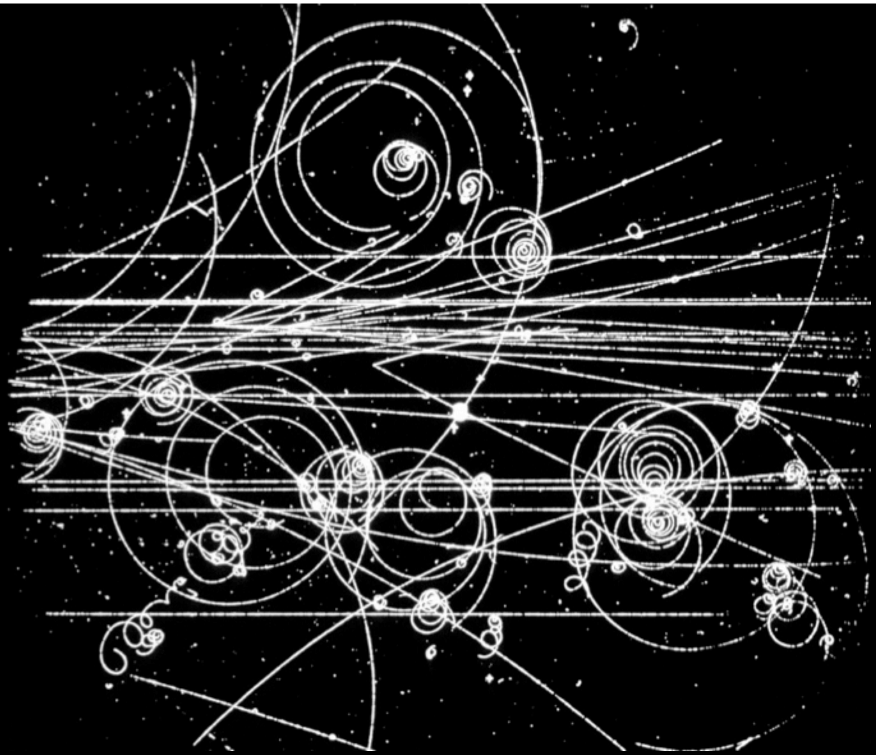
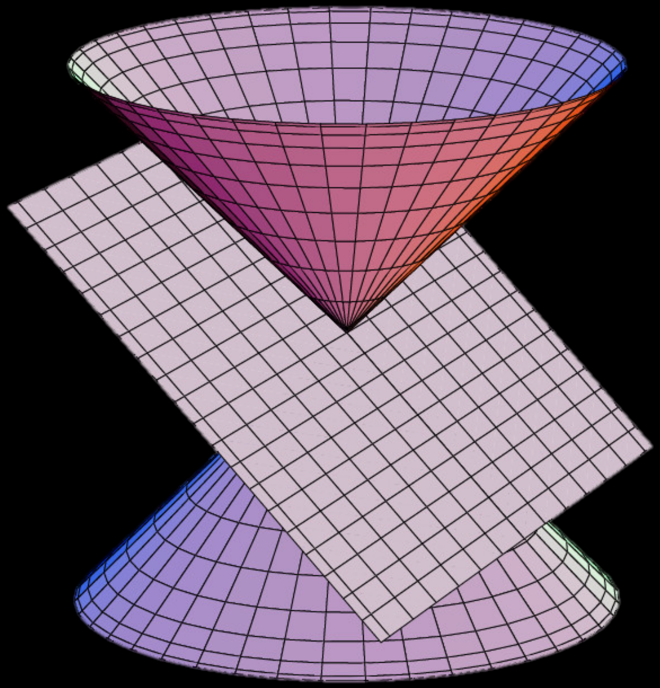
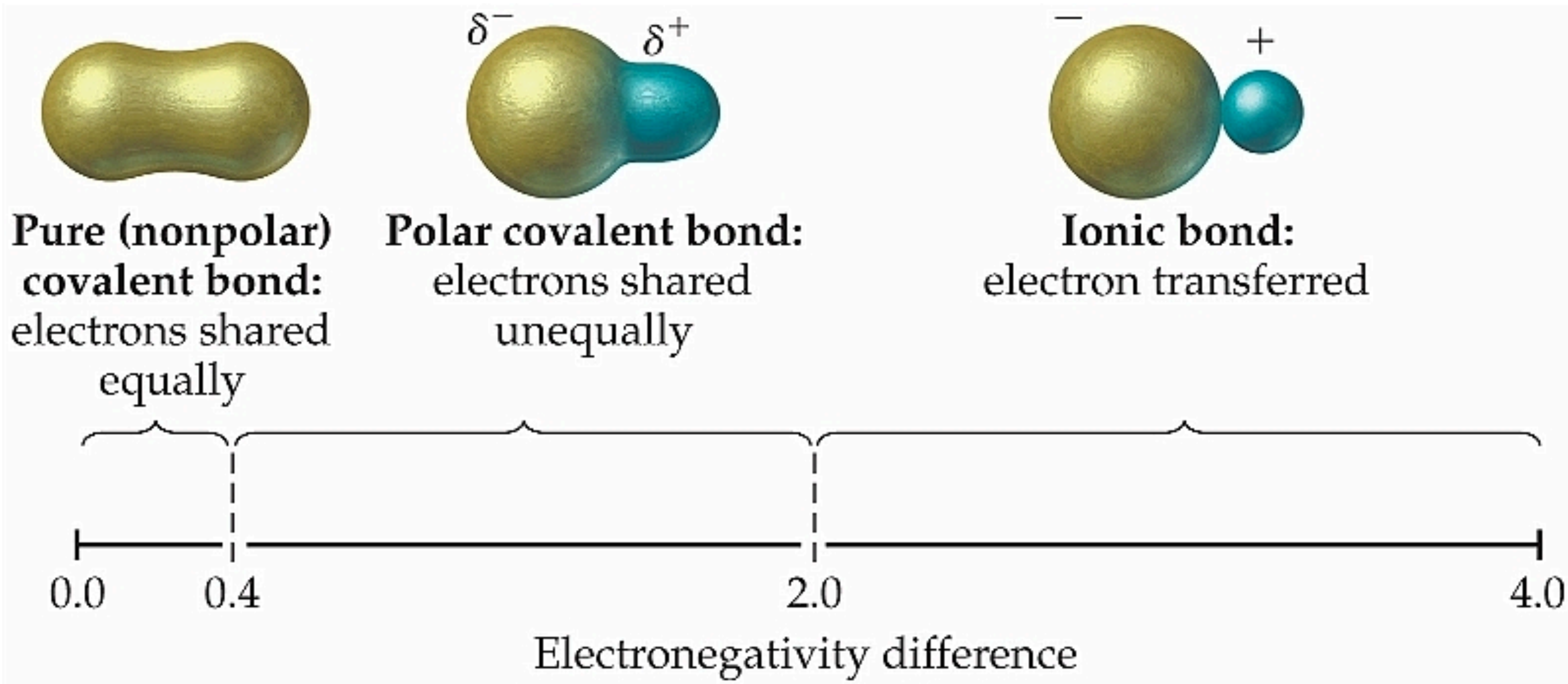




Modern Physics (Phys. IV): 2704

Professor Jasper Halekas
Van Allen 70
MWF 12:30-1:20 Lecture

Covalent Vs Ionic Bonding



Concept Check

- What will happen if a molecule is placed in an ambient electric field?

