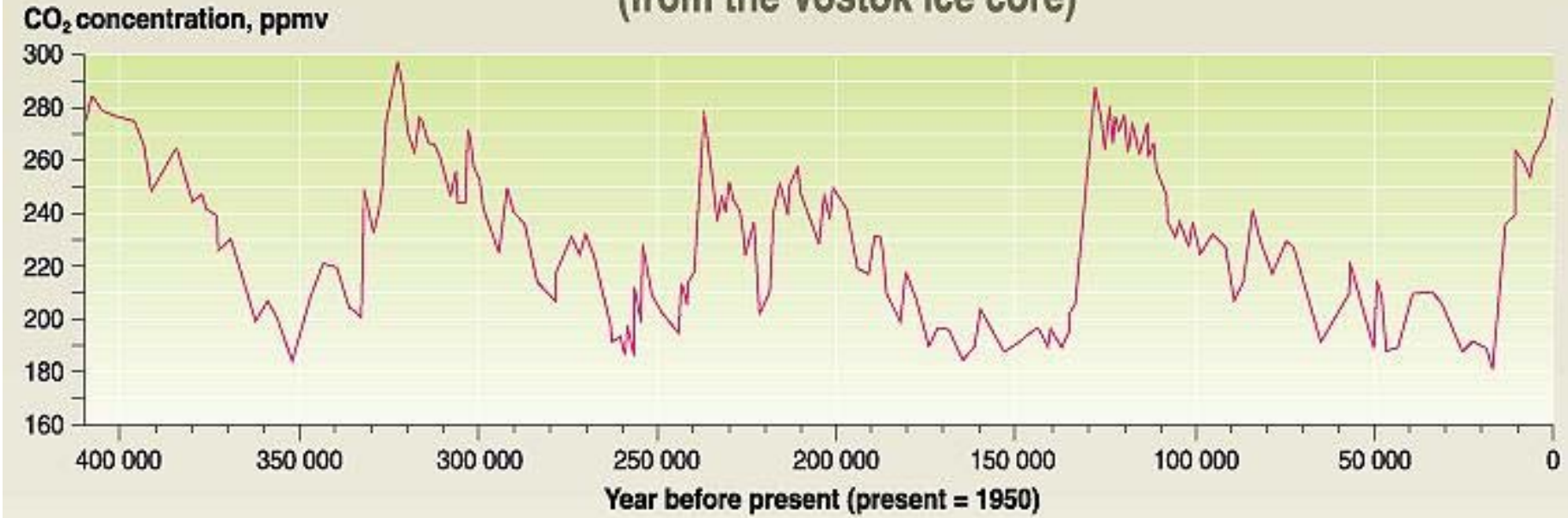


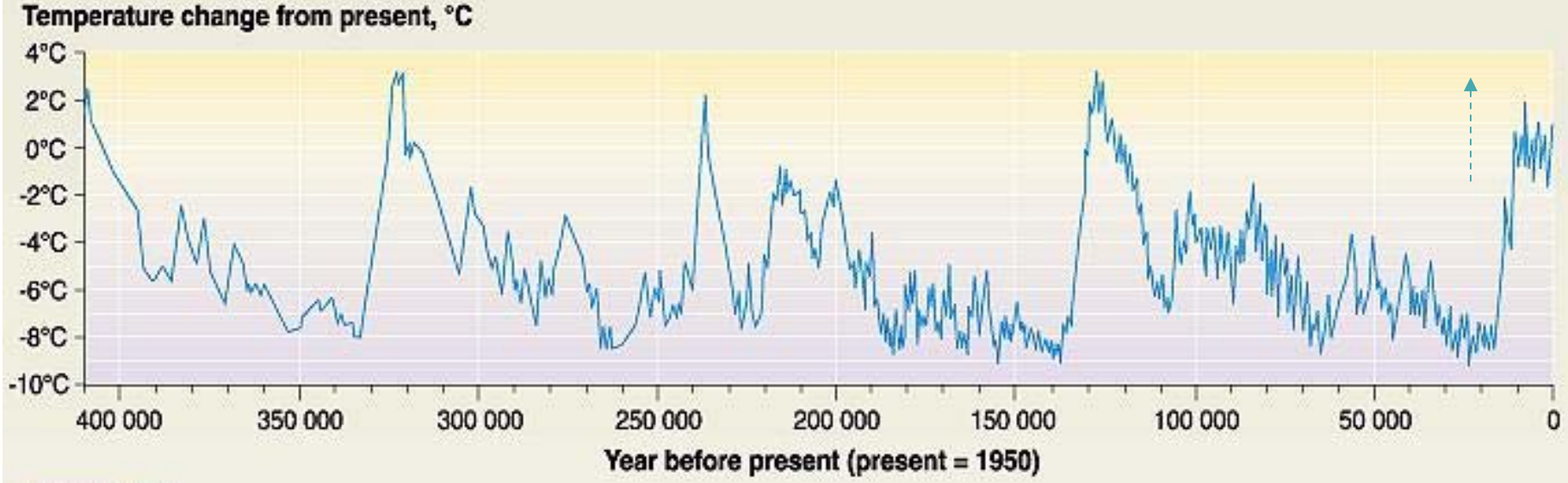
Venus
Average temperature 840°F
Average pressure: 90 atm
Atmosphere 96% CO_2
Clouds of Sulfuric Acid
(100°C)

Earth
Average temperature 59°F
Average pressure: 1 atm
Atmosphere 78% N_2
Clouds of Water
(-18°C)



Temperature and CO_2 concentration in the atmosphere over the past 400 000 years (from the Vostok ice core)

