Quiz questions

1. The energy levels of the hydrogen atom are given in terms of the principal quantum number n and a positive constant A by the expression:

(A) $A(1-n^2)$

(B) $A\left(n+\frac{1}{2}\right)$

(C) An^2

(D) $-\frac{A}{n^2}$

(E) $A\left(-\frac{1}{4}+\frac{1}{n^2}\right)$

2. An electric dipole consists of a positive charge q and negative charge $-q$ separated by a distance a. Describe the electric field **E** due to these charges along y axis perpendicular to the line connected the charges.

3. Describe the behavior of an electric dipole in a uniform electric field **E**.

4. Why is it impossible to simultaneously measure with infinite accuracy the position and speed of a particle?

Properties of Particles. Wave–Particle Duality

Three approaches are used for describe the properties of materials:

The first is a *continuum* approach, which considers only macroscopic quantities, disregarding the structure of matter.

The second approach was accomplished at the turn of the twentieth century by introducing *atomistic principles* into the description of matter.

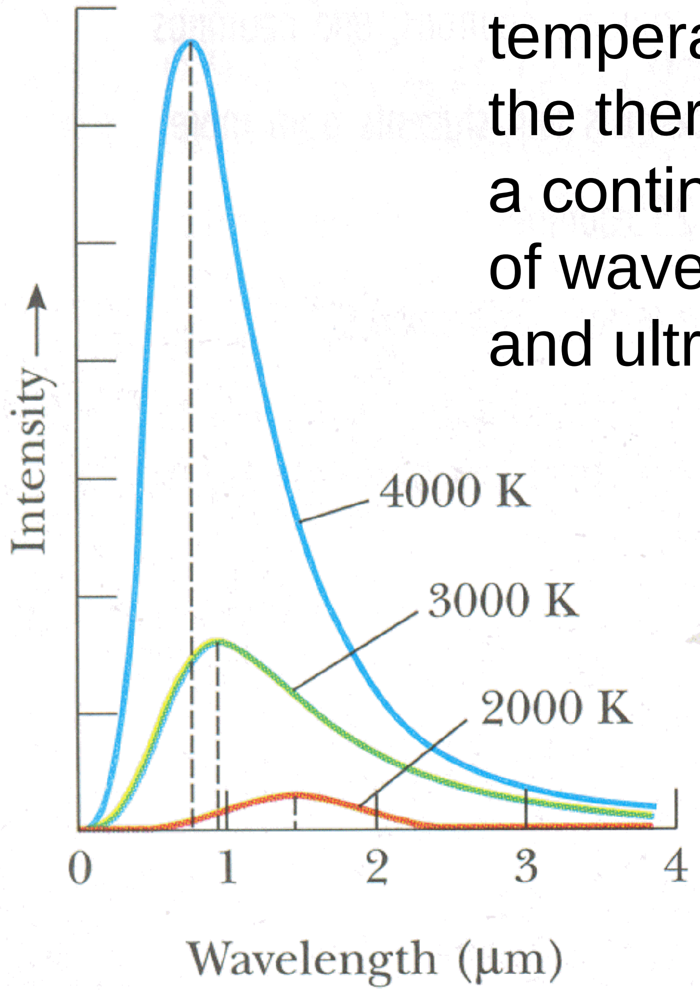
The "classical electron theory" postulated that free electrons in metals drift under the action of field gradient and interact with crystal lattice.

The third approach was accomplished at the beginning of the twentieth century by *quantum* theory. This approach explained important experimental observations, which could not be interpreted by classical means.

BLACKBODY RADIATION AND PLANCK'S HYPOTHESIS

An object at any temperature emits radiation called thermal radiation. The characteristics of this radiation depend on the temperature and properties of the object. From a classical viewpoint, thermal radiation originates from accelerated charges near the surface of the object; those charges emit radiation much as small antennas do.

Careful study shows that, as the temperature an object increases, the thermal radiation it emits consists of a continuous distribution of wavelengths from the infrared, visible, and ultraviolet portions of the spectrum



The basic problem was understanding the observed distribution of wavelengths in the radiation emits by a black body.