A. Will always rotate to align with E-field
B. Will rotate to align with E-field if covalent
C. Will rotate to align with E-field if ionic
D. Will not be affected by E-field

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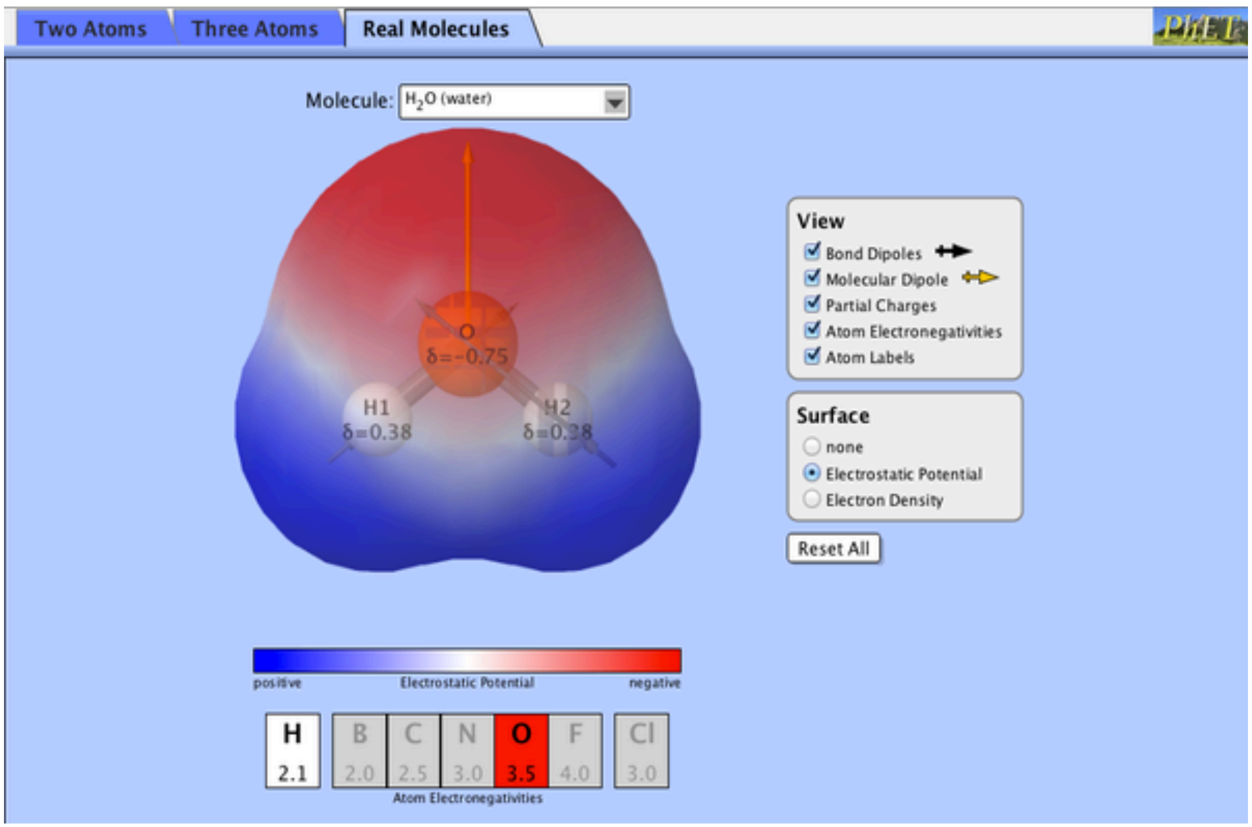
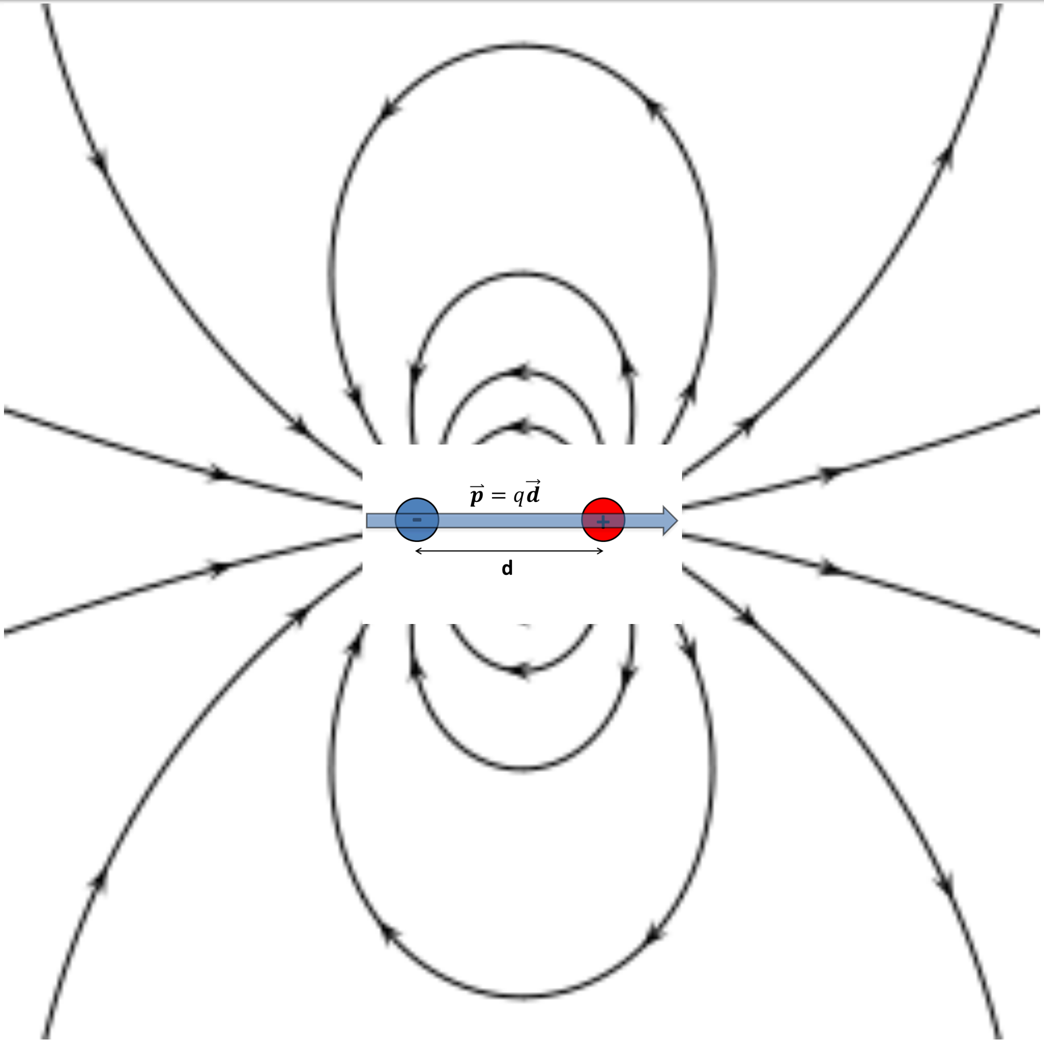
Covalent Vs. Ionic Bonds

