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E P 4 Sheet 5

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1) Hydrogen atom emits a photon with ν of transition 1st excited state $\rightarrow$ ground. Find velocity!

Consume Momentum!

Energy of photon is $E_\gamma = h\nu$

Momentum of photon is $P_\gamma = \frac{E_\gamma}{c}$

The emission frequency is that of $n=2 \rightarrow n=1$ transition

So the $E_\gamma = \Delta E_{2\to 1} = 1.632 \text{ eV}$ with $\nu = 2.45 \times 10^{15} \text{ s}^{-1}$

$\lambda = 1.22 \times 10^{-7} \text{ m}$

Momentum Conservation tells us that

$$P_\gamma + P_{atom,f} = P_{initial} \Rightarrow \cancel{P_\gamma = P_{final,a} - P_{initial,a}}$$

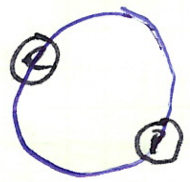
and that the $P_{initial} = 0$, we know that

$$P_\gamma = -P_{atom,final}!$$

So the magnitude velocity of the photon is equal to the magnitude velocity of the atom, and thus with $P_\gamma = \frac{E_\gamma}{c} = 5.45 \times 10^{-27} \frac{\text{kg m}}{\text{s}}$

then $P_\gamma = m_H v_f \Rightarrow \frac{P_\gamma}{m_H} = v_f \Rightarrow m_H = 1.67 \times 10^{-27} \text{ kg}$

$$v_f = \frac{5.45 \times 10^{-27}}{1.67 \times 10^{-27}} = \boxed{3.26 \frac{m}{s}}$$

2) 

electric charge = +e

$m_p = m_e$

We know the energy levels for the n'th level of an atom is given by:

$$E_n = -\frac{Z\, k_e e^2}{2 r_n} \quad ; \quad r_n = \frac{n^2 \hbar^2}{Z\, k_e e^2 \mu}$$

replace $Z = 1$, r_n, new $E_n \Rightarrow$ reduced mass

$$E_n = -\frac{k_e e^2}{2} \cdot \frac{k_e e^2 \mu}{n^2 \hbar^2} = -\mu \frac{k_e^2 e^4}{2 n^2 \hbar^2}$$

reduced mass with $m_e = m_p \Rightarrow \mu = \frac{m_e m_p}{m_e + m_p} = \frac{m_e^2}{2 m_e} = \frac{m_e}{2}$

$$E_n = -\frac{m_e}{2} \cdot \frac{k_e^2 e^4}{2 n^2 \hbar^2} = \frac{-m_e k_e^2 e^4}{4 \hbar^2} \cdot \frac{1}{n^2}$$

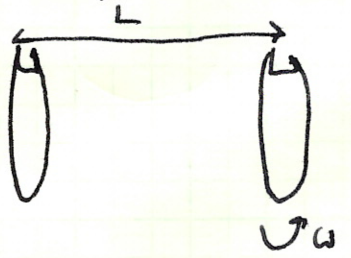
~~$m_e = 9.109 \times 10^{-31}$ kg , $k_e = 14.3996$ eV Å / e ; $\hbar =$~~

Colomb constant $= \frac{1}{4\pi\varepsilon_0}$ $\quad \hbar = \frac{h}{2\pi} \Rightarrow \frac{k_e^2}{\hbar^2} = \frac{1}{16\pi^2\varepsilon_0^2} \cdot \frac{4\pi^2}{h^2}$

$$\Rightarrow \frac{-m_e e^4}{16 \varepsilon_0^2 h^2} \cdot \frac{1}{n^2} = \boxed{E_n = \frac{-6.8\,\text{eV}}{n^2}} = \frac{1}{4\varepsilon_0}$$

use $\varepsilon_0 = 55.263 \frac{e^2\,\text{GeV}}{10^{-15}\,\text{m}}$

3) deBroglie wavelength: $\lambda = \frac{h}{p}$



The speed of the neutrons that are passed through (selected)

must be equal to $\frac{\Delta L}{\Delta t} = V_n$

Δt must be equal to the time it takes for the right disk to be alligned with initial left disk.

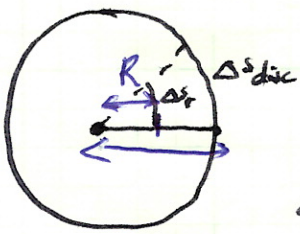
$\omega = \frac{\Delta \phi}{\Delta t}$ and so $\Delta t = \frac{\phi}{\omega} \Rightarrow V_n = \frac{L \cdot \omega}{\phi}$

Angular velocity is $\frac{\Delta \phi}{\Delta t}$,

$P = m_n \cdot V_n \Rightarrow$ $\boxed{\lambda = \frac{h}{m_n V_n} = \frac{h}{m_n} \cdot \frac{\phi}{L\omega}}$

I think the hole diameter ÷ disc diameter is irrelevant

This would be for a case where the hole is on the edge



$\Delta \theta_d = \frac{\Delta S_{disc}}{R_{disc}}$ ← arc length

$\omega = \frac{\Delta \phi}{\Delta t}$

$\Delta \theta_R = \frac{\Delta S_R}{R_{disk}}$

$\omega =$

The angular velocity is dependent on $\Delta\theta$, which we know is independent of radius:

i.e. the ratio of $\frac{\text{arc length}}{\text{radius}}$ is constant, thus ω