

# MULTI-STEP PROBLEMS: CHAPTER 25

## Problem 25.4

The C-H bonds of the four deuterated molecules illustrated by planes on panels (A) through (D) above, are shown. Indicate the relative order of the vibrational wavenumbers of these molecules, assuming bonding with the other acid-catalyzed species with chlorine. The frequency around the terminal hydrogen bond (each carbon atom is  $1.5 \text{ \AA}$ ) and the H-H distance is  $0.1 \text{ nm}$ .

### Part A

Indicate the relative vibrational wavenumbers of the hydrogen-bonded bonds along quadrupoles of molecules (A) through (D) with H-H bond.

$$\mu = \frac{m_1 m_2}{m_1 + m_2}$$

$$Q_{\text{H-H}} = \frac{m_{\text{H}} m_{\text{H}}}{m_{\text{H}} + m_{\text{H}}} = \frac{m_{\text{H}}}{2}$$

$$Q_{\text{C-H}} = \frac{m_{\text{C}} m_{\text{H}}}{m_{\text{C}} + m_{\text{H}}} = 0.92 \text{ amu}$$

$$Q_{\text{C-D}} = \frac{(12.011 + 2.016) \text{ amu}}{12.011 + 2.016} = 0.92 \text{ amu}$$

$$\left( \frac{1}{12.011 + 2.016} \right) \left( \frac{1}{12.011 + 2.016} \right) \left( \frac{1}{12.011 + 2.016} \right) \left( \frac{1}{12.011 + 2.016} \right) = \frac{1}{12.011 + 2.016}$$

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$$Q_{\text{H-H}} = \frac{m_{\text{H}} m_{\text{H}}}{m_{\text{H}} + m_{\text{H}}} = \frac{m_{\text{H}}}{2}$$

$$Q_{\text{C-H}} = \frac{m_{\text{C}} m_{\text{H}}}{m_{\text{C}} + m_{\text{H}}} = 0.92 \text{ amu}$$

$$Q_{\text{C-D}} = \frac{(12.011 + 2.016) \text{ amu}}{12.011 + 2.016} = 0.92 \text{ amu}$$

$$\left( \frac{1}{12.011 + 2.016} \right) \left( \frac{1}{12.011 + 2.016} \right) \left( \frac{1}{12.011 + 2.016} \right) \left( \frac{1}{12.011 + 2.016} \right) = \frac{1}{12.011 + 2.016}$$

$$\mu = \frac{m_1 m_2}{m_1 + m_2} = \frac{(12.011 + 2.016) \text{ amu}}{12.011 + 2.016} = \boxed{0.92 \text{ amu}}$$

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