Course Title:Physical Chemistry
Course Code:Chem 5101
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DE-BROGLIE HYPOTHESIS & ITS DERIVATION

WAVE PARTICLE DULAITY

- "Quantum nature of light refers to the particle attribute of light".
- "Quantum nature of particle refers to the wave attribute of particle".
- Light (classically EM waves) is said to display wave particle duality.

"It behave like wave in one equation but as particle in other equation".

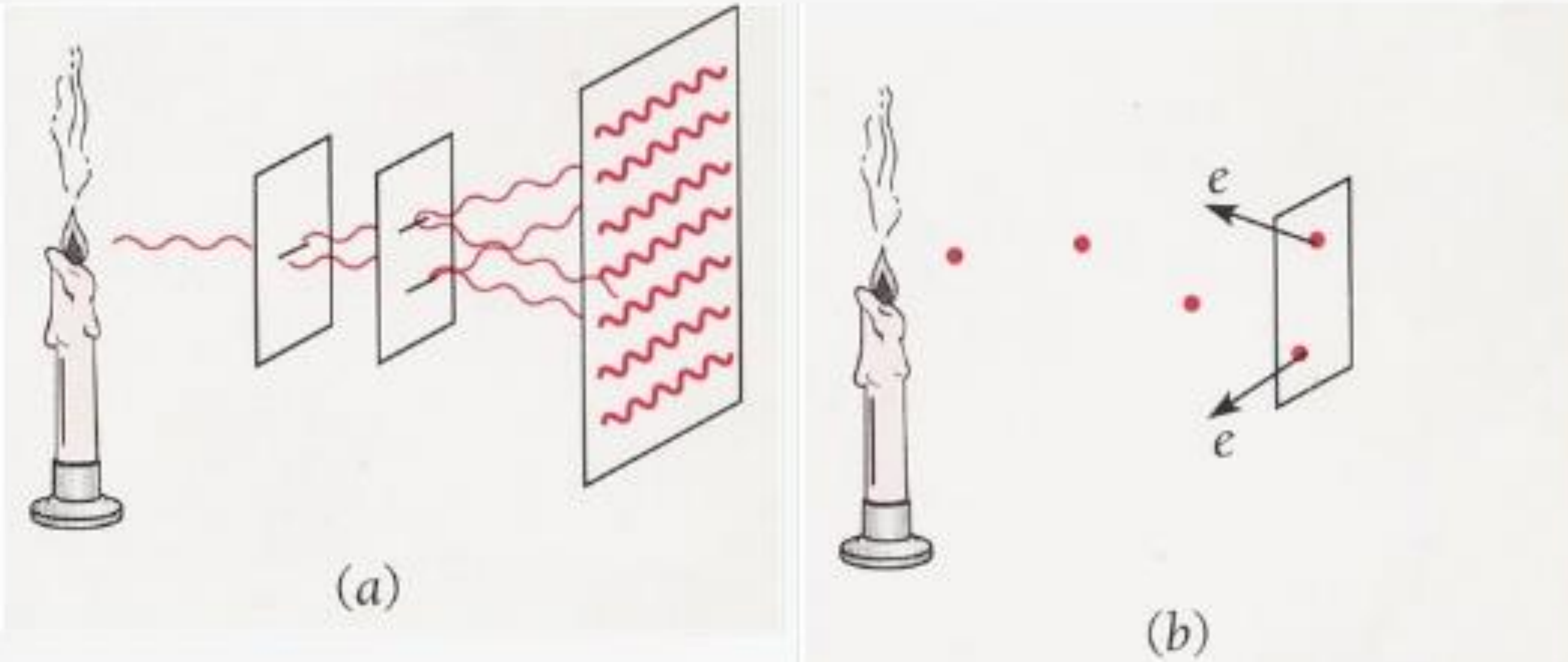


Figure 2.14 (*a*) The wave theory of light explains diffraction and interference, which the quantum theory cannot account for. (*b*) The quantum theory explains the photoelectric effect, which the wave theory cannot account

WHEN IS IT A LIGHT WAVE AND WHEN IS IT A PARTICLE ?

- **Whether light displays wave or particle nature depends on the object it is interacting with,and also on the experimental set-up to observe it.**
- **If an experiment is set-up to observe the wave nature (such as in interference,diffraction experiment), it displays wave nature.**
- **If the experimental set-up has a scale that is corresponding to the quantum nature of radiation,when light will displays particle behaviour,such as in 'Compton scattering'**

WAVE LIKE PROPERTIES OF PARTICLE

- In 1923,while still a graduate student at the University of Paris, Louis de Broglie published a brief note in the journal *Comptes rendus* containing an idea that was to revolutionize our understanding of the physical world at the most fundamental level :That particle has intrinsic wave propertise...

