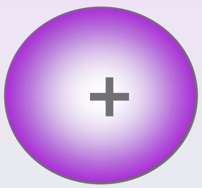
The Structure of the Atom

Review

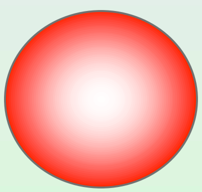
Atoms are composed of

PROTONS



positively charged — mass = 1.6726×10^{-27} kg

NEUTRONS



neutral — mass = 1.6750×10^{-27} kg

ELECTRONS

negatively charged — mass = 9.1096×10^{-31} kg

positive and negative charges

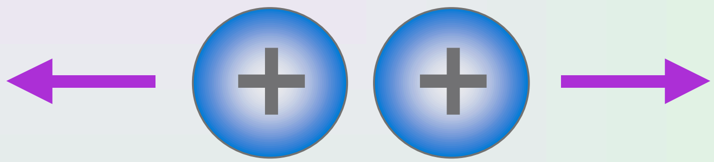
- every object normally has both kinds of charges in equal amounts

- objects with an equal amount of positive and negative charge are said to be electrically neutral

Forces between charges

Electrostatic Force

- objects with like charge repel

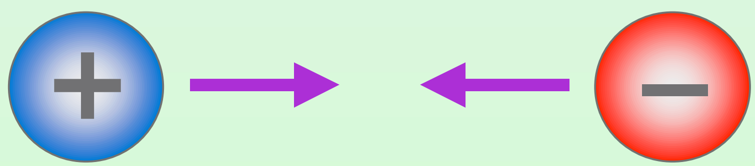


Forces between charges

Electrostatic Force

- objects with like charge repel

- objects with opposite charge attract



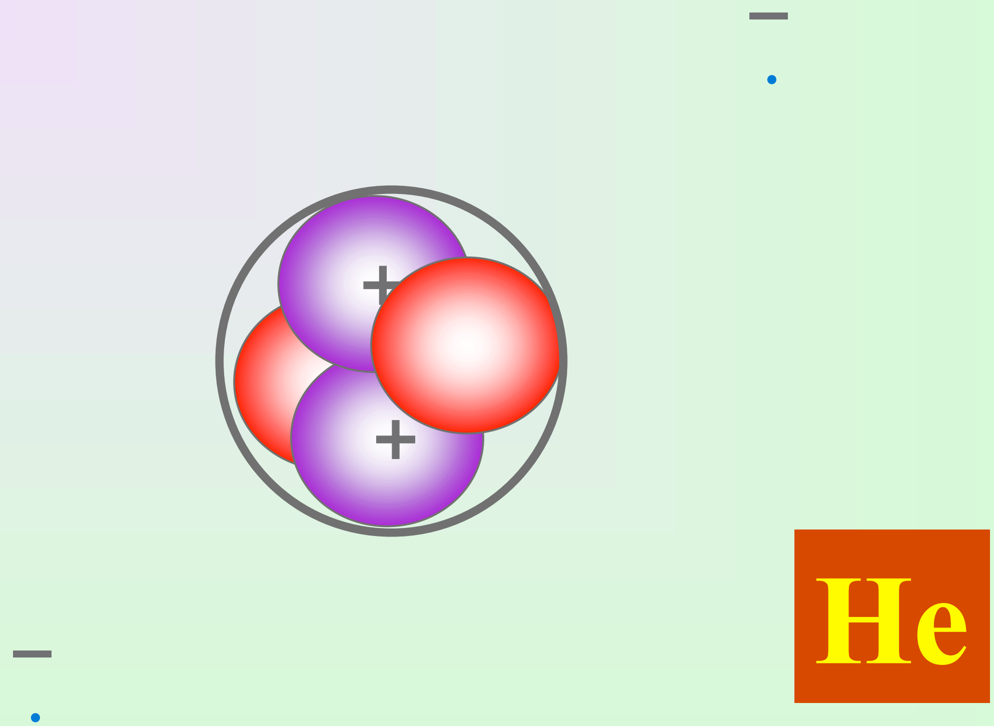
In a sense chemistry amounts to asking the following questions

How many electrons are present in a particular atom?

