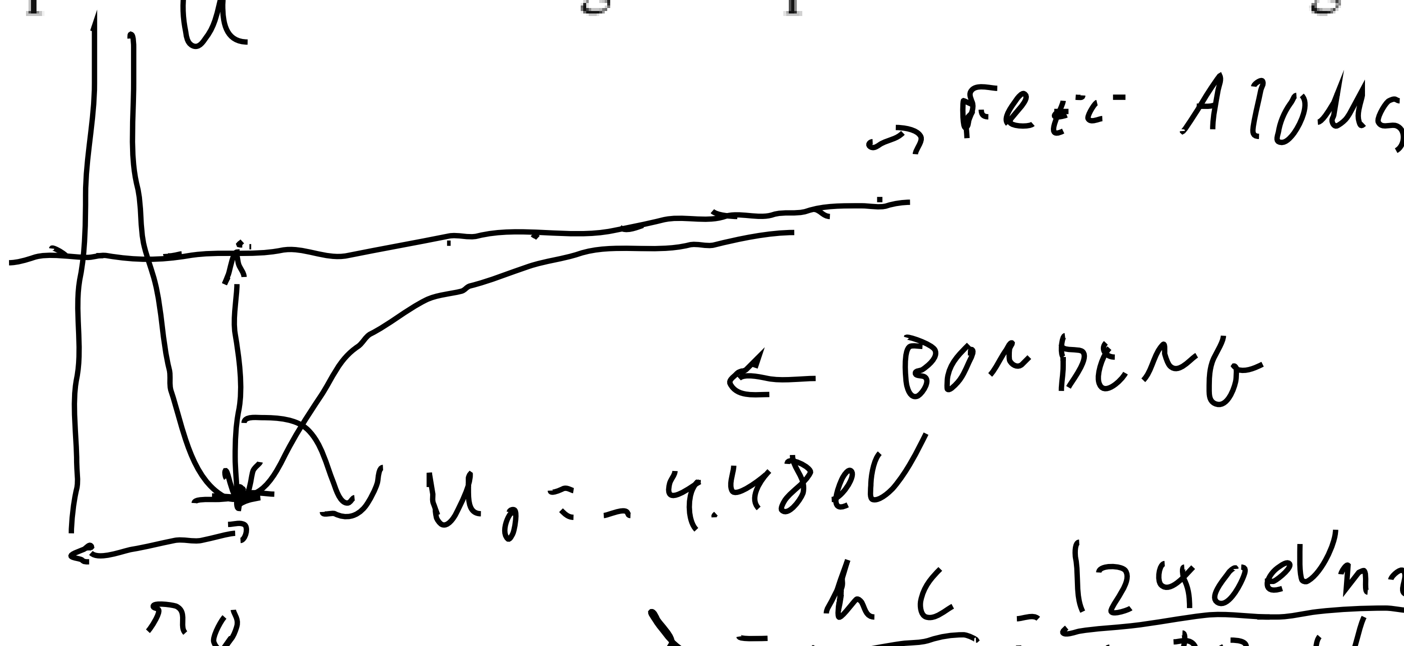
42.1 • If the energy of the H_2 covalent bond is −4.48 eV, what wavelength of light is needed to break that molecule apart? In what part of the electromagnetic spectrum does this light lie?



$$\lambda = \frac{hc}{-U_0} = \frac{1240\ \text{eV nm}}{4.48\ \text{eV}} = 277\ \text{nm}$$

$$E_\gamma = \frac{hc}{\lambda} = -U_0$$

UV

42.5 • For the H_2 molecule the equilibrium spacing of the two protons is r_0 0.074 nm. The mass of a hydrogen atom is m_H 1.67×10^{-27} kg. Calculate the wavelength of the photon emitted in the rotational transition $l = 2$ to $l = 1$.

$$\frac{hc}{\lambda} = E_2 - E_1$$

ROTATION $$E_l = l(l+1)\frac{\hbar^2}{2I}$$

$$= (2\cdot 3 - 1\cdot 2)\frac{\hbar^2}{2I} = 4\frac{\hbar^2}{2I} = 2\frac{\hbar^2}{I}$$

$$I = m_r r_0^2 \qquad m_r = \frac{m_H m_H}{m_H + m_H} = \frac{m_H}{2}$$

$$I = \frac{1}{2} m_H r_0^2$$

$$\lambda = \frac{Ihc}{2\hbar^2} \qquad \lambda = 40.8\,\mu m$$

42.8 • The water molecule has an $l = 1$ rotational level 1.01×10^{-5} eV above the $l = 0$ ground level. Calculate the wavelength and frequency of the photon absorbed by water when it undergoes a rotational-level transition from $l = 0$ to $l = 1$. The magnetron oscillator in a microwave oven generates microwaves with a frequency of 2450 MHz. Does this make sense, in view of the frequency you calculated in this problem? Explain.