- https://phet.colorado.edu/en/simulation/molecule-polarity



Note:
Blue is positive
Red is negative

Electric Dipole Moment

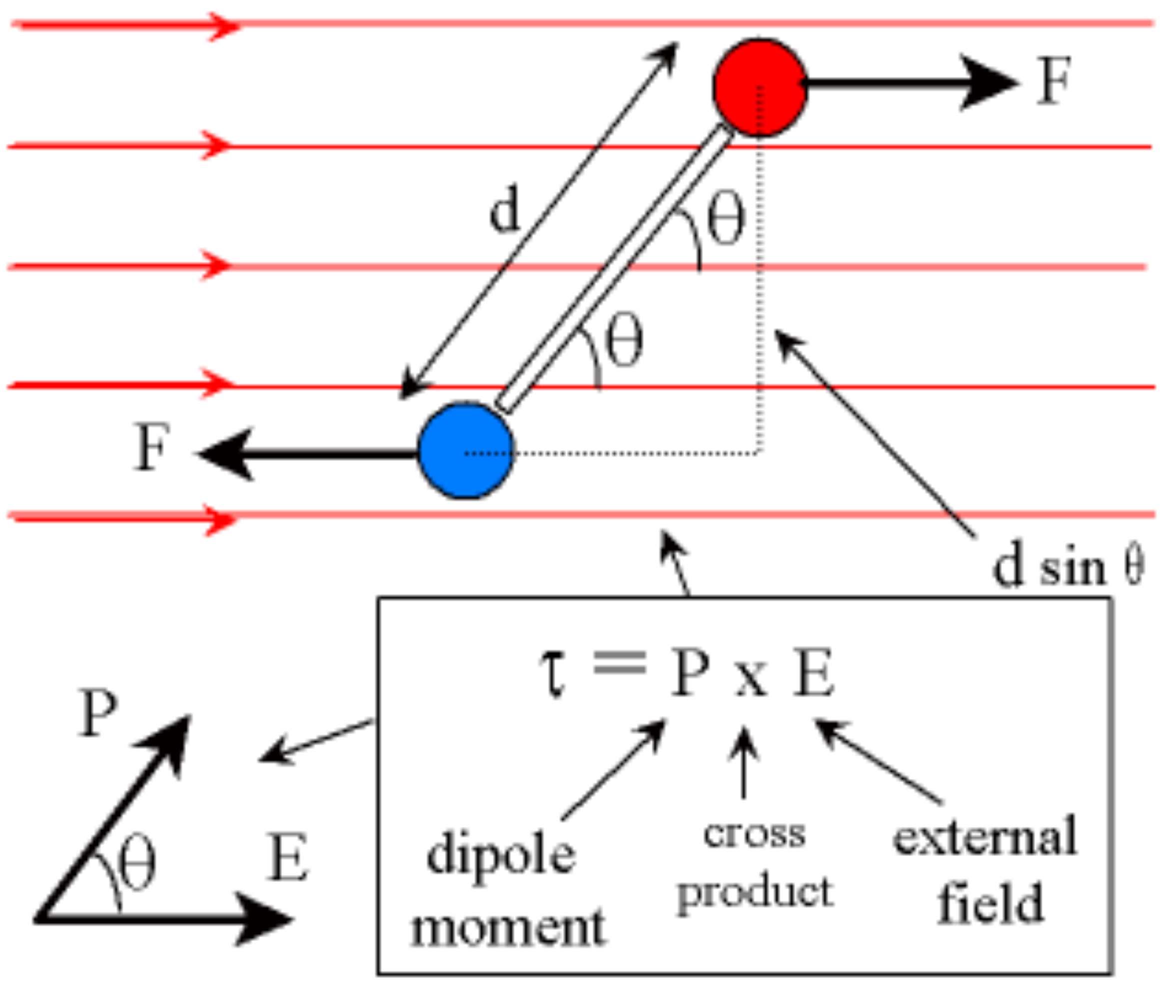


Note:
Blue is negative
Red is positive

Electric dipole points from – to +

Bond dipole points from + to – under some conventions

Torque on Electric Dipole



Note:
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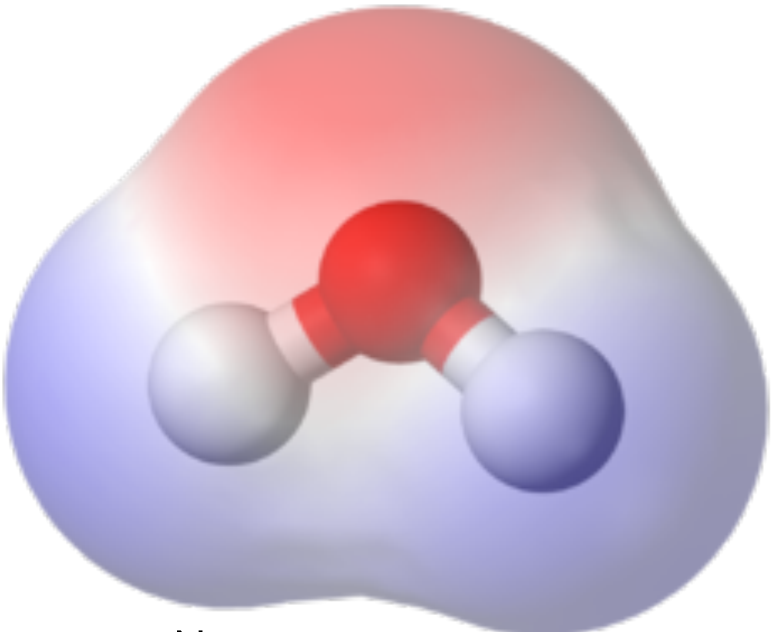
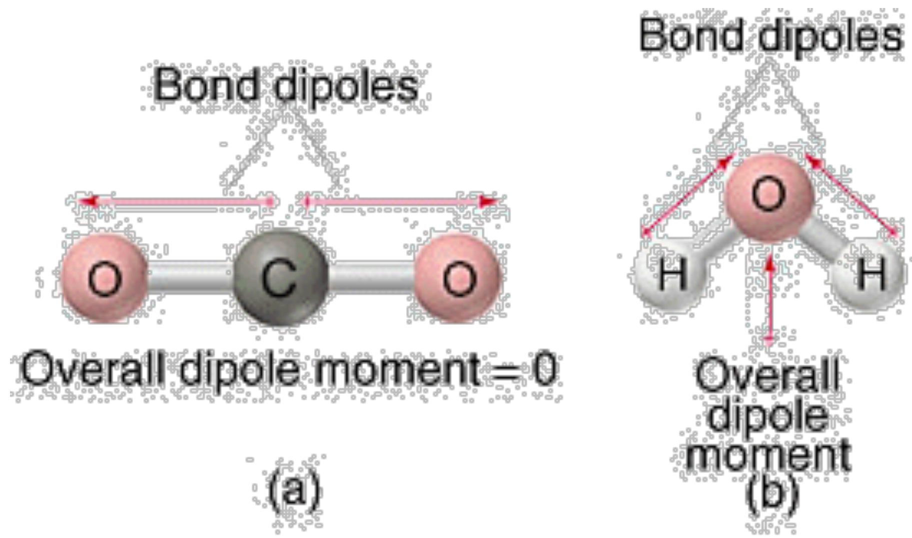
Red is positive