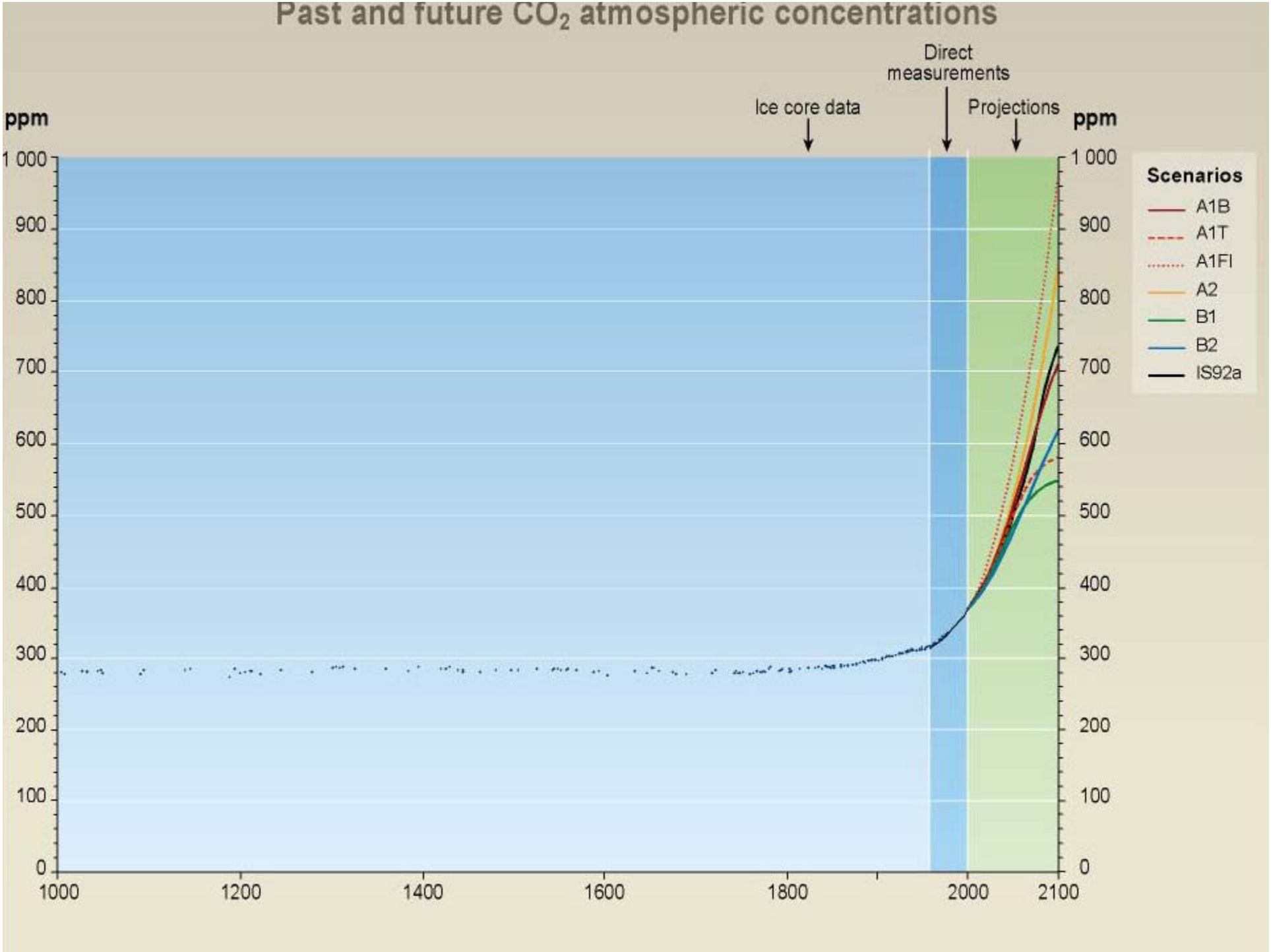




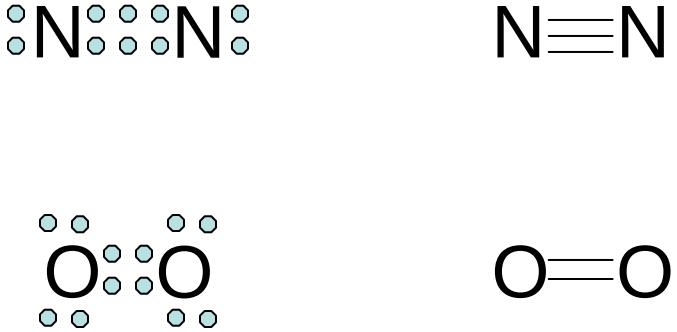
GRID Arendal UNEP

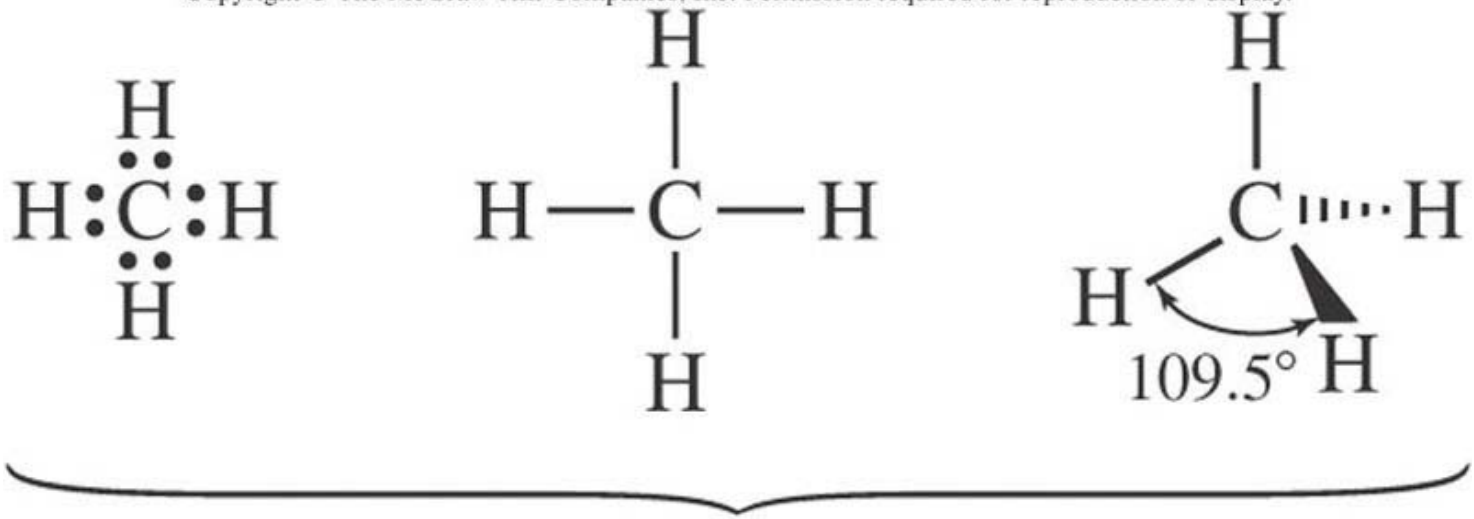
GRAPHIC DESIGN : PHILIPPE REKACEWICZ

Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3JUne), pp 429-436, 1999.

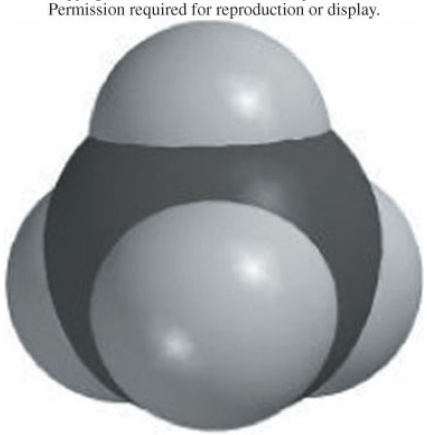

Past and future CO_2 atmospheric concentrations
Ice core data
Direct measurements
Projections
ppm
ppm
1 000
900
800
700
600
500
400
300
200
100
0
1000
1200
1400
1600
1800
2000
2100
Scenarios
A1B
A1T
A1FI
A2
B1
B2
IS92a

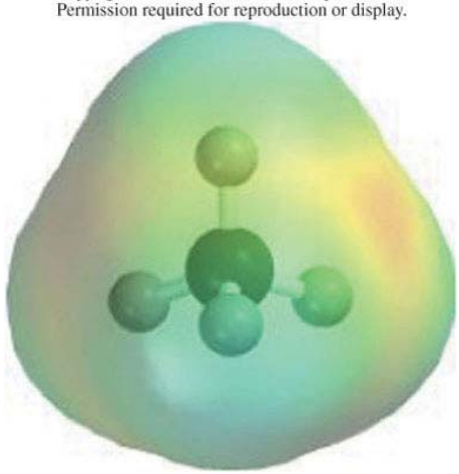
- Greenhouse Gases
  - H_2O, CO_2, CH_4
- Not Greenhouse Gases
  - N_2, O_2, Ar
- Molecular Structure
- Molecular Shape





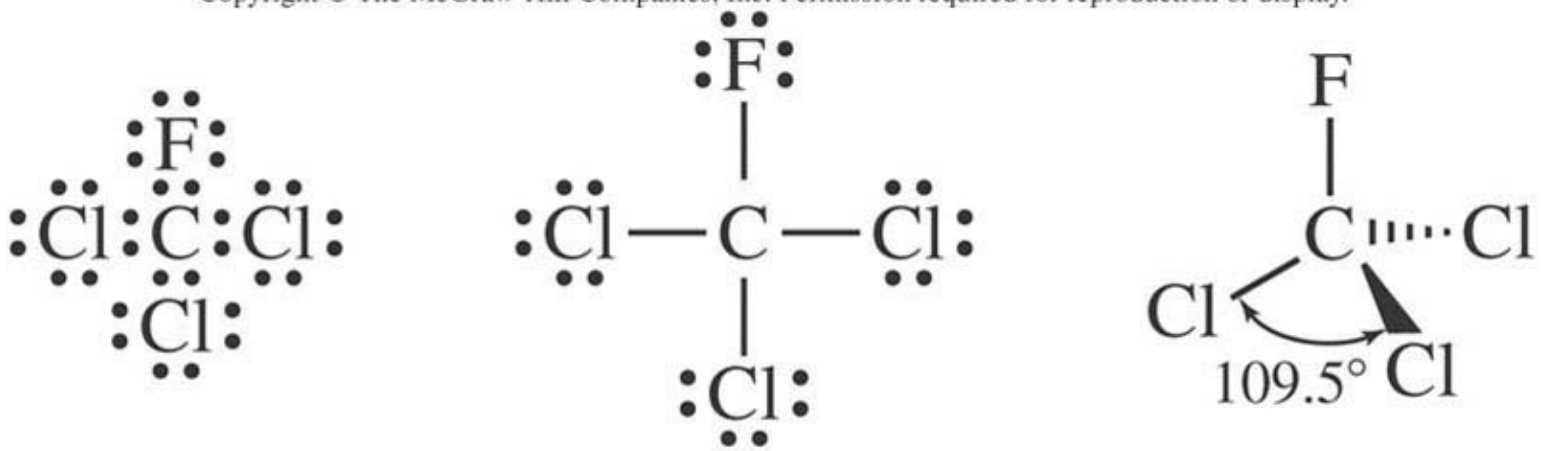
(a)



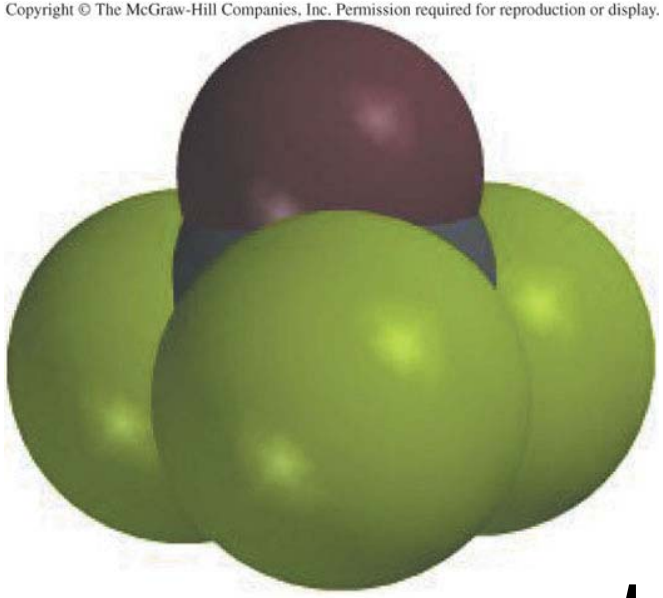


tetrahedron

(b) (c)

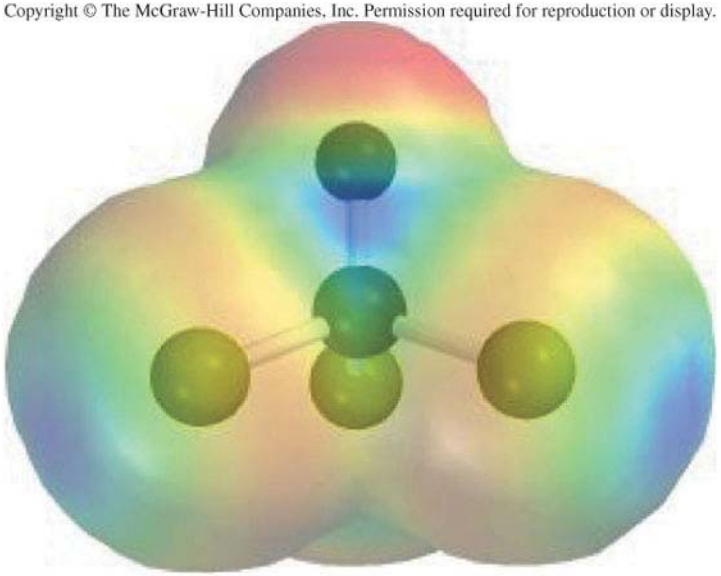


(a)

