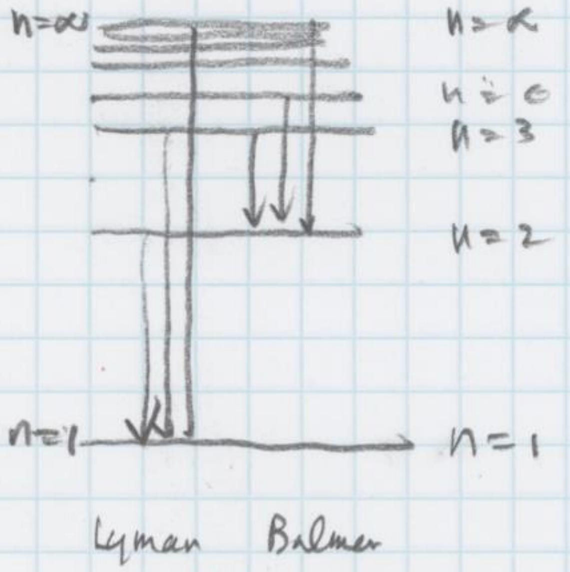
Hw Ans for Ch 39. More about Matter Waves P1

39#40 Bohr's Model gives the relationship between wavelength of the emitted photon and the energy state of the electron before and after it makes a transition.



Transition of e^- from n=2 and above to n=1 is named Lyman Series

Transition of e^- from n=3 and above to n=2 is named Balmer Series

R - Rydberg const = $1.097373 \times 10^7 m^{-1}$

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

n_f - Q.N. of final state

n_i - Q.N. of initial state

For Lyman Series $n_i = 2, n_f = 1$

$$\frac{1}{\lambda_{2\to1}} = (1.097373 \times 10^7)\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = 8{,}230{,}297.50 \ m^{-1}$$

$$\lambda_{2\to1} = 121.50 \ nm //$$

$$\frac{1}{\lambda_{\infty\to1}} = (1.097373 \times 10^7)\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right) = 10{,}973{,}730.00 \ m^{-1}$$

$$\lambda_{\infty\to1} = 91.13 \ nm //$$

Range 121.50nm to 91.13nm //

For Balmer Series $n_i = 3, n_f = 2$

$$\frac{1}{\lambda_{3\to2}} = (1.097373 \times 10^7)\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = 1{,}524{,}129.17 \ m^{-1}$$

$$\lambda_{3\to2} = 656.11 \ nm //$$

$$\frac{1}{\lambda_{\infty\to2}} = (1.097373 \times 10^7)\left(\frac{1}{4} - 0\right) = 2{,}743{,}432.50 \ m^{-1}$$

$$\lambda_{\infty\to2} = 364.51 \ nm //$$

Range 656.11nm to 364.51nm //

$\lambda f = c \quad f = \frac{c}{\lambda}$

P2

<u>Lyman</u>

$$f_{2\to1} = \frac{c}{\lambda_{2\to1}} = 2.47 \times 10^{15}\,Hz$$ min freq

$$f_{\infty\to1} = \frac{c}{\lambda_{\infty\to1}} = 3.29 \times 10^{15}\,Hz$$ max freq

Balmer

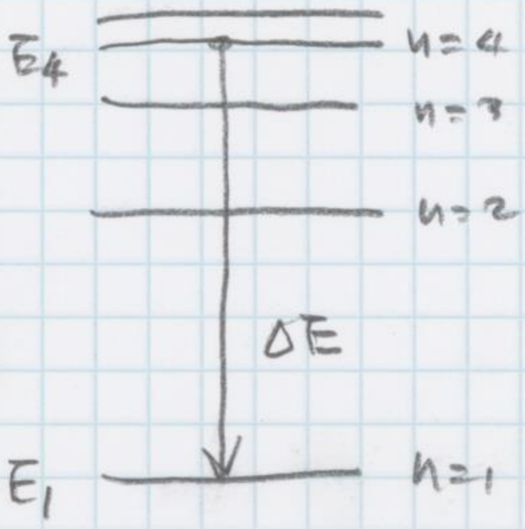
$$f_{3\to2} = \frac{c}{\lambda_{3\to2}} = 4.57 \times 10^{14}\,Hz$$ min freq

$$f_{\infty\to2} = \frac{c}{\lambda_{\infty\to2}} = 8.23 \times 10^{14}\,Hz$$ max freq

39-42

$\Delta E = E_4 - E_1$

with $E_n = \frac{-13.61}{n^2}$ for $n = 1, 2, 3$.