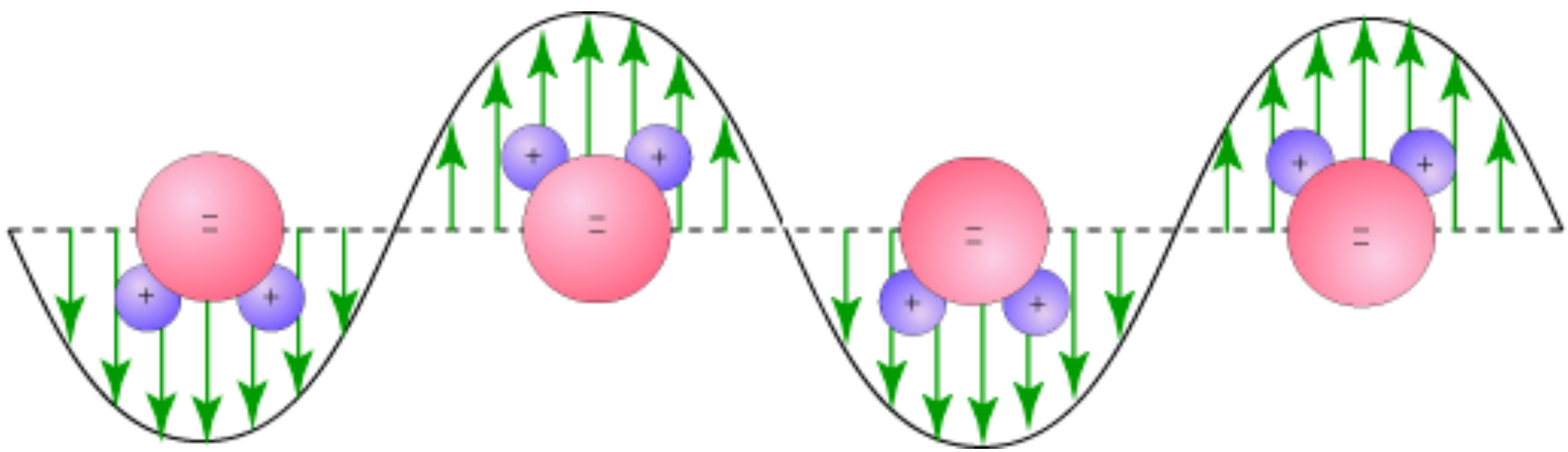
Water Dipole



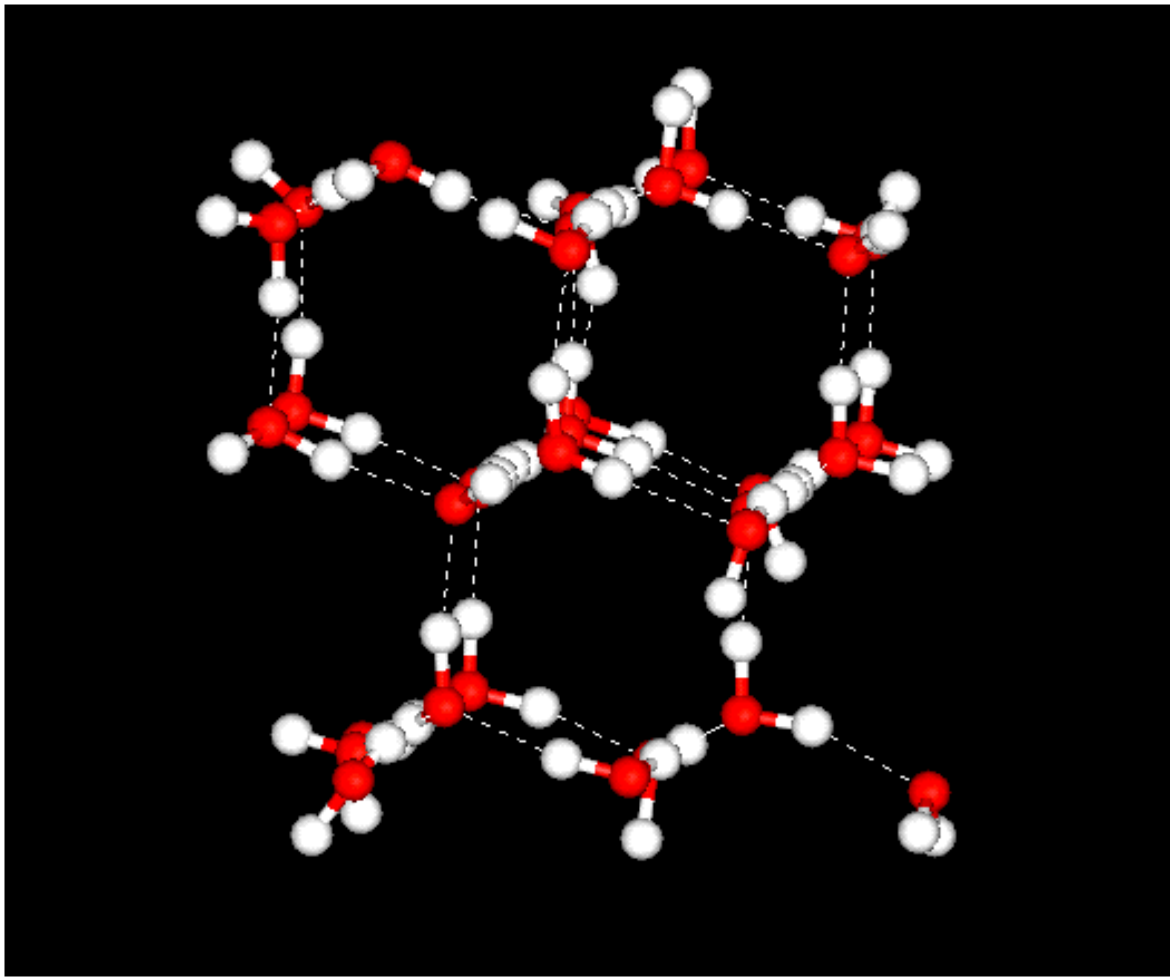
Note:
Blue is positive
Red is negative



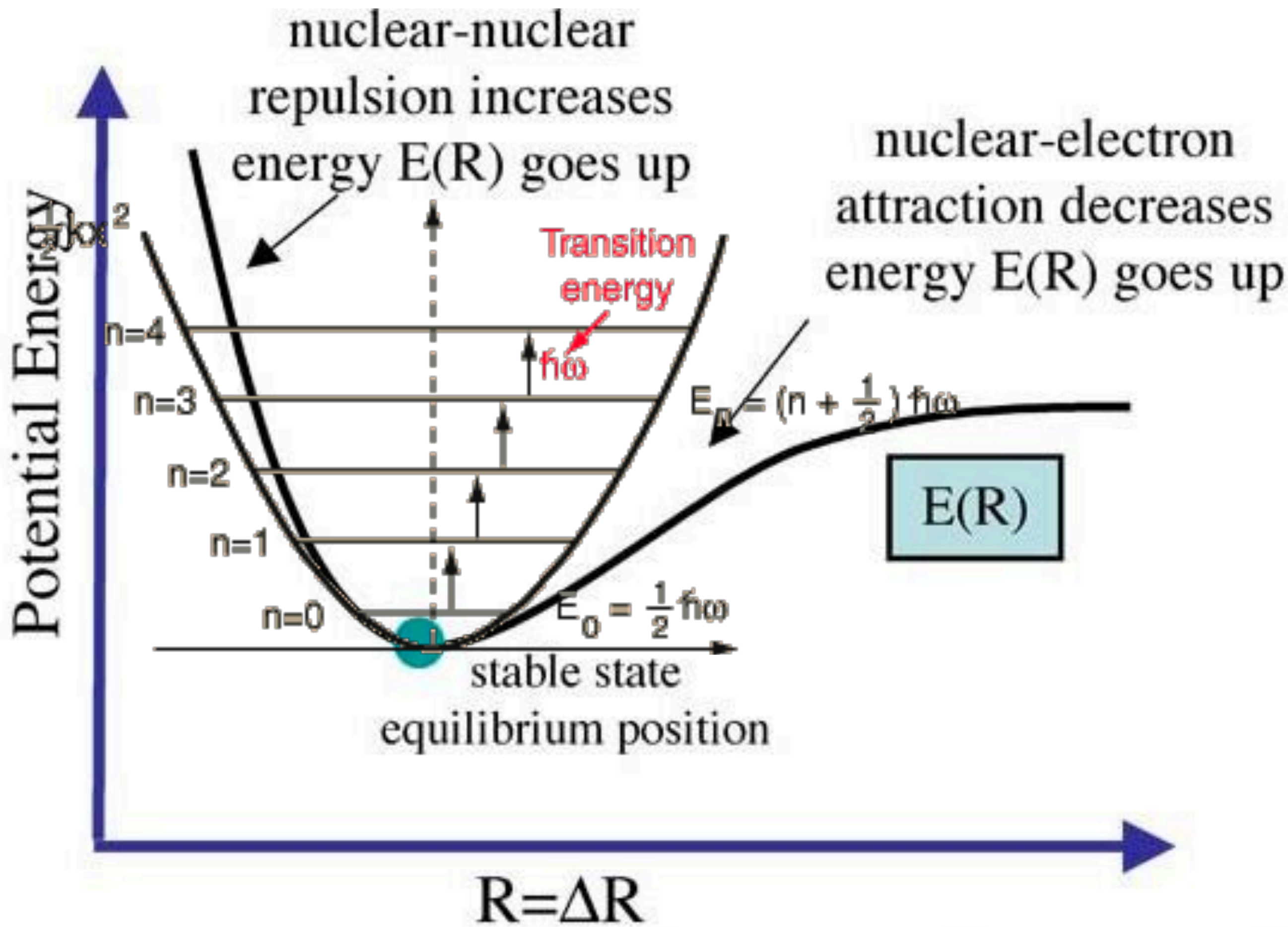
How Your Microwave Works



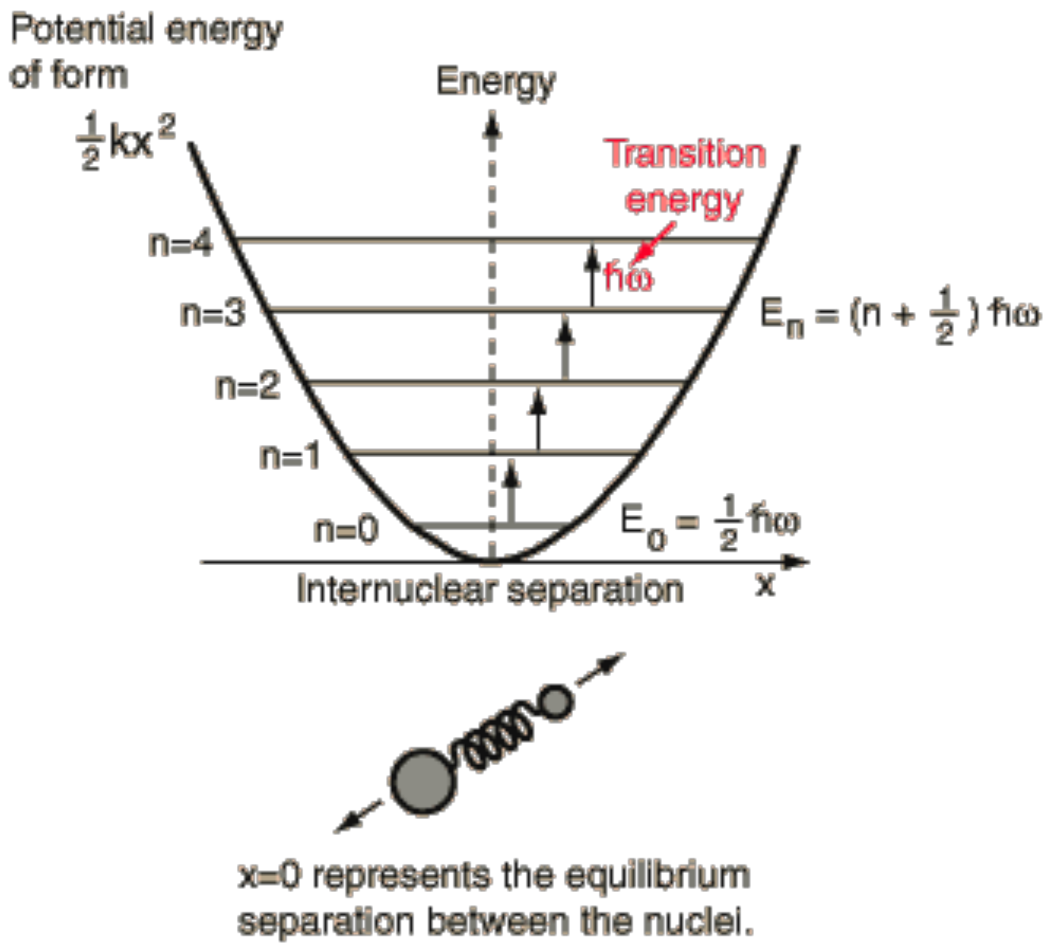
Ice



Diatomic Molecule Potential Energy Vs. Nuclear Separation



Quantum Harmonic Oscillator