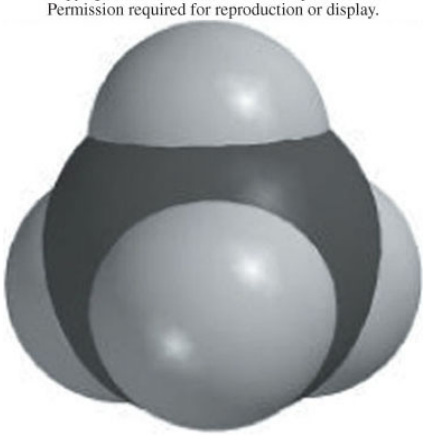


(b)

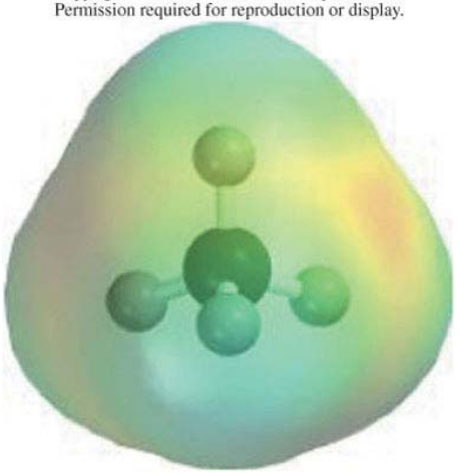
tetrahedron



(c)



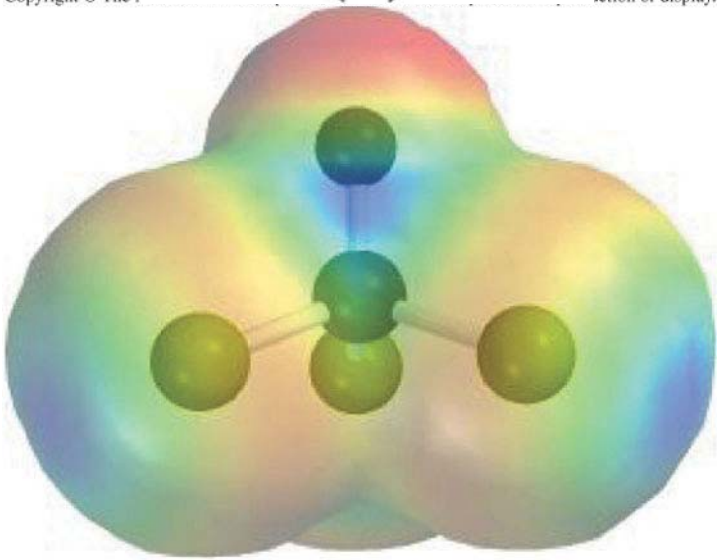
(b)



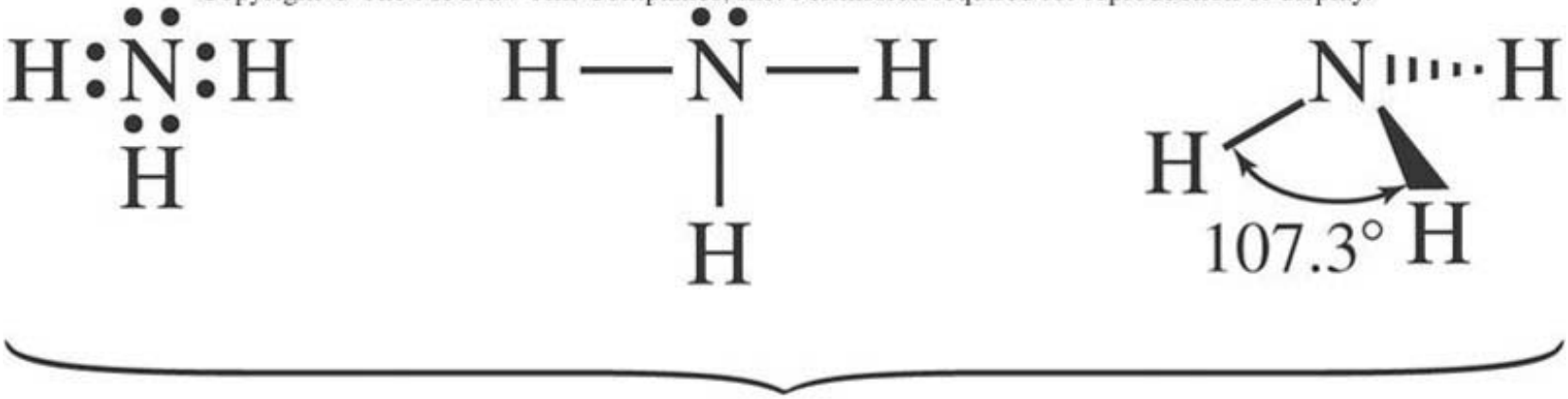
(c)

(b)

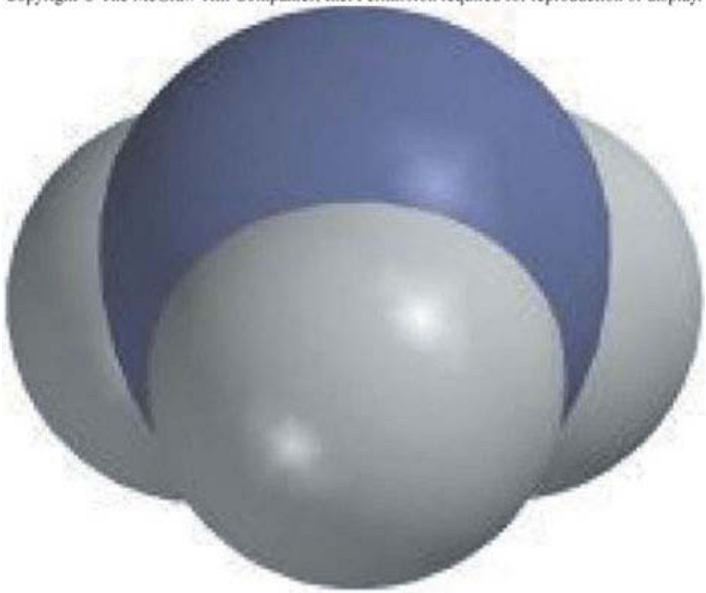
tetrahedron



(c)

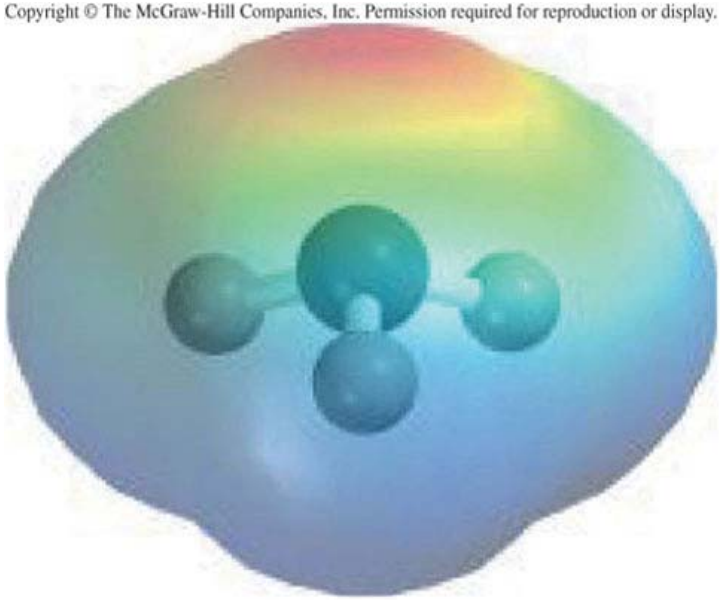


(a)



(b)

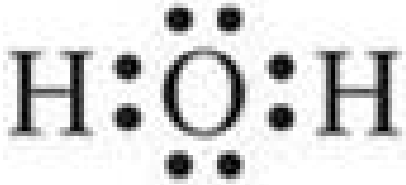
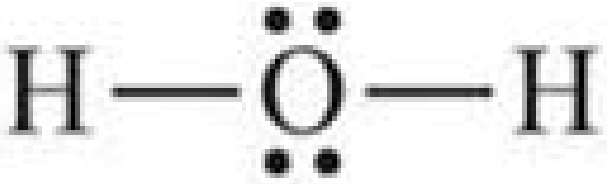
pyramid

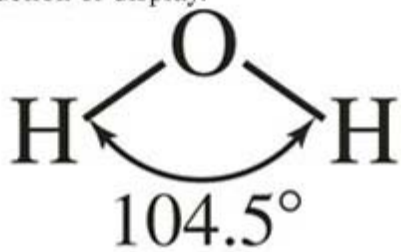


(c)

Water, H_2O

N=	8+2+2	= 12
A=	5+1+1	= 8
S=	N-A	4 e^- shared 2 bonds

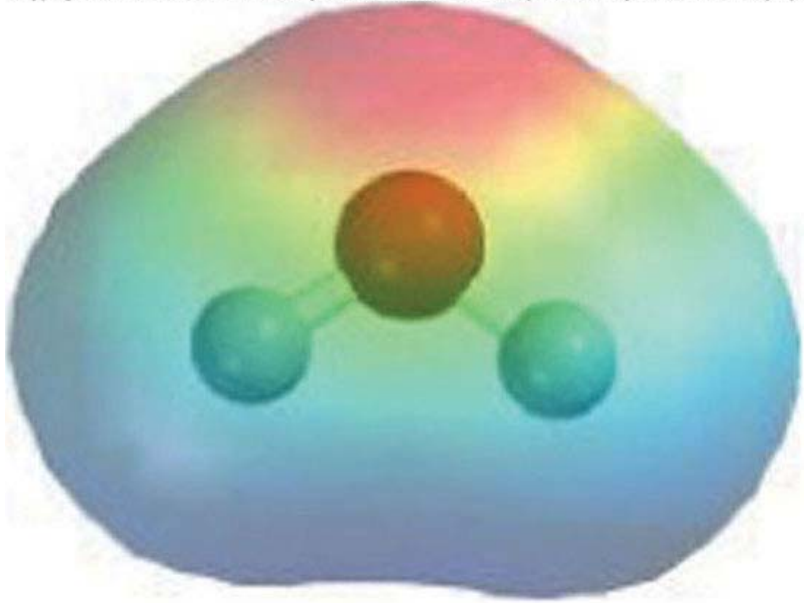





(a)