Louis de Broglie
1892-1987

DE BROGLIE POSTULATE (1924)

- The postulate: there should be a symmetry between matter and wave. The wave aspect of matter is related to its particle aspect in exactly the same quantitative manner that is in the case for radiation. The total energy E and momentum p of an entity, for both matter and wave alike, is related to the frequency ν of the wave associated with its motion via by Planck constant

- $E = h\nu; \; p = h/\lambda$

DERIVATION OF EXPRESSION FOR DE-BROGLIE WAVELENGTH:

We know that the energy of a photon of frequency ν (or wavelength λ)is

$$E = h\nu .$$

but from mass energy equivalence (or theory of relativity),energy of a photon is

$$E = mc^2$$

Where m is the moving mass of photon and c is the light of speed .

so,

$$h\nu = mc^2$$

or

$$m = h\nu/c^2$$

Therefore, momentum of photon

$p = mc = (h\nu/c^2)c = h\nu/c = h/\lambda$ (since $c = \nu\lambda$)

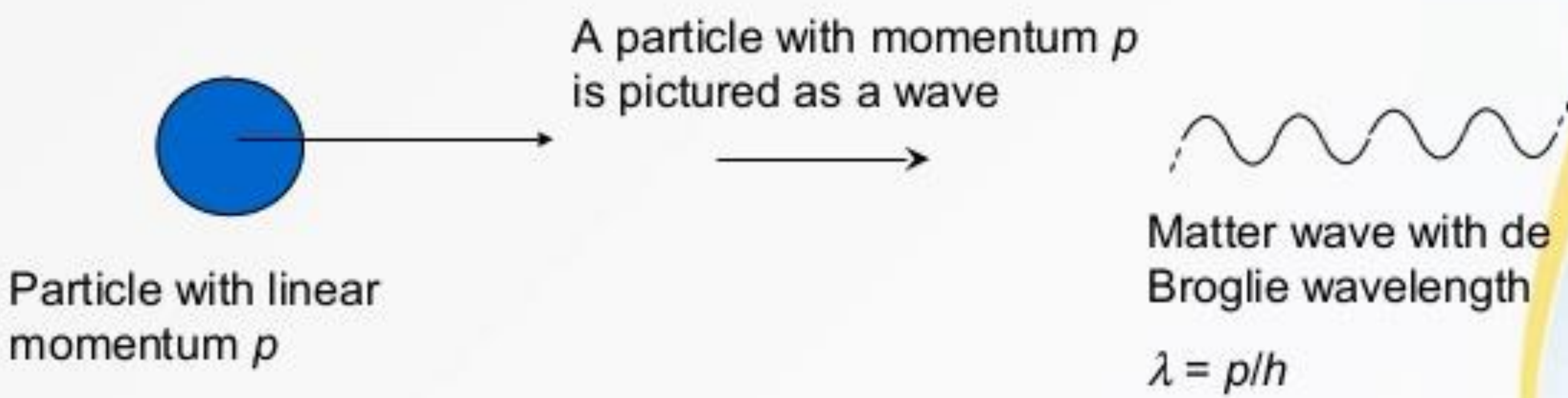
or wavelength of light $\lambda = h/p$.

where p is the momentum of photon.

A PARTICLE HAS WAVELETH !!!

$$\lambda = h/p$$

- Is the de Broglie relation predicting the wave length of the matter wave λ associated with the motion of a material particle with momentum p



PROBLEMS

Exercise 01 - The Wavelength of an Electron

Find the de Broglie wavelength of an electron ($m = 9.11 \times 10^{-31}\ kg$) moving at 2×10^6 m/s.

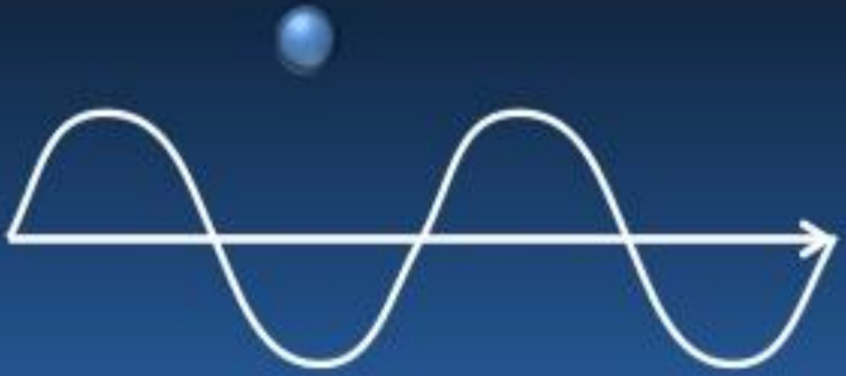
Compared with the classical electron radius which is about 2.8179×10^{-15} m, this is a relatively large wave length.

The de Broglie wave equation is:

$$\lambda = \frac{h}{mv}$$

$$\lambda = \frac{6.63 \times 10^{-34} J \cdot s}{9.11 \times 10^{-31} kg \times 2 \times 10^{6} m/s}$$

$$= 3.639 \times 10^{-10} m$$



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Exercise 02 - The Wavelength of a Baseball

A baseball with a mass of 0.15 kg is pitched at 45 m/s What is its De Broglie wavelength?

$$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34} J \cdot s}{0.15 kg \times 45 m/s}$$

$$= 9.8 \times 10^{-35}$$

Diffraction effects of a baseball are negligible.

This is an incredibly small figure compare with the size of the ball. However this is a wrong example, as we shall see later.

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