$E_l = l(l+1)\frac{\hbar^2}{2I}$ $\quad E_1 - E_0 = (2 \cdot 1 - 1 \cdot 0)\frac{\hbar^2}{2I} = \frac{\hbar^2}{I} = 1.01 \times 10^{-5}$ eV

$\frac{hc}{\lambda} = 1.01 \times 10^{-5}$ $\quad \lambda = \frac{1240 \text{ eV}\mu\text{m}}{1.01 \times 10^{-5} \text{ eV}}$

$\lambda = 1.23 \times 10^{5} \mu m = 123 \text{ mm} = 0.123 \text{ m}$ [MICROWAVES]

$f = \frac{c}{\lambda} = \frac{3 \times 10^{8} \text{ m/s}}{0.123 \text{ m}} = 24.39 \times 10^{8} \text{ Hz} = 2439 \text{ MHz}$

42.12 • If a sodium chloride (NaCl) molecule could undergo an $n \rightarrow n - 1$ vibrational transition with no change in rotational quantum number, a photon with wavelength 20.0 μm would be emitted. The mass of a sodium atom is 3.82×10^{-26} kg, and the mass of a chlorine atom is 5.81×10^{-26} kg. Calculate the force constant k' for the interatomic force in NaCl.

$$E_n = \left(n + \frac{1}{2}\right)\hbar w \qquad w = \sqrt{\frac{k'}{m_r}}$$

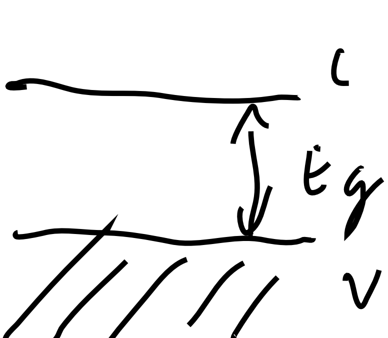
$$E_n - E_{n-1} = \hbar w = E_\gamma = \frac{hc}{\lambda} \; ; \; \frac{h}{2\pi} w = \frac{hc}{\lambda}$$

$$w = \frac{2\pi c}{\lambda} = \sqrt{\frac{k'}{m_r}} \qquad k' = m_r \left(\frac{2\pi c}{\lambda}\right)^2$$

$$k' = \left(\frac{m_{Na} m_{Cl}}{m_{Na} + m_{Cl}}\right) 4\pi^2 \left(\frac{3 \times 10^8 \, m/s}{2 \times 10^{-5} \, m}\right)^2 = 205 \, N/m$$

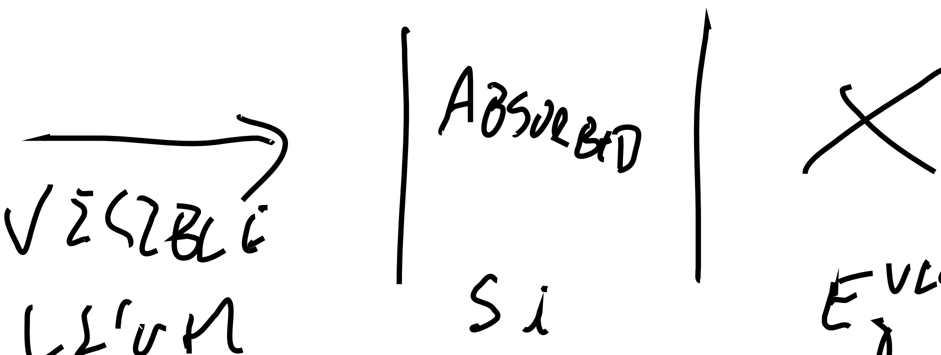
42.16 • The vibrational and rotational energies of the CO molecule are given by Eq. (42.9). Calculate the wavelength of the photon absorbed by CO in each of the following vibration–rotation transitions: (a) $n = 0,\ l = 1 \rightarrow n = 1,\ l = 2$; (b) $n = 0,\ l = 2 \rightarrow n = 1,\ l = 1$; (c) $n = 0,\ l = 3 \rightarrow n = 1,\ l = 2$.

42.19 • The maximum wavelength of light that a certain silicon photocell can detect is 1.11 μm. (a) What is the energy gap (in electron volts) between the valence and conduction bands for this photocell? (b) Explain why pure silicon is opaque.



$$\frac{hc}{\lambda} = E_g = \frac{1.240\ \text{eV}\,\mu\text{m}}{1.11\ \mu\text{m}} = 1.117\ \text{eV}$$

OPAQUE

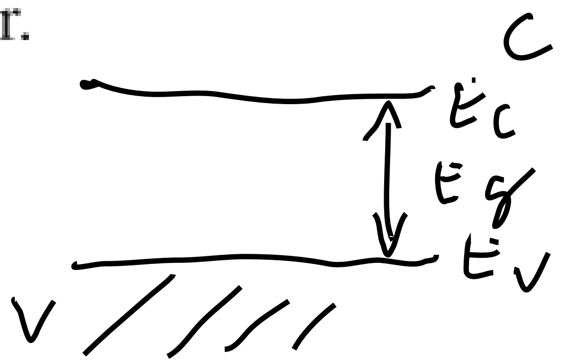


LIGHT

$0.4\ \mu m < \lambda < 0.7\ \mu m$

$E_g^{VISIBLE} > E_g \rightarrow$ ABSORBED

42.20 • The gap between valence and conduction bands in diamond is 5.47 eV. (a) What is the maximum wavelength of a photon that can excite an electron from the top of the valence band into the conduction band? In what region of the electromagnetic spectrum does this photon lie? (b) Explain why pure diamond is transparent and colorless. (c) Most gem diamonds have a yellow color. Explain how impurities in the diamond can cause this color.



$$E_c - E_v = E_g = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{E_g} = 227\ \text{nm}\ \ \text{UV}$$