(b)

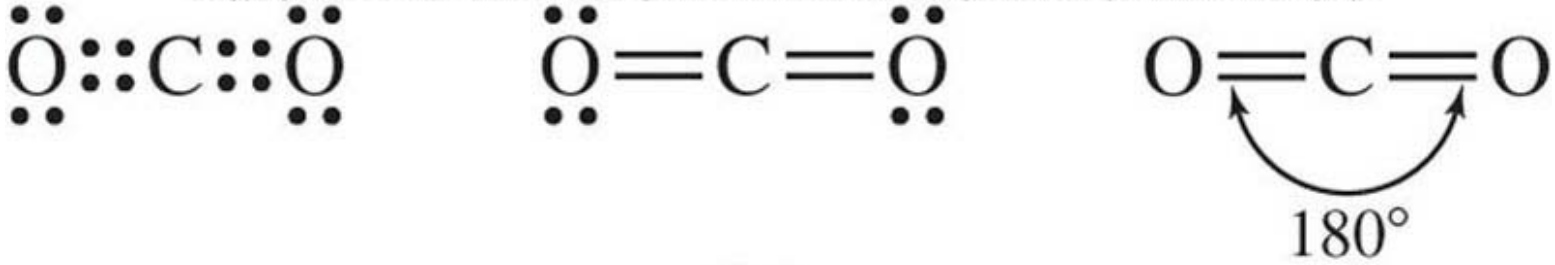
bent



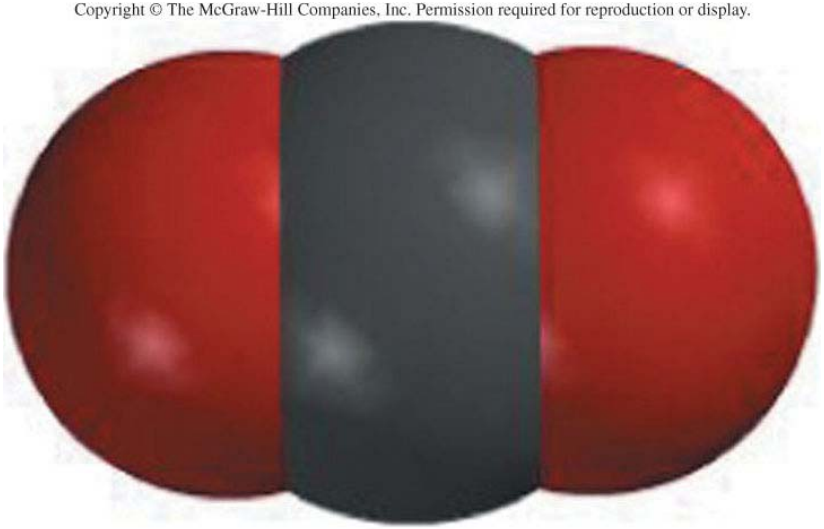
(c)

Carbon Dioxide, CO_2

N=	8+8+8	= 24
A=	4+6+6	= 16
S=	N-A	8 e^- shared 4 bonds

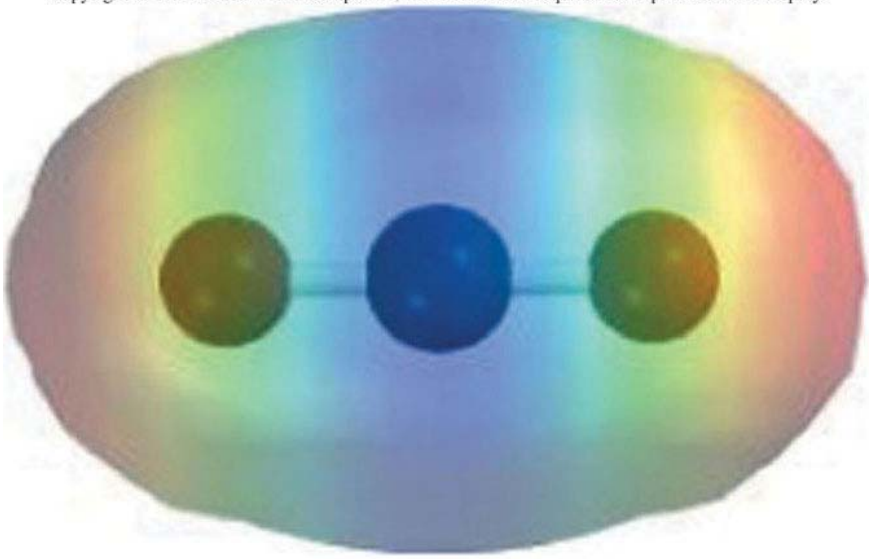


(a)



(b)

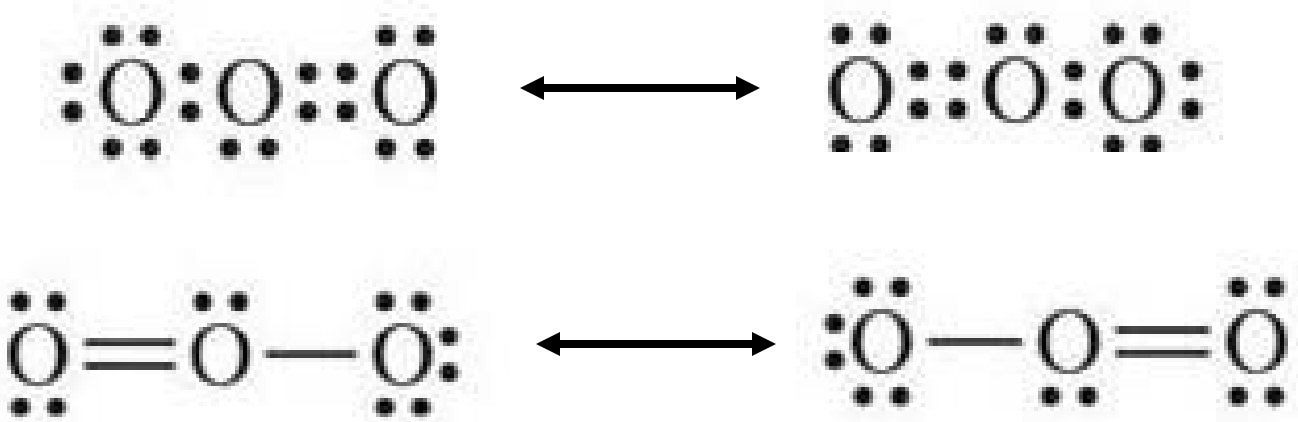
linear

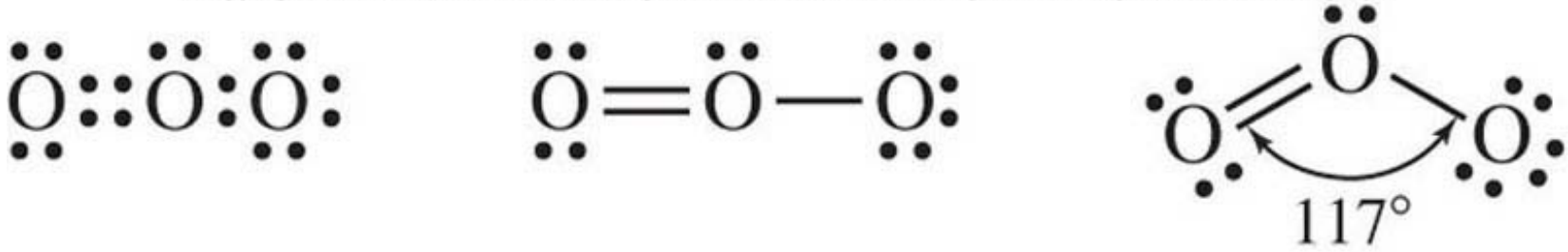


(c)

Ozone, O_3

N=	8+8+8	= 24
A=	6+6+6	= 18
S=	N-A	6 e^- shared 3 bonds

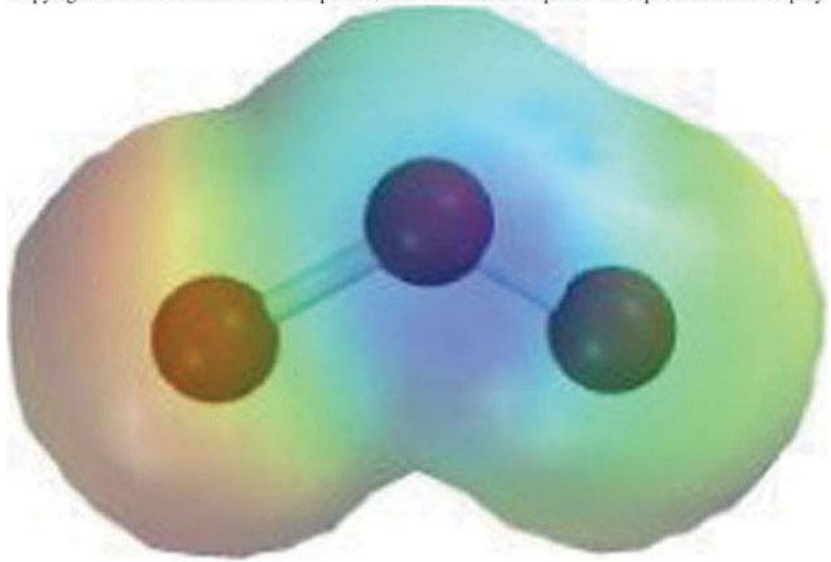




(a)

