1. a. \( \ddot{\mathbf{u}} = \mu_x \hat{x} + \mu_y \hat{y} \)
   
   \[ = -e a_0 \cos \phi \hat{x} - e a_0 \sin \phi \hat{y} \]

b. \( -\ddot{\mathbf{u}} \cdot \mathbf{E}_{\text{rad}} = e a_0 E_{\text{rad}} \cos \phi \)
   
   \[ = e a_0 E_{\text{rad}} \frac{1}{2} \left\{ e^{i \phi} + e^{-i \phi} \right\} \]

\[ = \frac{e a_0 E_{\text{rad}}}{4 \pi} \int_0^{2\pi} e^{-i k_2 \phi} e^{i \phi} e^{i k_1 \phi} d\phi + \frac{e a_0 E_{\text{rad}}}{4 \pi} \int_0^{2\pi} e^{-i k_2 \phi} e^{-i \phi} e^{i k_1 \phi} d\phi \]

\[ = \frac{e a_0 E_{\text{rad}}}{4 \pi} \int_0^{2\pi} e^{i (k_1 - k_2 + 1) \phi} d\phi + \frac{e a_0 E_{\text{rad}}}{4 \pi} \int_0^{2\pi} e^{i (k_1 - k_2 - 1) \phi} d\phi \]

\( k_2 = k_1 \pm 1 \) only non-zero when argument \( = 0 \)

\( \int_0^{2\pi} e^{i (k_1 - k_2 + 1) \phi} d\phi = 2 \pi \) when allowed

\[ \int_0^{2\pi} e^{i (k_1 - k_2 - 1) \phi} d\phi = 0 \]

d. \( E(V/\text{cm}) = \sqrt{\frac{10^3}{1 \times 10^{-2}}} = 3.2 \times 10^2 \text{ V/cm} \)

e. \( |\langle \phi_{k_1} | - \ddot{\mathbf{u}} \cdot \mathbf{E}_{\text{rad}} | \phi_{k_2} \rangle| = e a_0 E_{\text{rad}} \frac{2 \pi}{4 \pi} \]

\[ = (1.6 \times 10^{-19} e^2) (5.3 \times 10^{-11} \text{ m}) (3.2 \times 10^4 \text{ V/m}) \]

\( = 1.3 \times 10^{-9} \text{ V-s} \)

f. \( e^{-H_{\text{vision}}} \) of vision occurs \( < 10^3 \text{ s} \)

\[ 7.7 \times 10^{-5} \text{ V-s} \]
2. a.

\[ \begin{align*}
\Delta E &= \frac{3 \hbar^2}{2mr^2} = \frac{2 \pi \hbar c}{2m \times 10^{-7} m} \\
\Gamma &= \sqrt{\frac{(3 \hbar)(\lambda)}{4\pi mc}} = \sqrt{\frac{\lambda}{\pi}} \\
&= 1.55 \times 10^{-10} \sqrt{\frac{(kg \cdot m^2)}{(S^2/kg)}} = 1.55 \AA^0
\end{align*} \]

c. \[1.40 \AA = \text{radius} \]
\[1.40 \AA = \text{C-C bond length} \]
\[\text{equilateral triangle}\]

d. confinement of the \( \text{Fe}^- \) to be near the C nuclei. This is why radial atom model works well and leads to transition energy consistent with actual benzene radius.

e. \( e^- \) distributions are different in ground and excited configurations so \( e^- e^- \) repulsions energy may be different in the two configurations.