For explain this phenomenon Planck (1900) made two assumption:

1. **The molecules can have only discrete units of energy *E_n*.**

$$E_n = h\nu$$

The energy is ***quantized.***

$$h = 6.626 \times 10^{-34}\ \mathrm{J \cdot s}$$

2. The molecules emit or absorb energy in discrete packets called photons.

Planck's analysis led to the experimental curve and the function proposed by Planck is:

$$I(\lambda,T)=\frac{2\pi hc^2}{\lambda^5\left[\exp\left(\frac{hc}{\lambda k_B T}\right)-1\right]}$$

h is Planck's constant

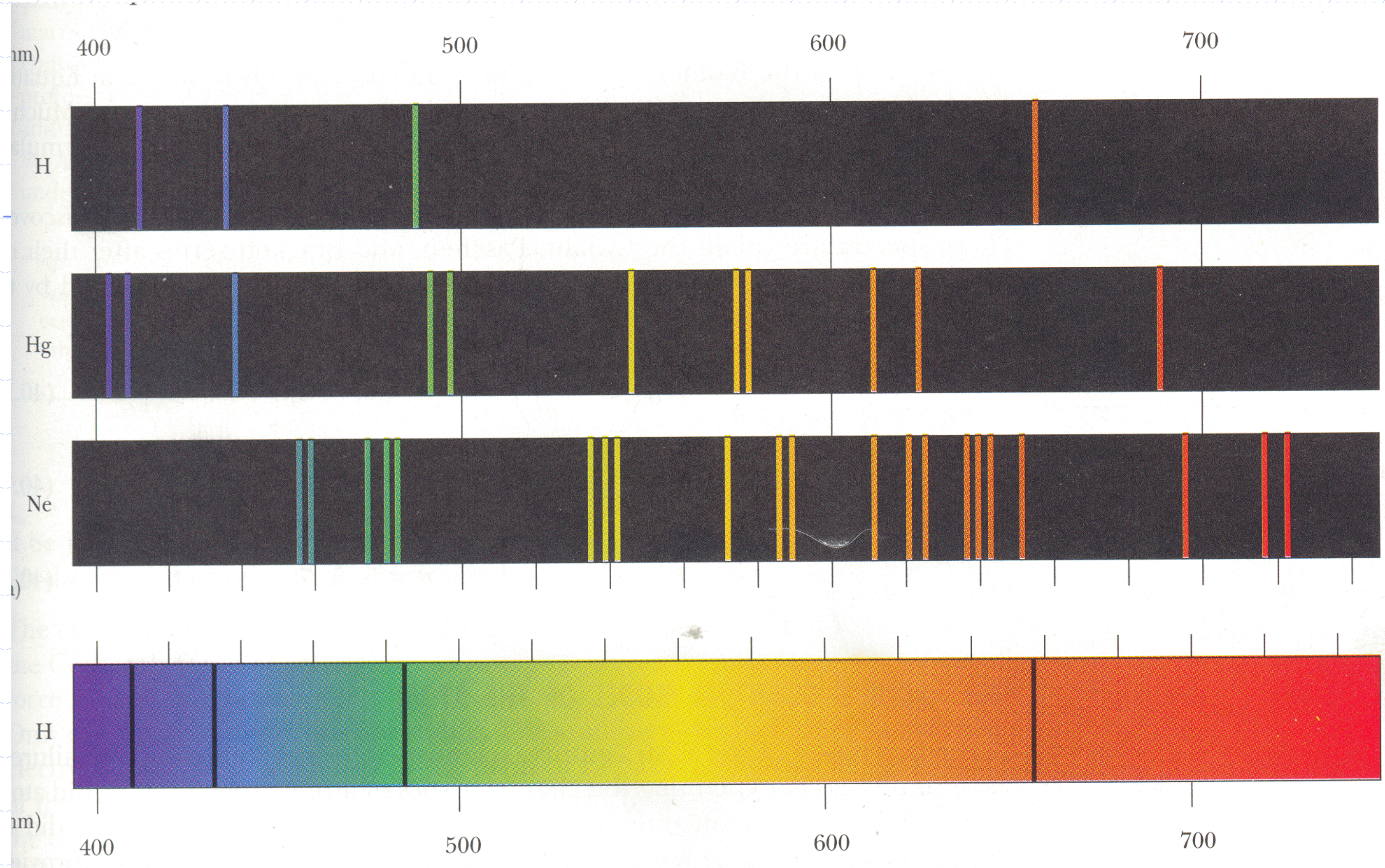
The key point in Planck's theory is radical assumption of ***quantized*** energy states.