(b)

bent

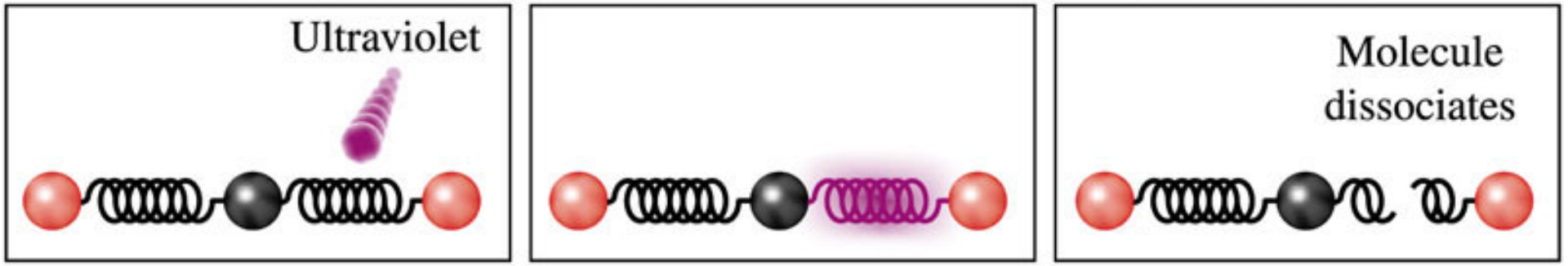


(c)

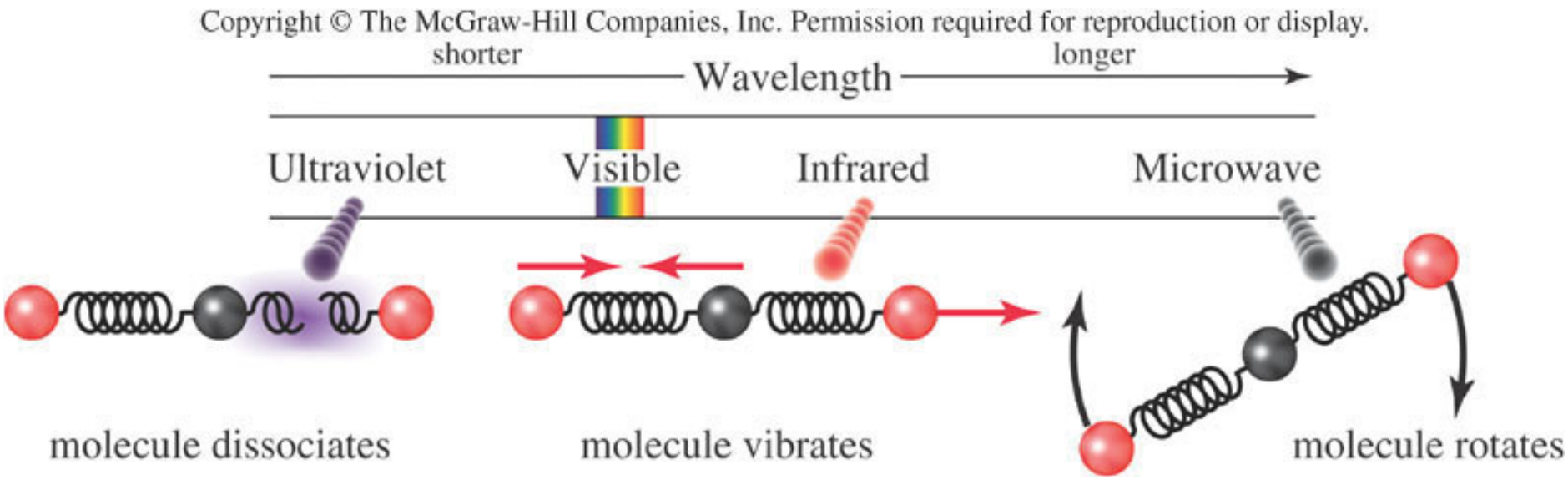
The Interaction of Light with Molecules

•It turns out that the energy in one photon of ultraviolet light has approximately the same energy as a molecular bond!

•If a molecule is struck by a photon of the right energy – that is, of the right frequency! – the molecular bonds will break



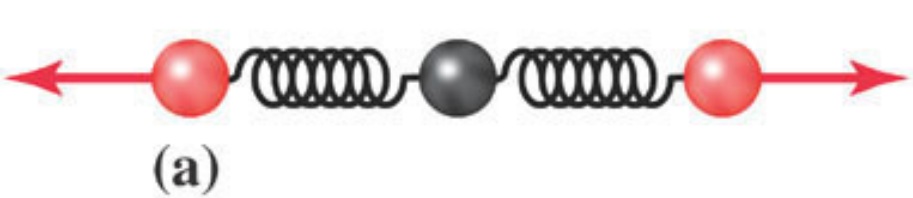
The Interaction of Light with Molecules

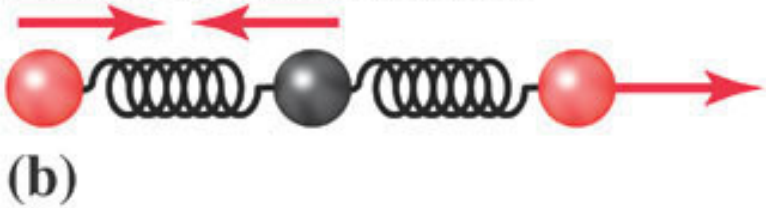


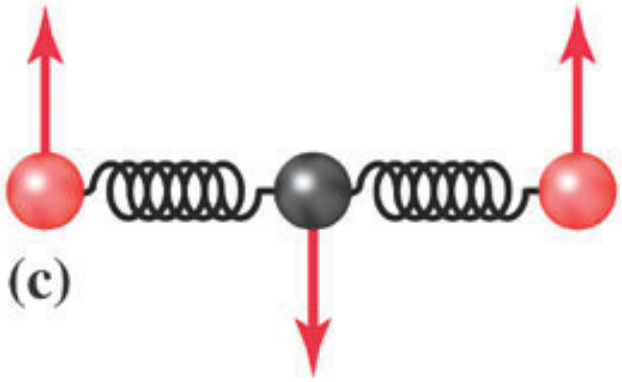
Molecular Vibrations in CO_2

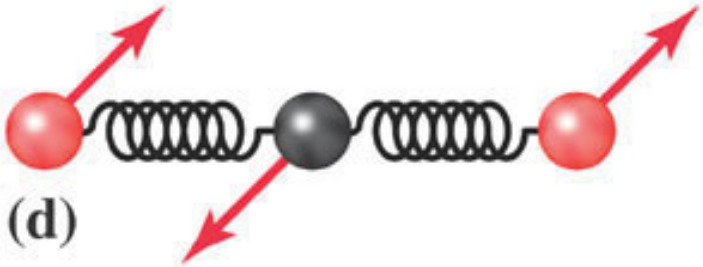
Symmetric stretch

Asymmetric stretch





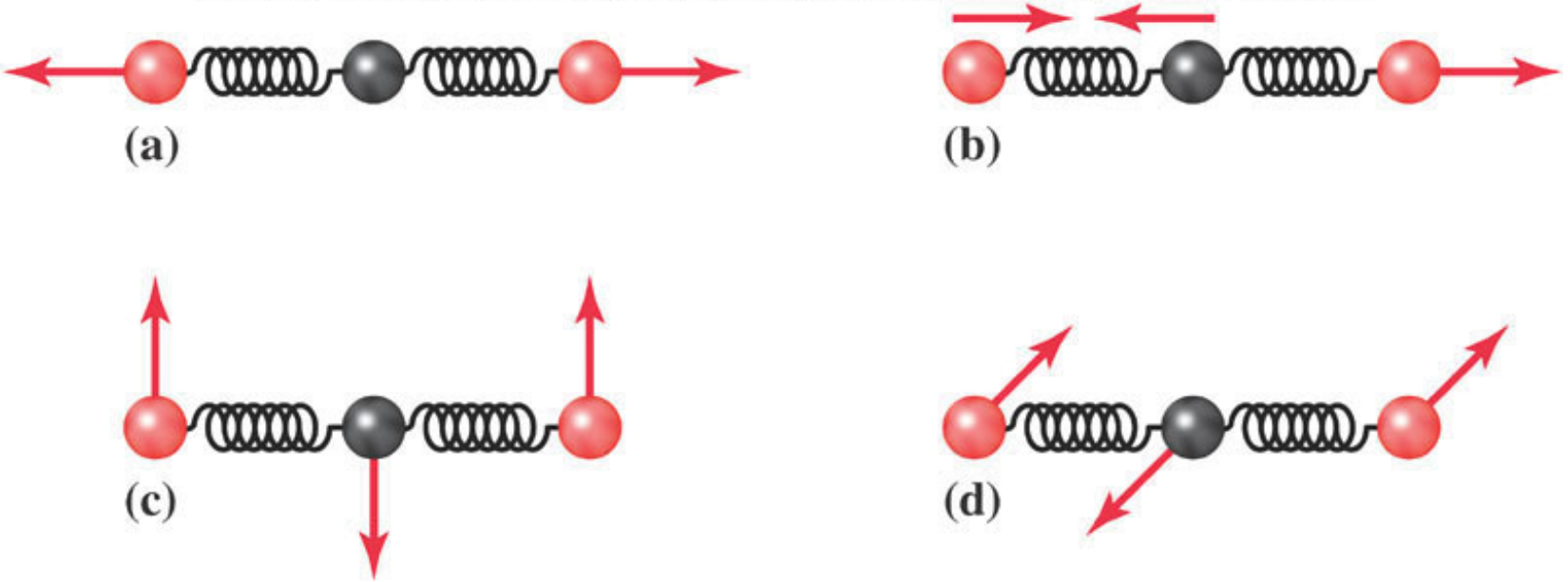




Bend (in plane)

