

Lecture 29 CH101 A2 (MWF 11:15 am) Fall 2017 Copyright © 2017 Dan Dill dan@bu.edu

[TP] A student asked, "I understand the transfer of a photon of energy takes about 100,000 oscillations of the electric field. But won't the photon have moved away from the atom in that time." A good answer to this question is ...

20% 1. The photon is attracted to the atom and so stays close by.

20% 2. The atom moves back and forth with the photon.

20% 3. It is the tugs of the electric field that transfer the energy.

20% 4. The photon disappears after the first electric field oscillation, but its energy doesn't appear in the atom until all of the field oscillations are complete.

20% 5. Some other answer.

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Lecture 29 CH101 A2 (MWF 11:15 am)

Wednesday, November 15, 2017

For today ...

- Light and matter exchange energy smoothly and slowly
- Light energy is exchanged in tiny amounts called photons
- Electron waves and quantization (de Broglie)

Next lecture: Hydrogen atom electron clouds: <http://goo.gl/XPkcxv>; H atom energy diagrams; H, He⁺, Li²⁺, etc., photon energies; Ionization (photoelectric effect)

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Light and matter exchange energy smoothly and slowly

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Resonant tugs by light on an electron cloud


<http://goo.gl/Ac4HGM>

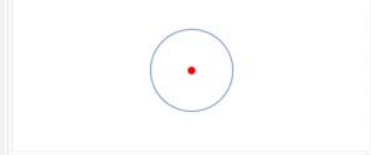
H atom 1s → 2p transformation by light

Transition progress: Slider full left = 1s, full right = 2p

Light oscillations: 

Tune light frequency ν relative to resonance frequency ν_0

ν/ν_0  = 1.0



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Resonant tugs by light on an electron cloud

Each oscillation takes about $1/\nu \sim 10^{-14}$ seconds

About 100,000 oscillations are required to complete the transformation

So about 10^{-9} second are required to transform the **1s cloud** into the **2p cloud**.



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Resonant tugs by light on an electron cloud

What have we seen?

Response requires resonance.

Change is smooth

“Transition” takes time



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Light energy is exchanged in tiny amounts called photons



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Total energy exchanged is $h\nu_{\text{light}} = hc/\lambda_{\text{light}}$

This amount energy is called a photon.



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$$\Delta E_{\text{light}} + \Delta E_{\text{atom}} = 0$$

Photon energy units are **exchanged** between light and atoms,
 $\Delta E_{\text{light}} + \Delta E_{\text{atom}} = 0$, that is $\Delta E_{\text{light}} = -\Delta E_{\text{atom}}$

Emission of light:
 Light gains (a photon of) energy, $\Delta E_{\text{light}} = hc/\lambda$
 Atom electron cloud **loses** energy, $\Delta E_{\text{atom}} = -hc/\lambda$

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$$\Delta E_{\text{light}} + \Delta E_{\text{atom}} = 0$$

Photon energy units are **exchanged** between light and atoms
 $\Delta E_{\text{light}} + \Delta E_{\text{atom}} = 0$, that is $\Delta E_{\text{light}} = -\Delta E_{\text{atom}}$

Absorption of light:
 Light **loses** (a photon of) energy, $\Delta E_{\text{light}} = -hc/\lambda$
 Atom electron cloud **gains** energy, $\Delta E_{\text{atom}} = hc/\lambda$

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$$\Delta E_{\text{light}} + \Delta E_{\text{atom}} = 0$$

Photon energy units are **exchanged** between light and atoms
 $\Delta E_{\text{light}} + \Delta E_{\text{atom}} = 0$, that is $\Delta E_{\text{light}} = -\Delta E_{\text{atom}}$

Sketch the energy diagram of the atom corresponding to **emission of blue light**,
 $\lambda_{\text{blue}} = 420 \text{ nm}$.

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$$\Delta E_{\text{light}} + \Delta E_{\text{atom}} = 0$$

Photon energy units are **exchanged** between light and atoms
 $\Delta E_{\text{light}} + \Delta E_{\text{atom}} = 0$, that is $\Delta E_{\text{light}} = -\Delta E_{\text{atom}}$

On the same energy axis, add the energy diagram corresponding to the atom
then absorbing of red light, $\lambda_{\text{red}} = 710 \text{ nm}$.

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Electron waves and quantization (de Broglie)



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Electron clouds are built from waves

By analogy to the energy-frequency relation for light,

$$E_{\text{photon}} = h\nu_{\text{light}}$$

De Broglie **guessed** that electron clouds are built from waves with wavelength

$$\lambda_{\text{electron}} = h/p_{\text{electron}}$$

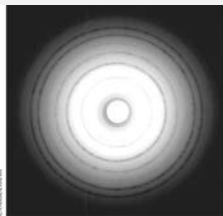
inversely proportional to electron momentum

$$p_{\text{electron}} = mu$$

Units are OK:

$$\begin{aligned} h/mu &= \text{J s} / (\text{kg m/s}) \\ &= \text{kg m}^2/\text{s}^2 \text{ s} / (\text{kg m/s}) = \text{m} \end{aligned}$$

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Electron "waves"

Big idea 1:

Integer number of loops, $\lambda/2$, must "fit" in the atom

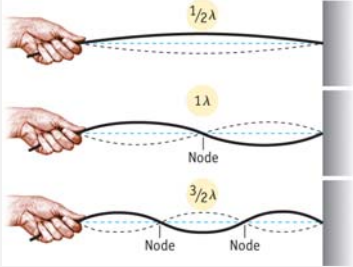


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Integer number of loops fit in the atom

- 1 loop
- 2 loops
- 3 loops



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Electron “waves”

Big idea 2:
More loops, ...
more energy

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Let's see:
Integer number of loops
More loops, more energy

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