What energies do individual electrons possess?

Where in an atom can electrons be found?

Our Current Model of the Atom



From Classical Physics to Quantum Theory

The properties of atoms are not governed by the same laws of physics as larger objects

Quantum Mechanics:

the physics of the very small

The Players

- Erwin Schrodinger
- Werner Heisenberg
- Louis Victor De Broglie
- Neils Bohr
- Albert Einstein
- Max Planck
- James Clerk Maxwell

James Clerk Maxwell

Proposed that visible light consists of electromagnetic waves.

waves

A vibrating disturbance by which energy is transmitted.

Electromagnetic radiation

is energy propagated at the speed of light

$$c = 3 \times 10^8 \text{ m/sec}$$

Consists of electric and magnetic fields that simultaneously oscillate in planes mutually perpendicular to each other.

Properties of Waves

wavelength, λ = m

Frequency ν = 1/s = Hz (Hertz)

$$c = \lambda \nu$$

Frequency and wavelength are inversely proportional

c = □□

high frequency-short wavelength

low frequency-long wavelength

Types of electromagnetic radiation

	ν (s^{-1})	λ (m)
gamma rays	10^{21}	10^{-13}
X-rays	10^{19}	10^{-11}
ultraviolet light	10^{17}	10^{-9}
visible light	10^{15}	10^{-7}
infrared radiation	10^{13}	10^{-5}
microwaves	10^{11}	10^{-3}
radio waves	10^{8}	10^{0}

Types of electromagnetic radiation

high frequency	**gamma rays**	**short wavelength**
	X-rays	
	ultraviolet light	
	visible light	
	infrared radiation	
low frequency	**microwaves**	**long wavelength**
	radio waves	

Types of electromagnetic radiation

high frequency

ultraviolet light

short wavelength

visible light

low frequency

infrared radiation

long wavelength

The Continuous Spectrum of Visible Light

containing all wavelengths

The Players

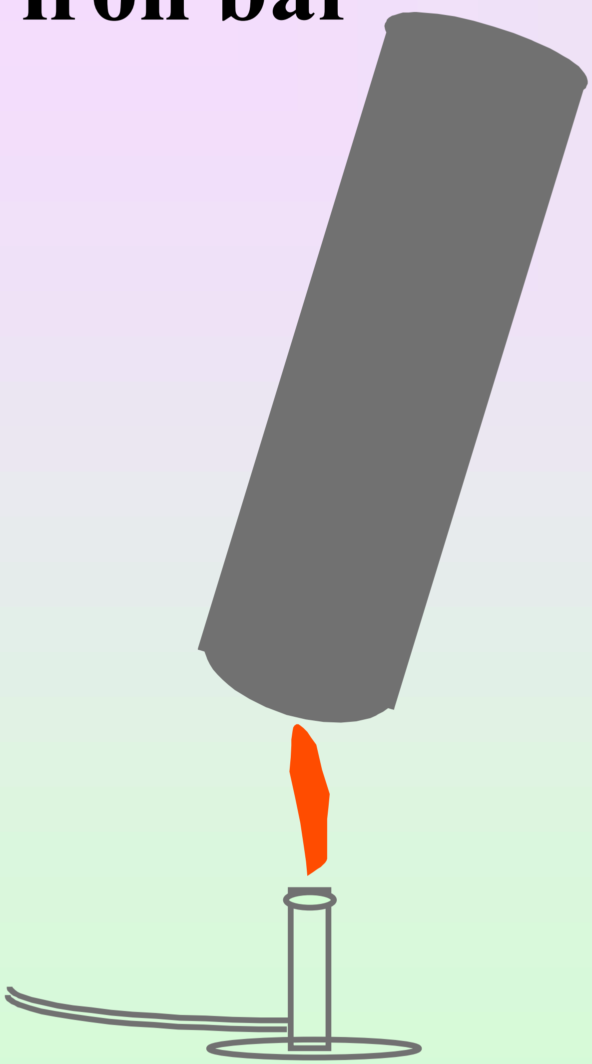
- **Erwin Schrodinger**
- **Werner Heisenberg**
- **Louis Victor De Broglie**
- **Neils Bohr**
- **Albert Einstein**
- ▶ **Max Planck**
- **James Clerk Maxwell**