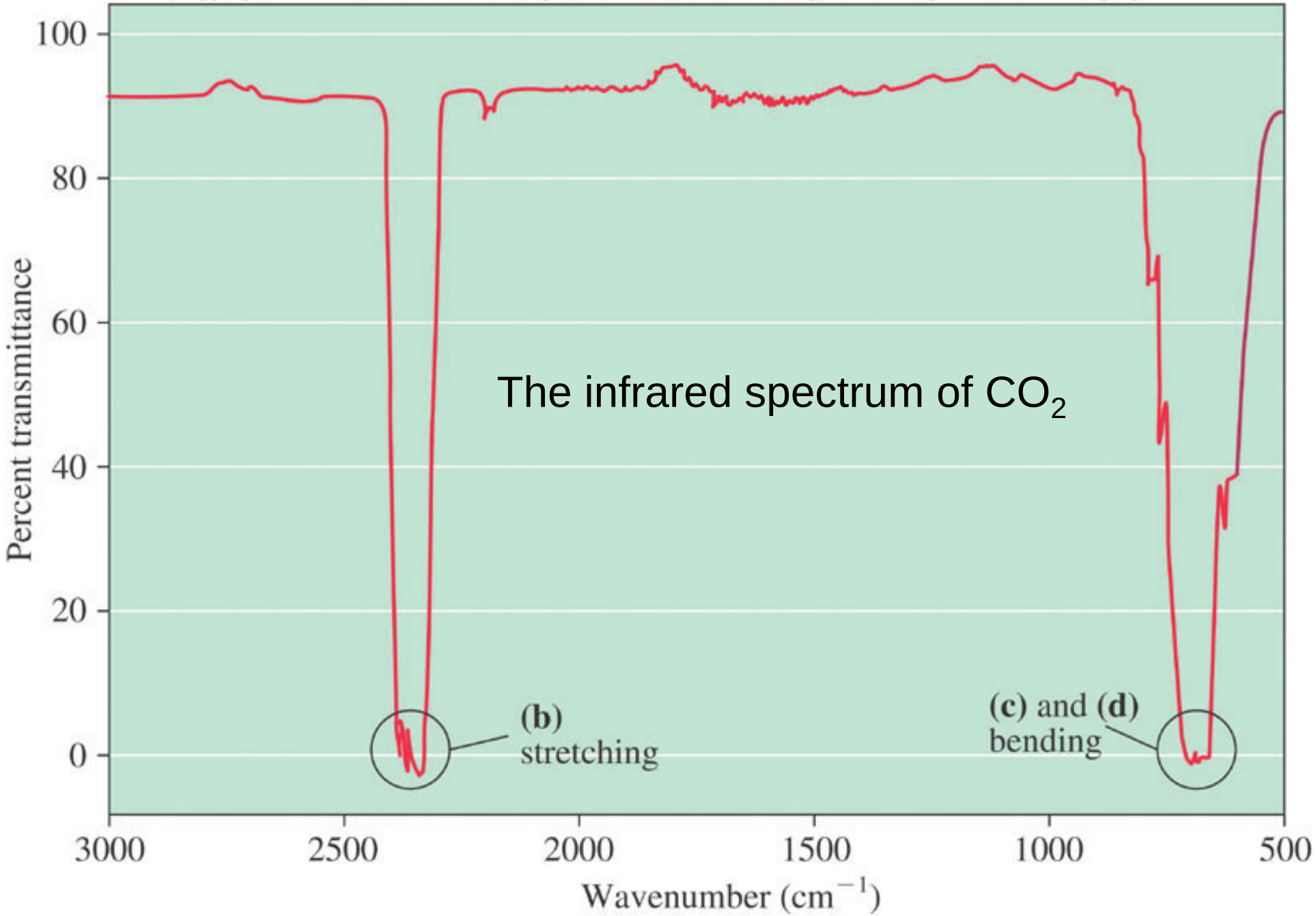
Bend (out of plane)

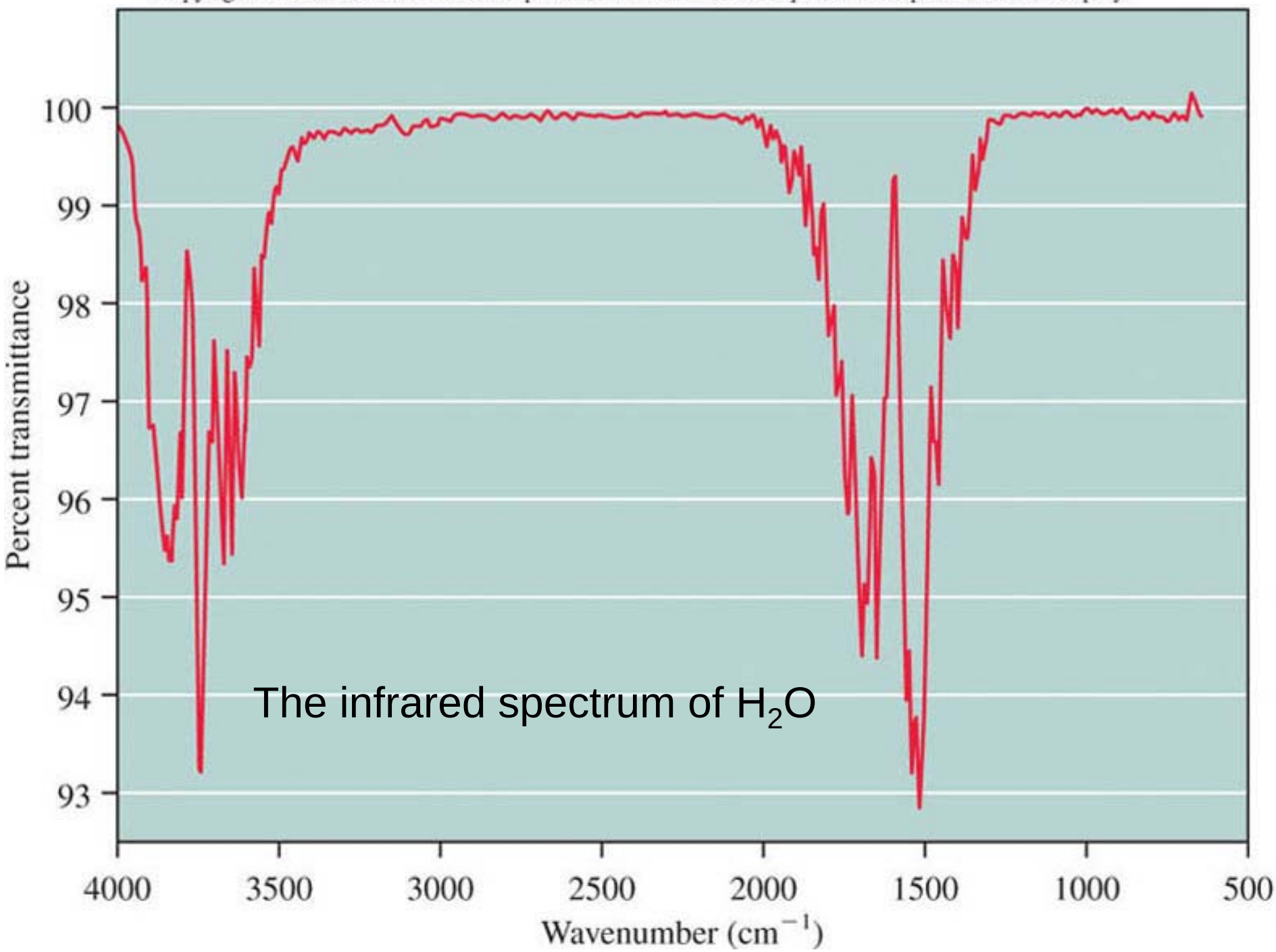
Molecular Vibrations in CO_2



Recall that each bond has its own particular frequency that corresponds to the amount of UV radiation needed to break it.

Similarly, each **vibration** of a bond has a given frequency that corresponds to the frequency of IR radiation needed to make it oscillate.





The infrared spectrum of H_2O

Wavelength to Wavenumber

$\bar{\nu} = wavenumber\ (cm^{-1} = /cm)$ $\lambda = wavelength\ (\mu m = \times 10^{-6} m)$