$\Delta E = -13.61\left(\frac{1}{n_4^2} - \frac{1}{n_1^2}\right)$

when $n_4 = 4$, $n_1 = 1$

ΔE = Energy released by an excited hydrogen atom and is distributed among the hydrogen atom in its ground state and the photon emitted. (Conservation of Energy)

$\Delta E = E_H + hf$ where E_H is the KE of hydrogen atom and f is the freq of the photon

$$\boxed{\Delta E = \frac{1}{2} m_H V_H^2 + hf} \quad \text{— (1)}$$

Also conservation of momentum

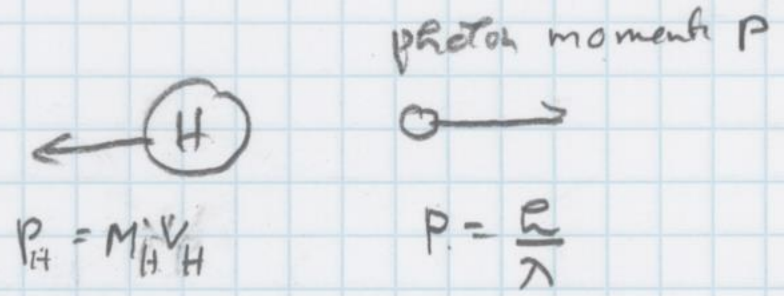
Σ momentum before a stationary excited H atom $= 0 = \Sigma_i p$

Σ momentum after a photon is emitted and hydrogen recoil backward $= \Sigma_f p$

$\Sigma P_i = \Sigma P_f$

$0 = -m_p V_p + \frac{h}{\lambda}$ where $\frac{h}{\lambda}$ is the photon momentum

or $$\boxed{m_H V_H = \frac{h}{\lambda} = \frac{hf}{c}} \quad \text{— (2)}$$



we have two equation and two unknown f & V_H

To solve for V_H – vel of hydrogen sub (2) to (1) to eliminate f.

$$\Delta E = \frac{1}{2} m_H V_H^2 + \cancel{h} \frac{m_H V_H c}{\cancel{h}} = \frac{1}{2} m_H V_H^2 + m_H c V_H$$

or $\frac{1}{2} m_H V_H^2 + m_H c V_H - \Delta E = 0$

Let $a = \frac{1}{2} m_H$, $b = m_H c$ and $C = -\Delta E$

$$a V_H^2 + b V_H + c = 0$$

$$V_H = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \quad //$$

since m_H, c, and $\Delta E = -13.61 \left(\frac{1}{4^2} - \frac{1}{1} \right)$

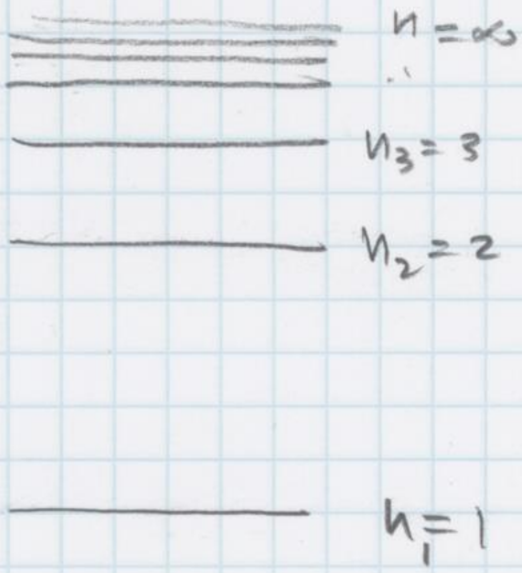
V_H can be calculated

In this calculation we ignore relativistic effect

39-48. Emission of H is 121.6nm Find n_i and n_f

where n_i = initial quantum state and n_f is the final quantum state

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$



Let $n_f = 1$ ground state.