An Observable Fact

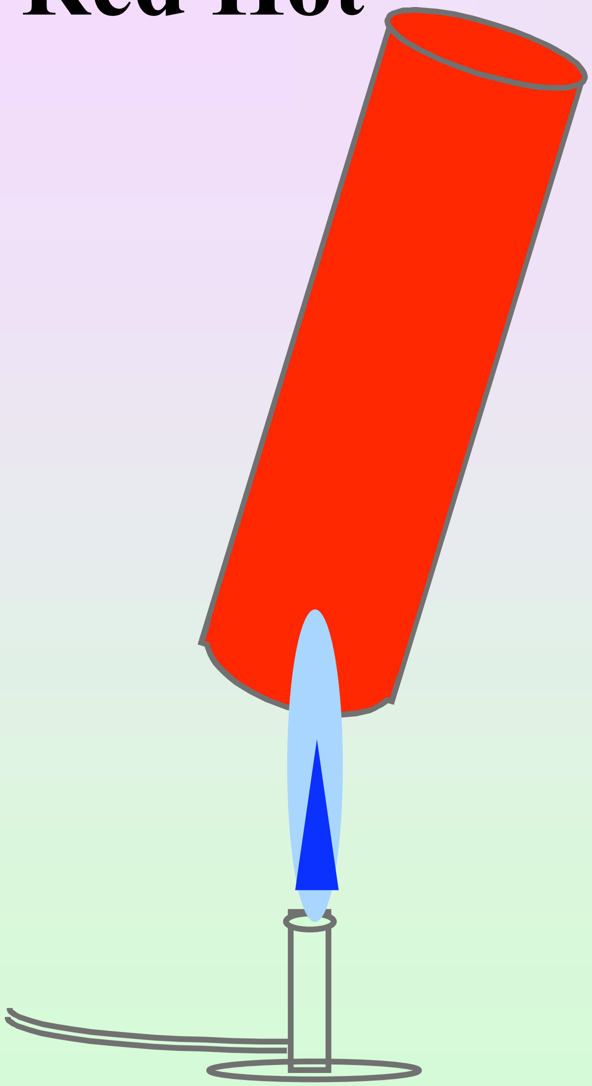
hot bodies radiate electromagnetic energy

classical physics assumed that radiating energy was continuous, due to its wavelike nature .