This development marked the birth of the quantum theory.

ATOMIC SPECTRA

In sharp contrast to this continuous distribution spectrum is the discrete line spectrum emitted by a low-pressure gaseous element subject to electric discharge.

When the light from such a low-pressure gas discharge is examined with a spectroscope, it is found to consist of a few bright lines of pure color on a generally dark background.



Line spectra produced by emission in visible range for hydrogen, mercury, and helium.

The wavelength of these lines can be described by the empirical equation

$$\frac{1}{\lambda} = R_H \left(\frac{1}{m^2} - \frac{1}{n^2} \right)$$

$$R_H = 1.0973732 \times 10^7 \, m^{-1}$$

were $m = 1,2,3\ldots$ and $n = m + 1$,

R_H called the Rydberg constant.

Lyman series $m = 1$, $n = 2,3,4,\ldots$

Balmer series $m = 2$, $n = 3,4,5,\ldots$

Pashen series $m = 3$, $n = 4,5,6,\ldots$

Brackett series $m = 4$, $n = 5,6,7,\ldots$

The model of atom was provided by Niels Bohr in 1913

The basic ideas of the Bohr theory as it applies to the hydrogen atom are as follows:

- ***The electron moves in circular orbits around the proton under the influence of the Coulomb force of attraction***
- ***Only certain electron orbits are stable. These stable orbits are ones in which the electron does not emit energy in the form of radiation.Radiation is emitted by the atom when the electron jumps from a more energetic initial orbit to a lower orbit.***

The angular momentum of electron is quantized

$$mvr = n\hbar$$

For hydrogen: $$E_n = -\frac{13{,}6}{n^2}\,\text{eV} \qquad n = 1,2,3,\ldots$$

For hydrogen-like atoms $$E_n = -\frac{k_e e^2}{2a_0}\left(\frac{Z}{n^2}\right) \qquad n = 1,2,3,\ldots$$

Photons and electromagnetic waves

"How can light be considered a photon (in other words, a particle) when we know it is a wave?" On the one hand, we describe light in terms of photons having energy and momentum. On the other hand, we recognize that light and other electromagnetic waves exhibit interference and diffraction effects, which are consistent only with a wave interpretation.

Which model is correct?

Is light a wave or a particle?

The end result is that we must accept both models and admit that the true nature of light is not describable in terms of any single classical picture. Light has a dual nature: it exhibits both wave and particle characteristics.

THE WAVE PROPERTIES OF PARTICLES

The relationship between the energy and momentum of a photon, which has a rest mass of zero, is

$$p = \frac{E}{c} = \frac{hc}{c\lambda} = \frac{h}{\lambda}$$

Louis de Broglie suggested that materials particles of momentum p have a characteristic wavelength

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

THE UNCERTAINTY PRINCIPLE

Quantum theory predicts that it is fundamentally impossible to make simultaneous measurements of a particle's position and speed with infinite accuracy.

In 1927, Werner Heisenberg (1901-1976) derived this notion, which is now known as the Heisenberg uncertainty principle.

THE UNCERTAINTY PRINCIPLE

If a measurement of position is made with precision Δx and a simultaneous measurement of momentum component Δp_x, than the product of the two uncertainties can never be smaller than

$$\Delta x \cdot \Delta p_x \geq \frac{\hbar}{2}$$

Energy-time uncertainty principle is:

$$\Delta E \cdot \Delta t \geq \frac{\hbar}{2}$$

Molecules and Solids

- Objective is Analysis of the aggregate of atoms known as molecules

First we describe

- the bonding mechanisms in molecules;
- the various modes of molecular excitation;
- the radiation emitted or absorbed by molecules.

Solids

- **Second we describe** how molecules combine to form solids, and by examining their electronic structures, we explain the differences between insulating, metallic, and semiconducting crystals.