**3.091 Fall Term 2004**

# Homework #3 addendum

## September 23 (to be tested on monthly Test 1 9/29)

**1.** A hockey puck weighing 3 oz. is fired on goaltender Louis de Broglie at a speed of 85 miles per hour. What value of wavelength would he ascribe to this event?

**2.** Calculate the wavelength, λ, of a proton capable of exciting an electron in $Li^{2+}$ from the state $n = 2$ to the state $n = 5$.

**3.** In a gas discharge tube filled with atomic hydrogen an incident proton (not photon!) excites an electron in H from the ground-state to n = 4.

(a) Calculate the maximum value of the de Broglie wavelength of the incident proton.

(b) Calculate the wavelength of the photon emitted when the excited electron falls back to the ground state.

**4.** An incident neutron excites an electron in $He^{+}$ from the ground-state to n = 3.

(a) Calculate the maximum value of the de Broglie wavelength of the incident neutron.

(b) Calculate the wavelength of the photon emitted when the excited electron falls back to the ground state.

**1.** $$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{6.6\times10^{-34}\,\text{Js}}{3\text{oz}\times\frac{28.4\text{g}}{\text{oz}}\times\frac{1\text{kg}}{1000\text{g}}\times\frac{85\text{mi}}{\text{hr}}\times\frac{1\text{hr}}{3600\text{s}}\times\frac{5280\text{ft}}{\text{mi}}\times\frac{12\text{in}}{\text{foot}}\times\frac{2.54\text{cm}}{\text{in}}\times\frac{1\text{m}}{100\text{cm}}}$$

$= 2.039 \times 10^{-34}$ m.

**2.** $$\Delta E_{2\to5} = -KZ^2\left(\frac{1}{5^2}-\frac{1}{2^2}\right) = \frac{21}{100}KZ^2 = E_{\text{proton}} = \frac{1}{2}mv^2 = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$$

for Li, $Z = 3$

$$\therefore \lambda = \left(\frac{h^2}{2mKZ^2}\bullet\frac{100}{21}\right)^{\frac{1}{2}} = \left[\frac{\left(6.6\times10^{-34}\right)^2 100}{2\times1.673\times10^{-27}\times2.18\times10^{-18}\times3^2\times21}\right]^{\frac{1}{2}} = 5.62\times10^{-12}\text{ m.}$$

**3.** (a) maximum wavelength implies minimum energy which is equal to the energy of transition

$$\therefore \text{E}_{\text{incident proton}} = \Delta E_{1\to4} = -K\left(\frac{1}{4^2}-\frac{1}{1^2}\right) \text{ and } E_{proton} = \tfrac{1}{2}mv^2 = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2},$$

$$\therefore \lambda = \frac{h}{\sqrt{2mE_{proton}}} = \frac{6.6\times10^{-34}}{\sqrt{2\times1.67\times10^{-27}\times2.18\times10^{-18}\times\frac{15}{16}}} = 7.99\times10^{-12}\,m$$

where $m$ is the mass of the proton, $m_p = 1.67 \times 10^{-27}$ kg

(b) equate energy of transition to energy of emitted photon

$$\Delta E_{4\to1} = E_{emitted\ photon} = \frac{hc}{\lambda_{emitted\ photon}}, \qquad \therefore \lambda = \frac{hc}{K\,\frac{15}{16}} = \frac{6.6\times10^{-34}\times3.00\times10^{8}}{2.18\times10^{-18}\times\frac{15}{16}} = 9.69\times10^{-8}\,m$$

**4.** (a) maximum wavelength implies minimum energy which is equal to the energy of transition

$$\therefore \text{E}_{\text{incident neutron}} = \Delta E_{1\to3} = -KZ^2\left(\frac{1}{3^2}-\frac{1}{1^2}\right) \quad \text{and} \quad E_{neutron} = \tfrac{1}{2}mv^2 = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2},$$

$$\therefore \lambda = \frac{h}{\sqrt{2mE_{neutron}}} = \frac{6.6\times10^{-34}}{\sqrt{2\times1.67\times10^{-27}\times2.18\times10^{-18}\times2^2\times\frac{8}{9}}} = 4.10\times10^{-12}\,m$$

where $m$ is the mass of the neutron, $m_n = 1.67 \times 10^{-27}$ kg

(b) equate energy of transition to energy of emitted photon

$$\Delta E_{3\to1} = E_{emitted\ photon} = \frac{hc}{\lambda_{emitted\ photon}}$$

$$\therefore \lambda = \frac{hc}{KZ^2\times\frac{8}{9}} = \frac{6.6\times10^{-34}\times3.00\times10^{8}}{2.18\times10^{-18}\times2^2\times\frac{8}{9}} = 2.55\times10^{-8}\,m$$