Concept Check

- In a harmonic oscillator, a single mass is attached to a spring fixed at one end. In molecular vibration, both masses move. How does this change the frequency of oscillation?

A. Increase
B. Decrease
C. Stay the same

Concept Check

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Reduced Mass

$$KE = p_1^2/2m_1 + p_2^2/2m_2$$

in center of mass frame

$$|p_1| = |p_2| = p$$

$$\Rightarrow K.E. = p^2/2\,(1/m_1 + 1/m_2)$$

$$= p^2/2\mu$$

w/ $\mu = 1/(1/m_1 + 1/m_2)$

= "reduced mass"

$$\mu < m_1, m_2$$

$$\omega = \sqrt{k/\mu} > \sqrt{k/m_1}, \sqrt{k/m_2}$$

$$f = \omega/2\pi$$

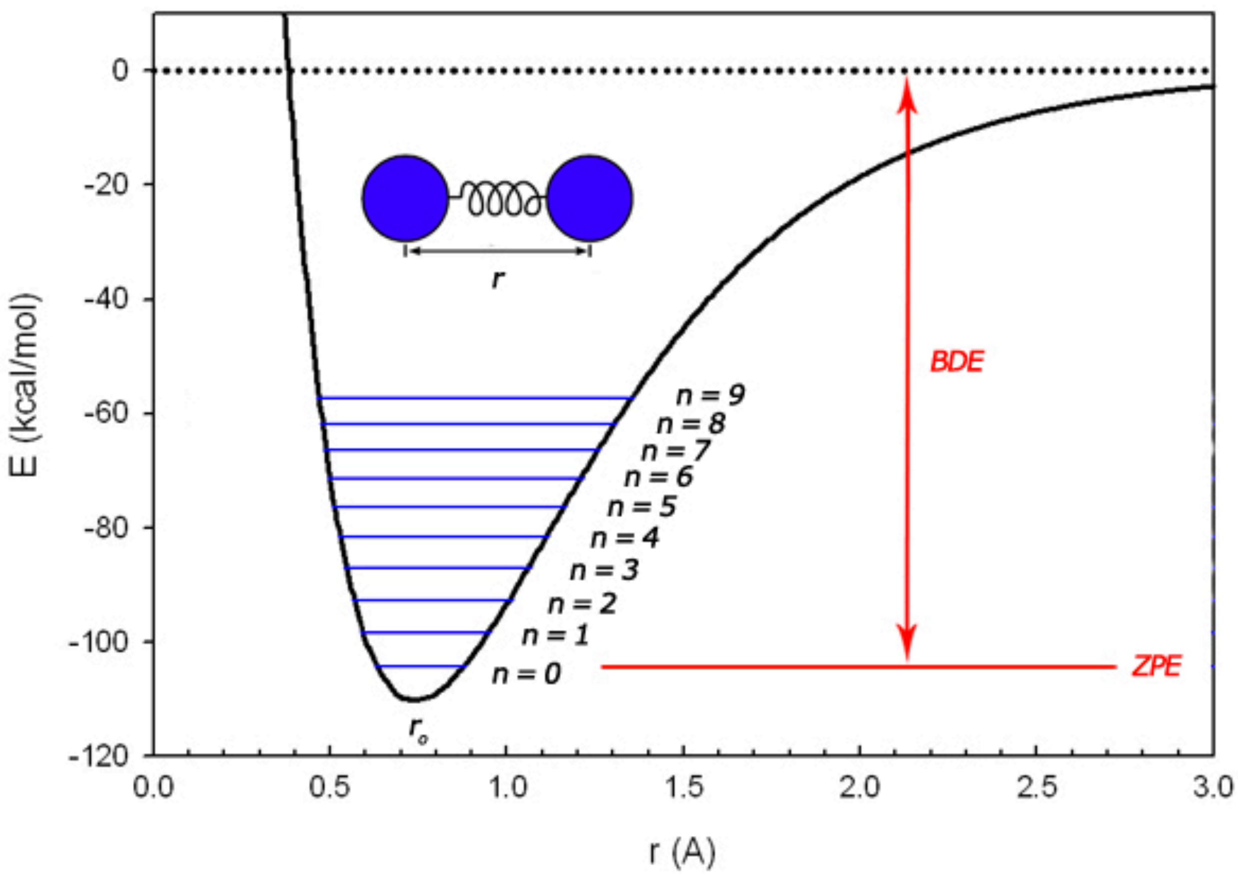
- Higher frequency since both masses can respond to the spring