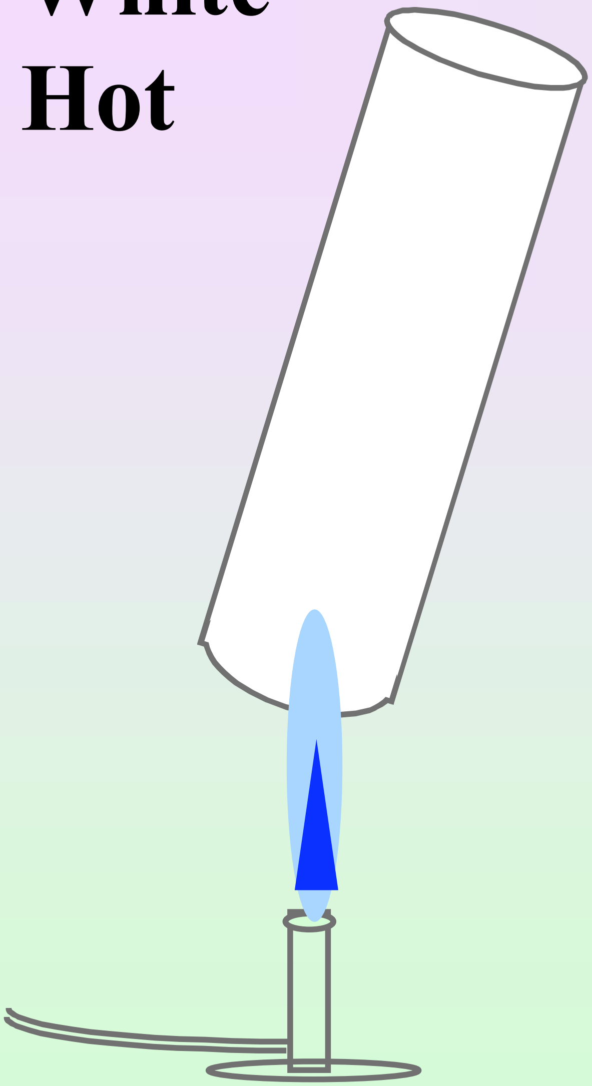
iron bar



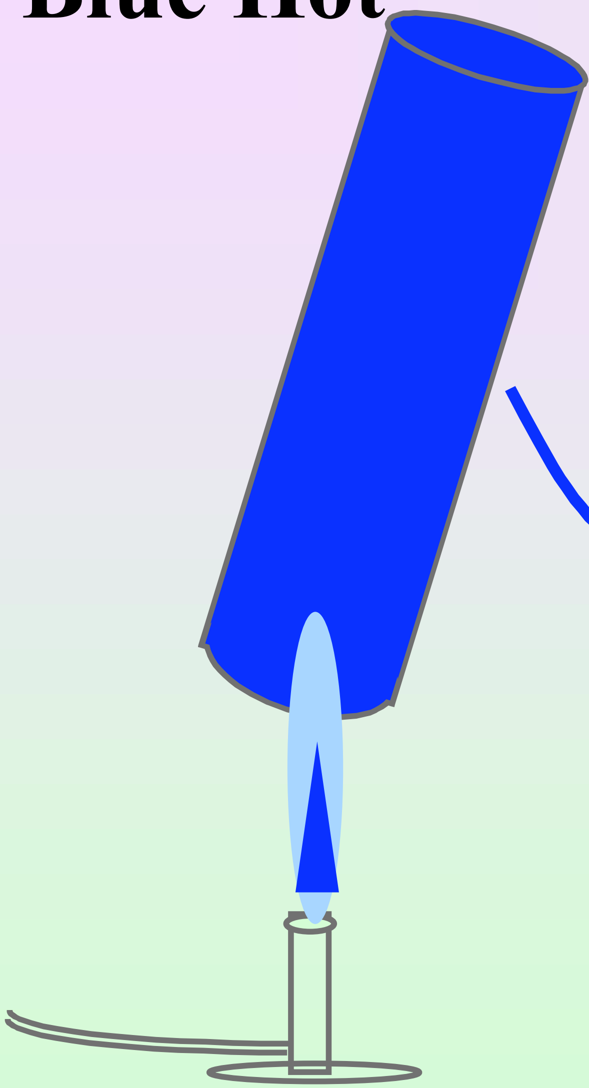
Red Hot



White Hot

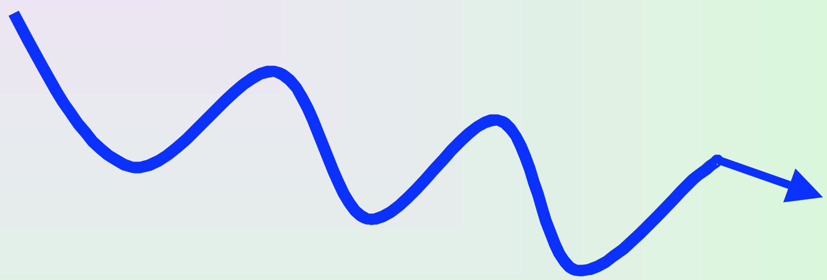


Blue Hot



"Classical physics"

a continuous radiating energy, due to wavelike nature .