$$\frac{1}{\lambda R} = \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\sqrt{\frac{1}{\lambda R} + \frac{1}{n_i^2}} = \frac{1}{n_f}$$

we can start $n_i = 2$

$$\frac{1}{n_f} = \sqrt{\frac{1}{(121.6)(10^{-9})(1.097373\times10^{7})} + \frac{1}{4}} = 1 \Rightarrow n_f = 1.$$

ie $n_f = 1$ and $n_i = 2$ satisfies the condition with $\lambda = 121.6$nm

This is the shortest emission for Lyman series

Let's look at Balmer series that the final state is @ $n = 2$

$$\frac{1}{\lambda R} = \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) \quad \text{with } n_f = 2$$

$$\sqrt{\frac{1}{n_i^2}} = \sqrt{\frac{1}{n_f^2} - \frac{1}{\lambda R}}$$

$$= \sqrt{\frac{1}{4} - \frac{1}{(121.6\times10^{-9})(1.097373\times10^{7})}}$$

$$= \sqrt{0.25 - 0.75}$$

$$= \sqrt{-0.5} \quad \text{imaginary number}$$

Balmer series can not emit 121.6nm photon

The only series is Lyman series and $n_i = 2$, $n_f = 1$. Transition //

39-52.

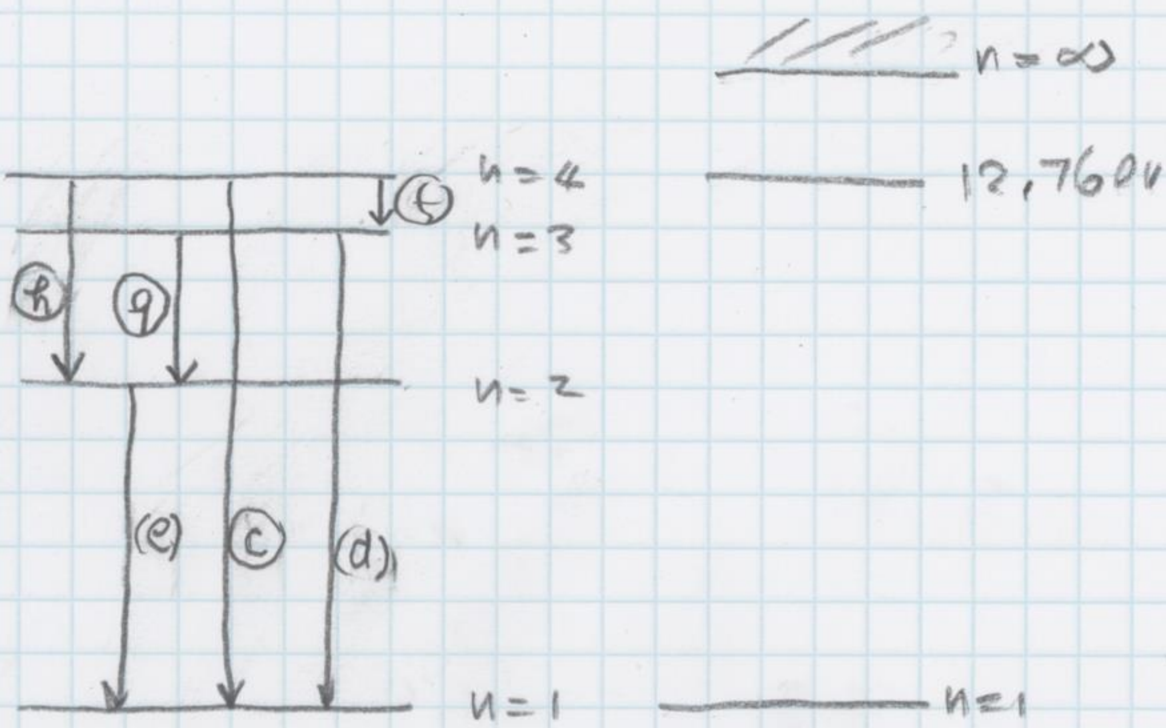
To excite H atom to $n=4$

from grnd state

$$\Delta E = -13.61\left(\frac{1}{n_4^2} - \frac{1}{n_1^2}\right)$$

with $n_4 = 4$, $n_1 = 1$

$$\Delta E_{4\text{-}1} = (-13.61)\left(\frac{1}{16} - \frac{1}{1}\right)$$



(a) $= \underline{12.76 \text{ eV}}$

part , (c), (d), (e), (f), (g) and (h) can be obtained qualitatively directly from Fig ①

The answer is marked on the diagram

(c) highest

(d) second highest

(e) 3rd highest

(f) lowest

(g) second lowest

(h) 3rd lowest.

(b) 6 different energy photon are possible assuming the transitions are allowed.