$$m_1 = m_2 = m \Rightarrow \mu = m/2$$

$$m_2 \gg m_1 \Rightarrow \mu \approx m_1$$

Molecular Hydrogen Vibrational Energy Levels

ħω = 0.54 eV for H_2



H_2 Molecule

$$\hbar\omega = 0.54 \text{ eV}$$

$$f = \omega/2\pi = \frac{0.54 \times 1.6\times10^{-19}}{2\pi \cdot 1\times10^{-34}}$$

$$= 1.3 \times 10^{14} \text{ Hz}$$

$$= \frac{1}{2\pi}\sqrt{\frac{k}{\mu}}$$

$$= \frac{1}{2\pi}\sqrt{\frac{k}{m_H/2}}$$

$$\Rightarrow k = \tfrac{1}{2} m_H \cdot \omega^2$$

$$= \tfrac{1}{2} \cdot 1.67\times10^{-27} \cdot (2\pi \cdot 1.3\times10^{14})^2$$

$$= 560 \text{ N/m}$$

Spring Constants

Round Wire Springs -Spring Constant 4.9~29.4 N/mm-

MISUMI

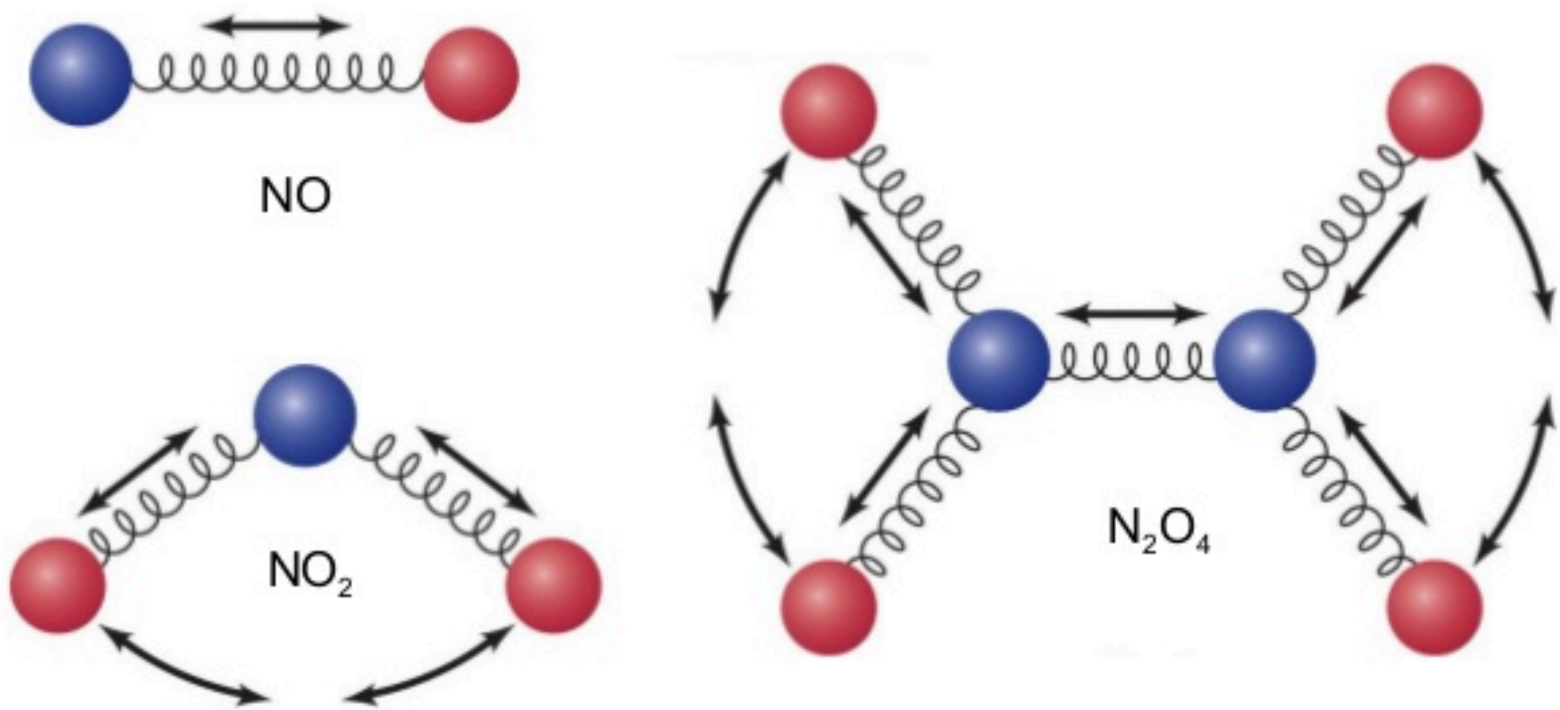
Volume Discount

CAD : 2D / 3D

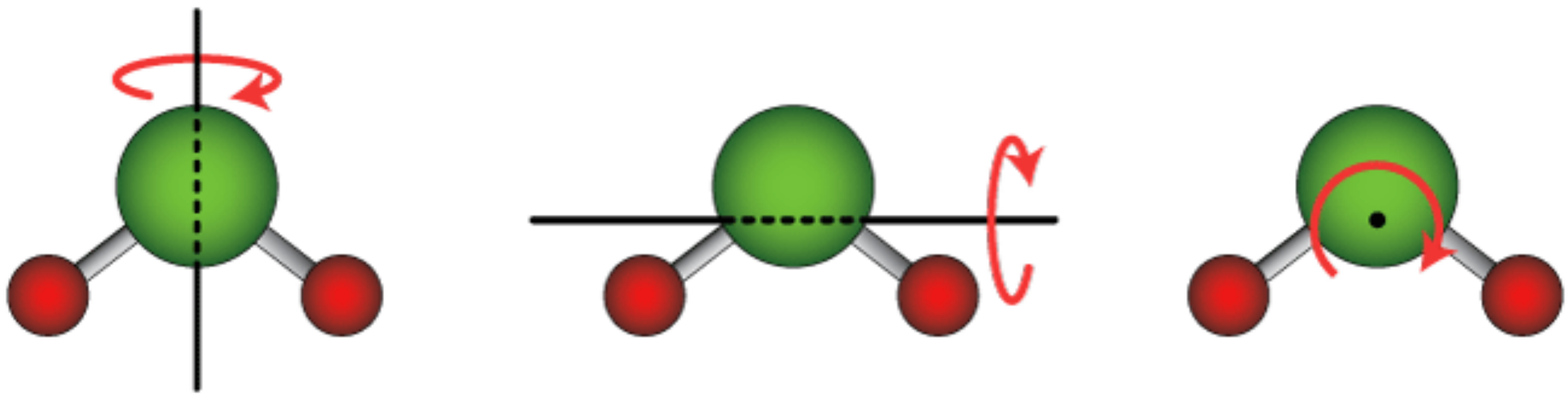
Days to Ship: **Same Day or more**

Stock Items Included

