ZCT 104/3E Modern Physics
Semester II, Sessi 2006/07
Open Book Quiz V
Duration: 30 min

Name:

Matrics No:

INSTRUCTION: Answer the following question. **[12 marks]**

Four possible transitions for a hydrogen atom are listed here.

(i) $n_i = 2$; $n_f = 5$ (ii) $n_i = 5$; $n_f = 3$ (iii) $n_i = 7$; $n_f = 4$ (iv) $n_i = 4$; $n_f = 7$

(a) For which transitions does the atom emit photon? [2 marks]

(b) Which transition emits the shortest wavelength? Show your argument and steps of calculation clearly. [4 marks]

(c) For which transitions does the atom gain energy? [2 marks]

(d) For which transition does the atom gain most energy? Show your argument and steps of calculation clearly. [4 marks]

(Serway, M & M. Q11, pg. 145)

Solution

For atom emitting photon, $\frac{1}{l} = \boldsymbol{R}\left(\frac{1}{\boldsymbol{n}_{\mathrm{f}}^2} - \frac{1}{\boldsymbol{n}_{\mathrm{i}}^2}\right) \Rightarrow l = \frac{1}{\boldsymbol{R}}\left(\frac{\boldsymbol{n}_{\mathrm{f}}^2\boldsymbol{n}_{\mathrm{i}}^2}{\boldsymbol{n}_{\mathrm{i}}^2 - \boldsymbol{n}_{\mathrm{f}}^2}\right)$ with $\boldsymbol{n}_{\mathrm{f}} < \boldsymbol{n}_{\mathrm{i}}$;

For atom absorbing photon, $\frac{1}{l} = \boldsymbol{R}\left(\frac{1}{\boldsymbol{n}_{\mathrm{i}}^2} - \frac{1}{\boldsymbol{n}_{\mathrm{f}}^2}\right) \Rightarrow l = \frac{1}{\boldsymbol{R}}\left(\frac{\boldsymbol{n}_{\mathrm{f}}^2\boldsymbol{n}_{\mathrm{i}}^2}{\boldsymbol{n}_{\mathrm{f}}^2 - \boldsymbol{n}_{\mathrm{i}}^2}\right)$ with $\boldsymbol{n}_{\mathrm{f}} > \boldsymbol{n}_{\mathrm{i}}$

(a) (ii), (iii) emit photon. [2 marks. 1 for each correct answer. No mark deduced for wrong answer.]

(b) Test the emitted photons' wavelength $l\left(\boldsymbol{n}_i, \boldsymbol{n}_f\right)$ for (ii), (iii) in turn:

For (ii), $l\left(\boldsymbol{n}_i = 5, \boldsymbol{n}_f = 3\right) = \frac{1}{\boldsymbol{R}}\left(\frac{(3)^2(5)^2}{(5)^2 - (3)^2}\right) = \frac{1}{\boldsymbol{R}}\left(\frac{225}{25-9}\right) = \frac{1}{\boldsymbol{R}}\left(\frac{225}{16}\right) \approx \frac{14.06}{\boldsymbol{R}}$

For (iii) $l\left(\boldsymbol{n}_i = 7, \boldsymbol{n}_f = 4\right) = \frac{1}{\boldsymbol{R}}\left(\frac{(4)^2(7)^2}{(7)^2 - (4)^2}\right) = \frac{1}{\boldsymbol{R}}\left(\frac{784}{49-16}\right) = \frac{1}{\boldsymbol{R}}\left(\frac{784}{33}\right) \approx \frac{23.8}{\boldsymbol{R}}$.

Hence, (ii) emits the shortest wavelength.

[1 mark for showing the correct use of $\frac{1}{l} = \boldsymbol{R}\left(\frac{1}{\boldsymbol{n}_{\mathrm{f}}^2} - \frac{1}{\boldsymbol{n}_{\mathrm{i}}^2}\right) \Rightarrow l = \frac{1}{\boldsymbol{R}}\left(\frac{\boldsymbol{n}_{\mathrm{f}}^2\boldsymbol{n}_{\mathrm{i}}^2}{\boldsymbol{n}_{\mathrm{i}}^2 - \boldsymbol{n}_{\mathrm{f}}^2}\right)$ with $\boldsymbol{n}_{\mathrm{f}} < \boldsymbol{n}_{\mathrm{i}}$]

[2 marks for showing $l\left(\boldsymbol{n}_i = 5, \boldsymbol{n}_f = 3\right) \approx \frac{14.06}{\boldsymbol{R}}$ and $l\left(\boldsymbol{n}_i = 7, \boldsymbol{n}_f = 4\right) \approx \frac{23.8}{\boldsymbol{R}}$ correctly.]

[1 mark for stating the correct answer, "(ii) emits the shortest wavelength"]

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(c) Atoms in (i), (iv) gain energy. [2 marks. 1 for each correct answer. No mark deduced for wrong answer.]

(d) Test the absorbed photons' wavelength $l\left(n_i, n_f\right)$ for (i), (iv) in turn:

For (i), $l\left(n_i = 2, n_f = 5\right) = \frac{1}{R}\left(\frac{(2)^2(5)^2}{(7)^2-(4)^2}\right) = \frac{1}{R}\left(\frac{100}{49-16}\right) = \frac{1}{R}\left(\frac{100}{33}\right) \approx \frac{3.03}{R}$

For (iv), $l\left(n_i = 4, n_f = 7\right) = \frac{1}{R}\left(\frac{(4)^2(7)^2}{(7)^2-(4)^2}\right) = \frac{1}{R}\left(\frac{784}{49-16}\right) = \frac{1}{R}\left(\frac{784}{33}\right) \approx \frac{23.8}{R}$

Hence, atom in (i) gains most energy since the shorter the wavelength of a photon, the larger the energy it has.

[1 mark for showing the correct use of $\frac{1}{l} = R\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right) \Rightarrow l = \frac{1}{R}\left(\frac{n_f^2 n_i^2}{n_f^2 - n_i^2}\right)$ with $n_f > n_i$.]

[2 marks for showing $l\left(n_i = 2, n_f = 5\right) \approx \frac{3.03}{R}$ and $l\left(n_i = 4, n_f = 7\right) \approx \frac{23.8}{R}$ correctly]

[1 mark for stating the correct answer, "(i) gains most energy"]

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