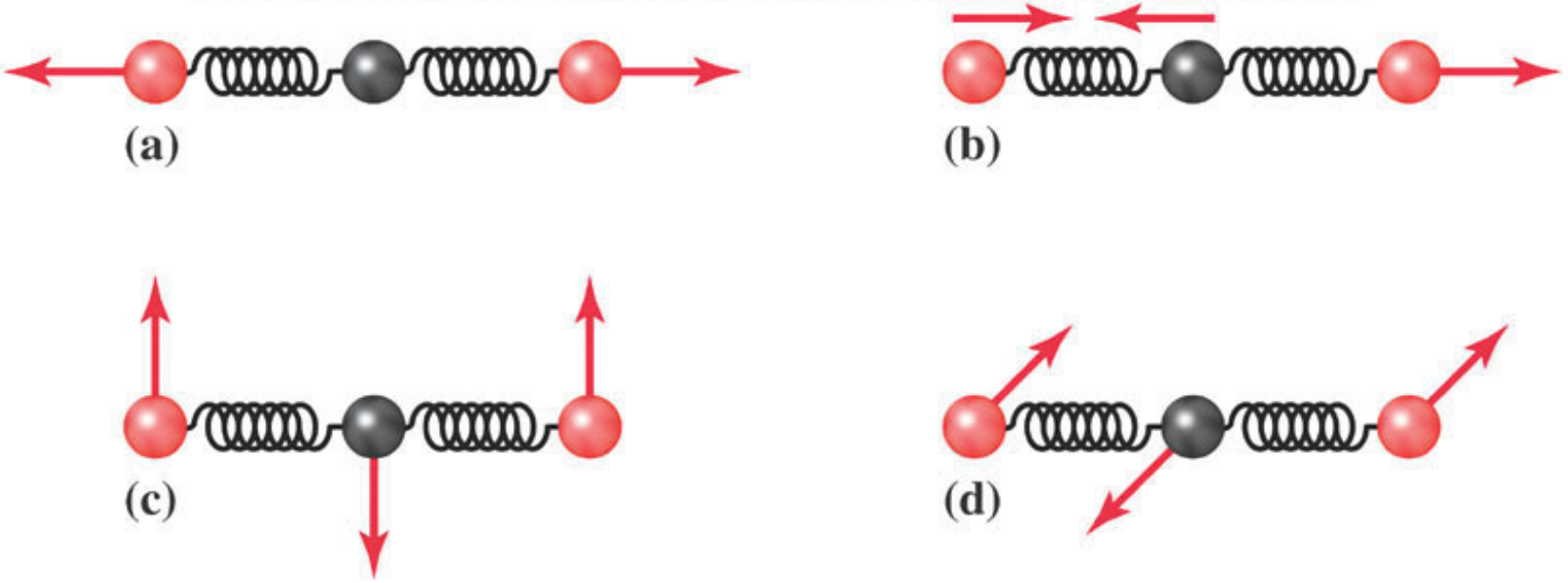
$$\lambda = \frac{1}{\bar{\nu}} \qquad \lambda = c / \nu$$

$$\bar{\nu} = 600\, cm^{-1} = \frac{600}{cm} \times \frac{100\, cm}{1m} = \frac{60{,}000}{m}$$

$$\lambda = \frac{1}{\bar{\nu}} = \frac{1}{\frac{60{,}000}{m}} = \frac{1m}{60{,}000} = 1.667 \times 10^{-5} m \times \frac{10^6\, \mu m}{1m} = 16.67\, \mu m$$

$$when\ \ \bar{\nu} = 2200\, cm^{-1} \quad \lambda = 4.545\, \mu m$$

Molecular Vibrations in CO_2

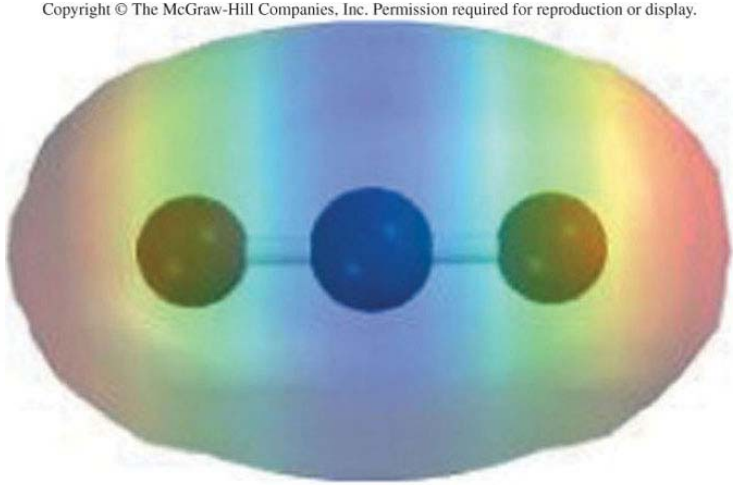


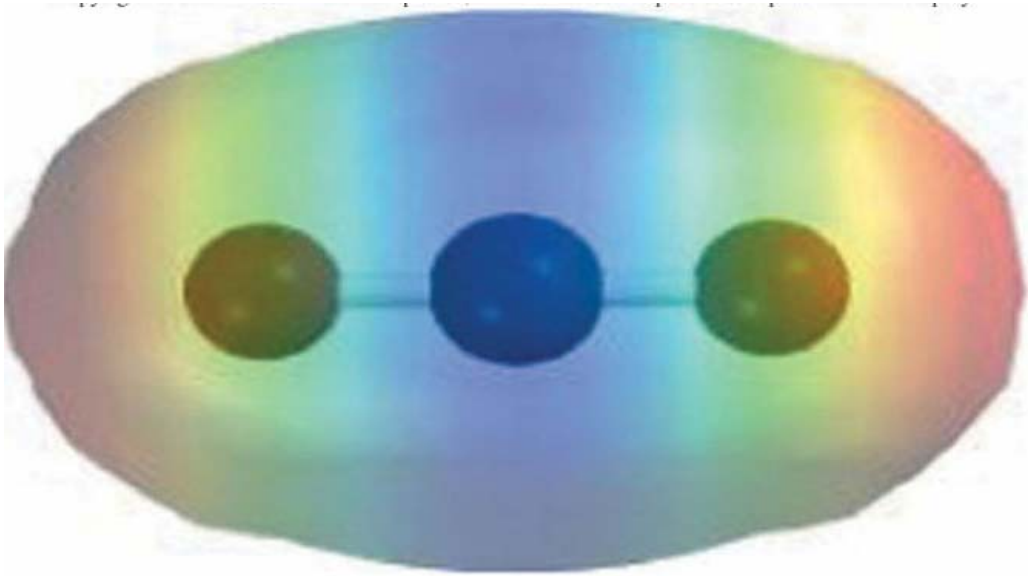
Similarly, each **vibration** of a bond has a given frequency that corresponds to the frequency of IR radiation needed to make it oscillate.

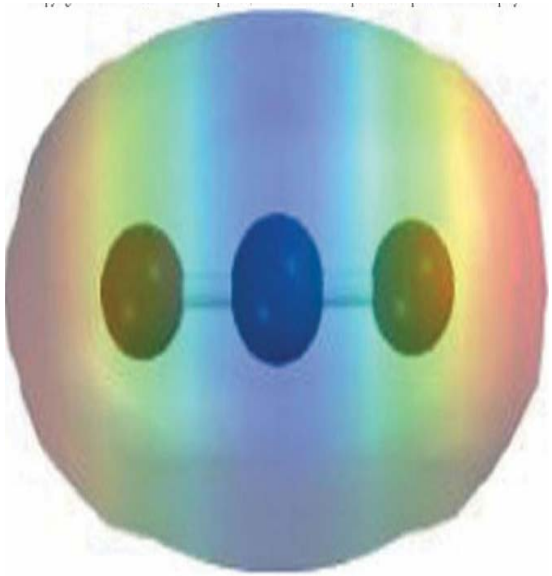
BUT... Not all vibrations absorb infrared radiation!