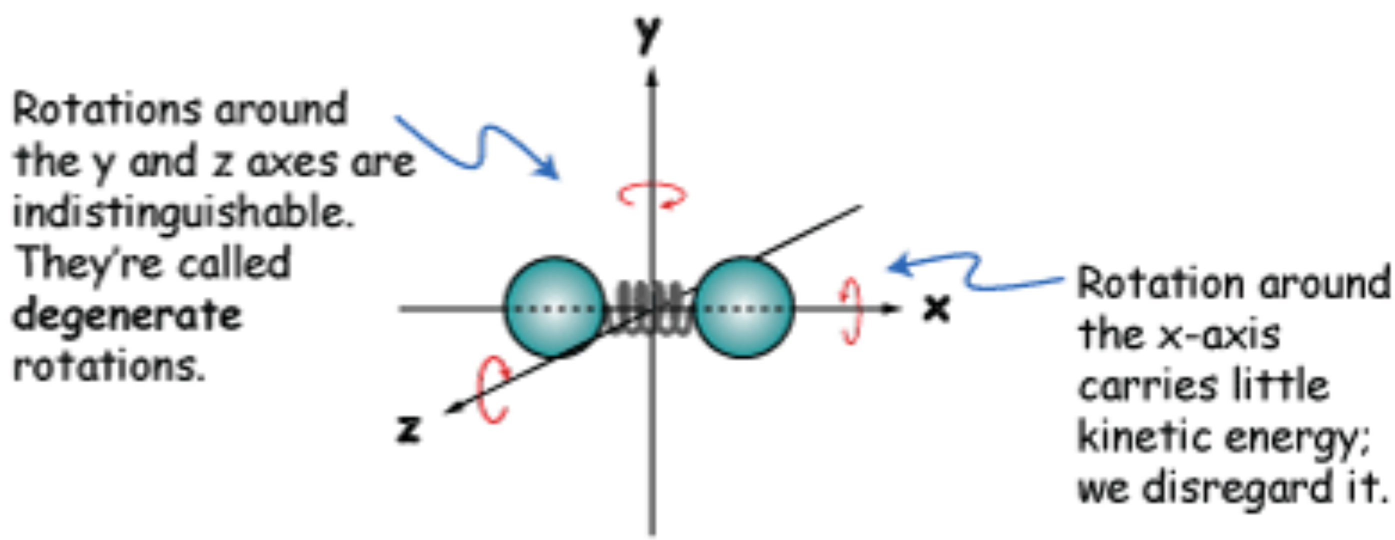
Molecular Vibrations



Molecular Rotation



Diatomic Molecule Rotation



Rotational Energy

$$KE = \frac{1}{2} m v_\varphi^2$$

$$= L^2 / 2mr^2 \quad \text{w/} \quad L = m r v_\varphi$$

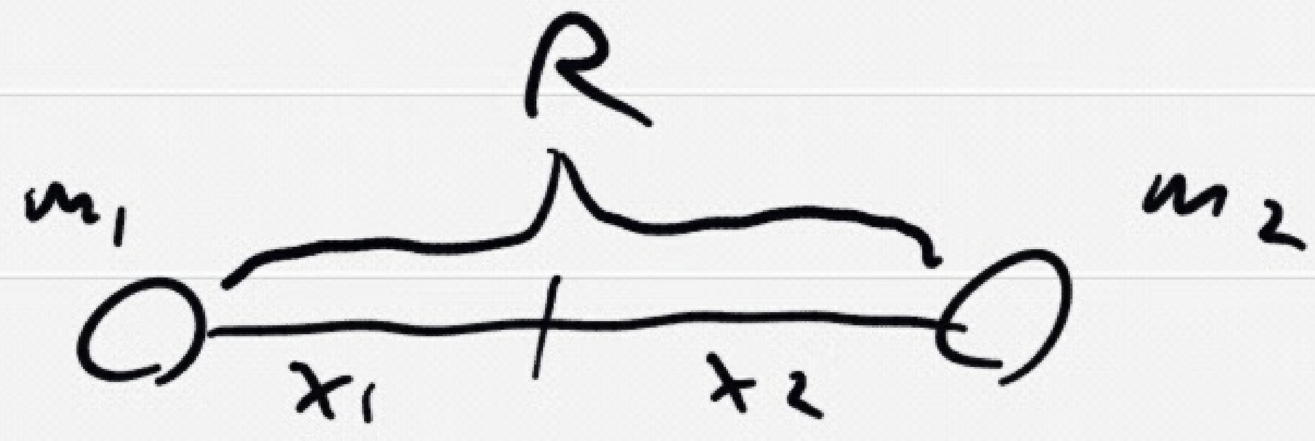
More generally

$$KE_{rot} = L^2 / 2I$$

w/ I = moment of inertia

QM $$E_L = \frac{L(L+1)\hbar^2}{2I}$$

E_L for diatomic molecule



$$I = m_1 x_1^2 + m_2 x_2^2$$
$$= \mu R^2$$

$$E_L = \frac{L(L+1)\hbar^2}{2\mu R^2}$$

$$= \frac{L(L+1)\hbar^2}{m_H R^2} \quad \text{for } H_2$$

$$E_1 - E_0 = \frac{2\hbar^2}{m_H R^2} \quad \text{for } H_2$$

$$= \frac{2 \cdot (1\times10^{-34})^2}{1.67\times10^{-27} \cdot (.074\times10^{-9})^2}$$

$$= 2.2 \times 10^{-21}\ \text{J}$$

$$= \boxed{0.014\ \text{eV}} \ll \hbar\omega$$

(rotational spacing $\ll$ vibrational)