1. Calculate the potential energy of an electron in the n=2 state of the hydrogen atom.

$$Z = 1 \quad n = 2$$

$$E_p = -\frac{Ze^2}{4\pi \varepsilon_0 n^2 a_0}$$

$$= -\frac{e^2}{4\pi \varepsilon_0 \cdot 4 a_0}$$

$$= \frac{(1.602 \times 10^{-19} C)^2}{16\pi \cdot (8.854 \cdot 10^{-12} C^2/Nm^2)(5.292 \times 10^{-11} m)}$$

$$= -10.9 \times 10^{-19} J$$

2. The Balmer spectrum of hydrogen (transitions into n=2) has a line of wavelength 656.7 nm. What is the wavelength of the corresponding line of deuterium? ($m_D = 3.3434 \times 10^{-27}$ kg; $m_H = 1.6727 \times 10^{-27}$ kg; $m_e = 9.1095 \times 10^{-31}$ kg)

$$\mu_H = \frac{m_e \cdot m_H}{m_e + m_H} = 9.1046 \times 10^{-31} kg, \quad \mu_D = \frac{m_e m_D}{m_e + m_D} = 9.1070 \times 10^{-31} kg$$

$$\frac{1}{\lambda} = \frac{Z^2 e^2}{8\pi \varepsilon_0 a_0 hc}\left(\frac{1}{n_2} - \frac{1}{4}\right); \; a_0 = \frac{h^2 \varepsilon_0}{\pi e^2 \mu} \Rightarrow \frac{1}{\lambda} \propto \mu$$

$$\Rightarrow \frac{\lambda(D)}{\lambda(H)} = \frac{\mu_H}{\mu_D} \quad \Rightarrow \lambda_D = \frac{\mu_H}{\mu_D} \cdot 656.7 nm \quad \Rightarrow \lambda \propto \frac{1}{\mu}$$

$$= 656.30 \text{ nm}$$

3. In the microwave spectrum of $^{12}C^{16}O$ the separation between lines (Δv) has been measured to be 115270 MHz. Calculate the interatomic distance.

$$\nu = 2(J+1)B \quad \Rightarrow \Delta\nu = 2B \Rightarrow B = 5.7635 \times 10^{10} \frac{1}{s}$$

$$B = \frac{h}{8\pi^2 I} \quad \Rightarrow I = \frac{h}{8\pi^2 B} = 1.456 \times 10^{-46} kg\, m^2$$

$$I = \mu d^2 \Rightarrow d = \sqrt{I/\mu} \qquad \mu = \frac{12 \times 16}{28 \times 6.022 \times 10^{23}} kg$$

$$= 1.1385 \times 10^{-26} kg$$

$$= 1.131 \times 10^{-10} m$$