Molecular Vibrations in CO_2

Symmetric stretch

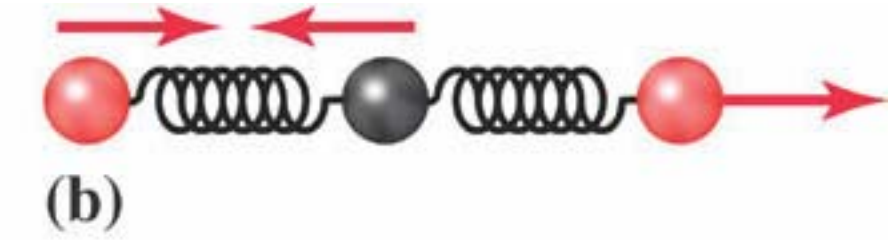


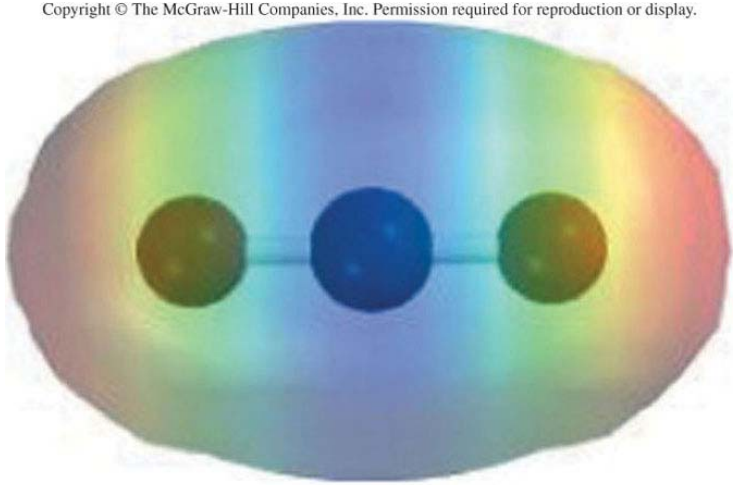


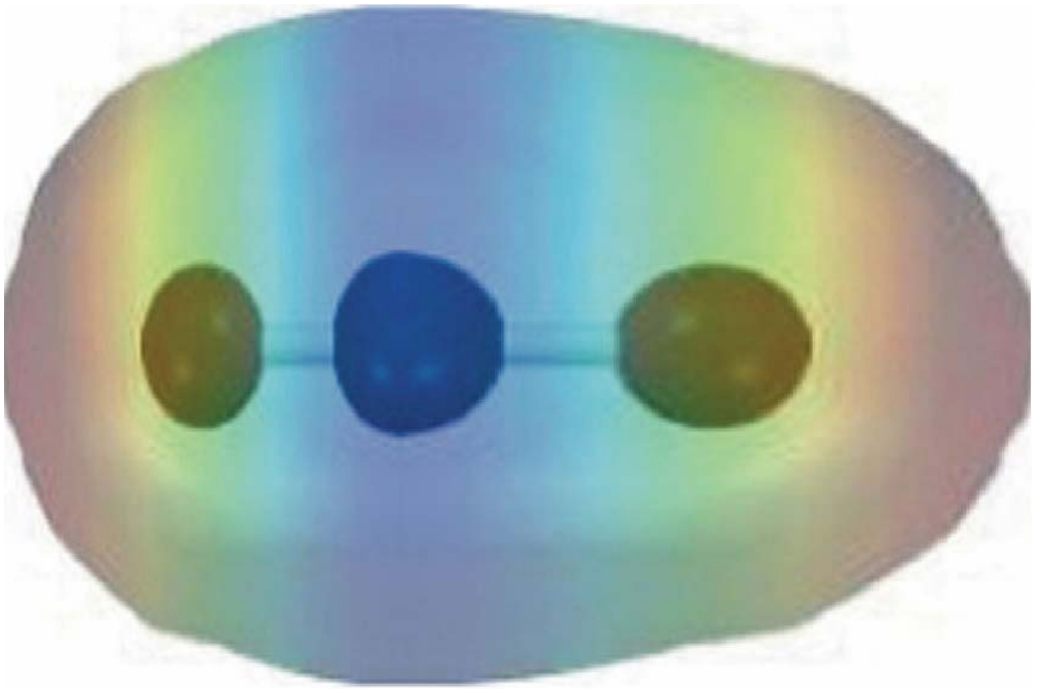


Molecular Vibrations in CO_2

Asymmetric stretch

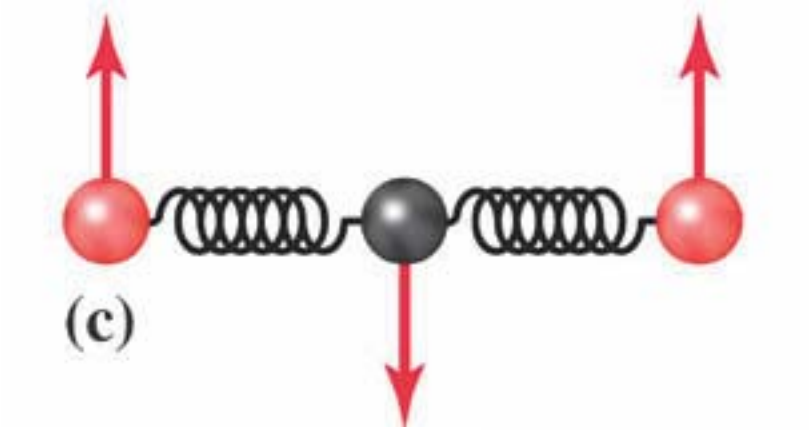


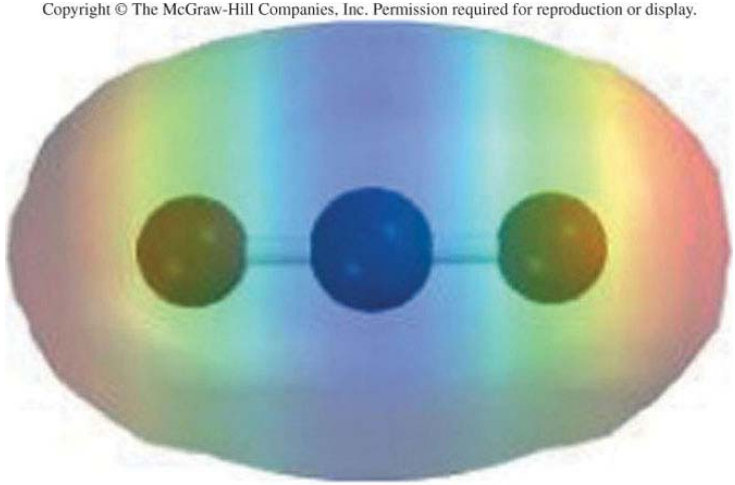


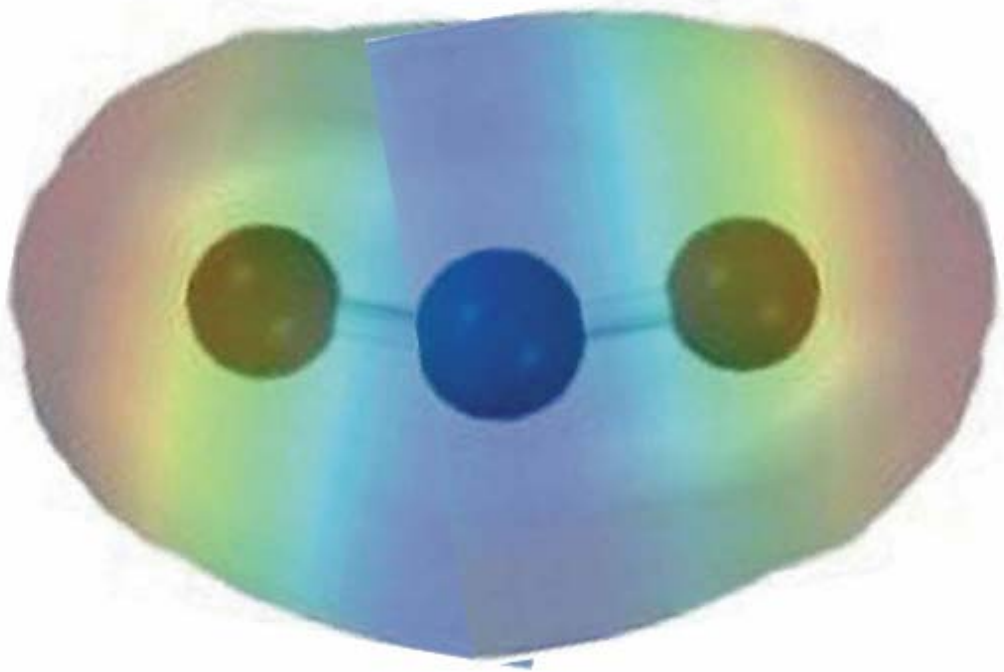


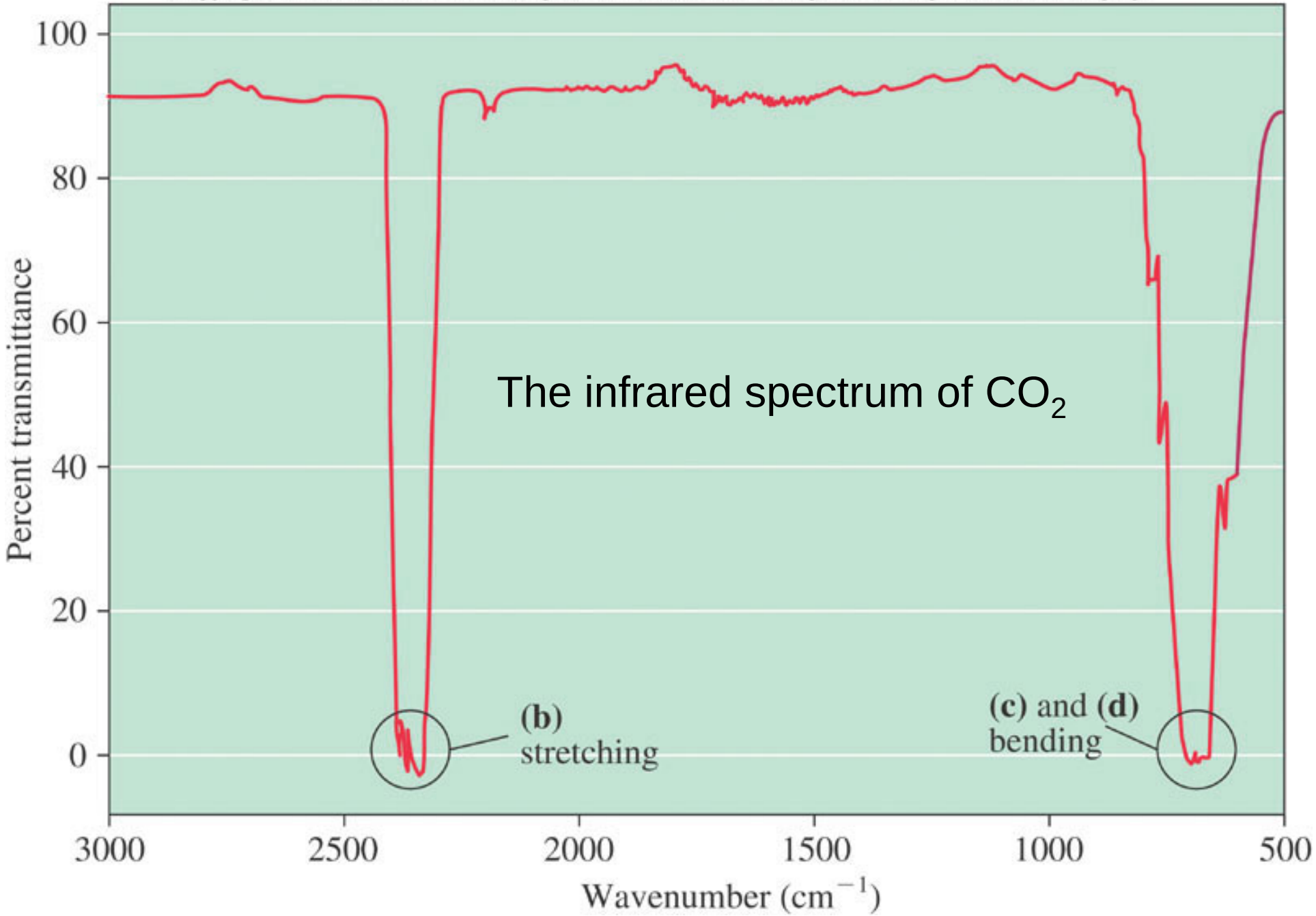
Molecular Vibrations in CO_2

Bend









- Greenhouse Gases
  - H_2O, CO_2, CH_4
- Not Greenhouse Gases
  - N_2, O_2, Ar
- Molecular Structure
- Molecular Shape