"an infinite amount of energy could be released in a radiation process ! "

Max Planck

the energy of the emitted electromagnetic radiation is proportional to frequency

$$\Delta E = h\nu$$

where h **= 6.626 x** 10^{-34} **J s**

h **is called Planck's constant**

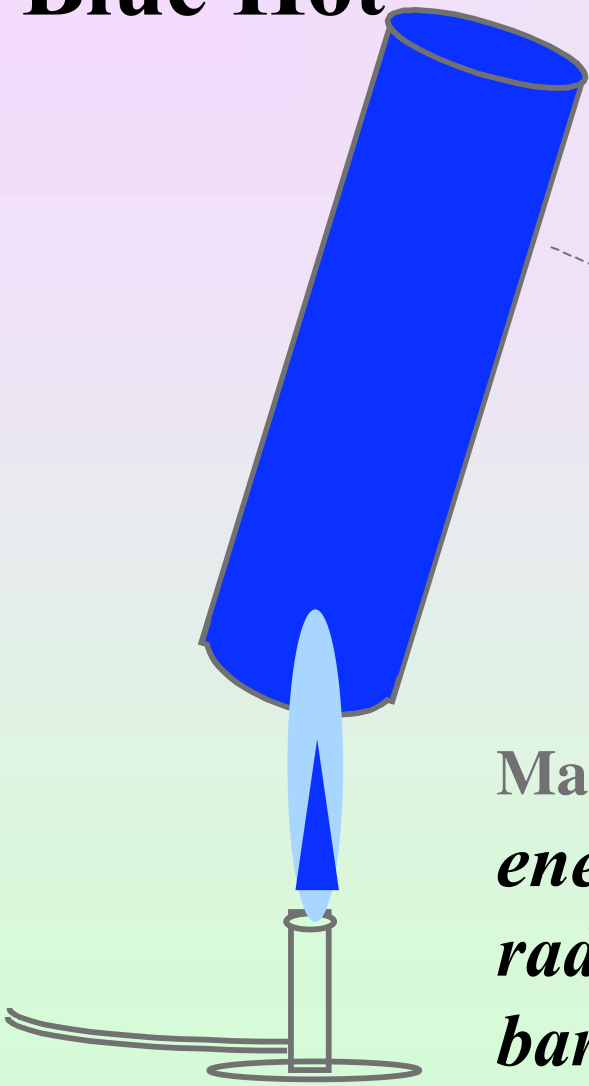
Max Planck

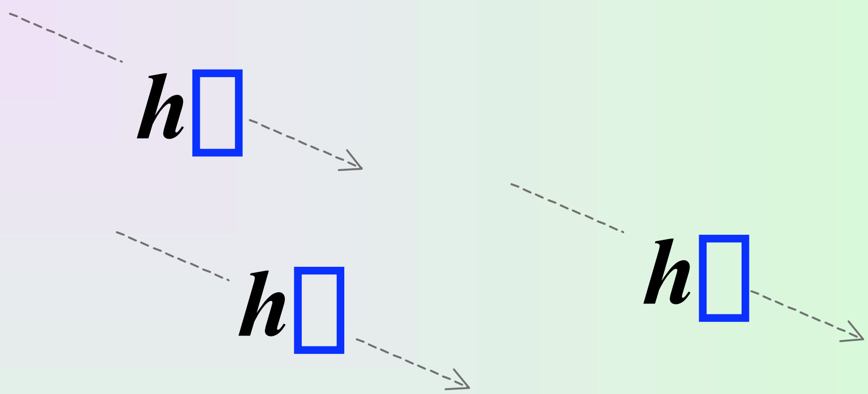
$\square E = n h \square$

Energy is always emitted in multiples of $h\square$.

n **is a whole number (integer)**

Blue Hot





Max Planck

energy emitted as electromagnetic radiation by an object (such as a hot iron bar) can have only certain discrete values, **not a continuous range of values.**

Energy of electromagnetic radiation comes in *h*□-sized
“packets”
“bundles”
“discrete units”

The energy of electromagnetic radiation is quantized.

quanta

The Players

- Erwin Schrodinger
- Werner Heisenberg
- Louis Victor De Broglie
- Neils Bohr
- ▶ Albert Einstein
- Max Planck
- James Clerk Maxwell

Another Mystery in Physics: The Photoelectric Effect

Experiments showed that electrons were ejected from the surface of certain metals exposed to light at a minimum threshold frequency.

Albert Einstein
1905

Accounted for the photoelectric effect by treating light as though it were a stream of particles -- photons.

quantization of electromagnetic radiation

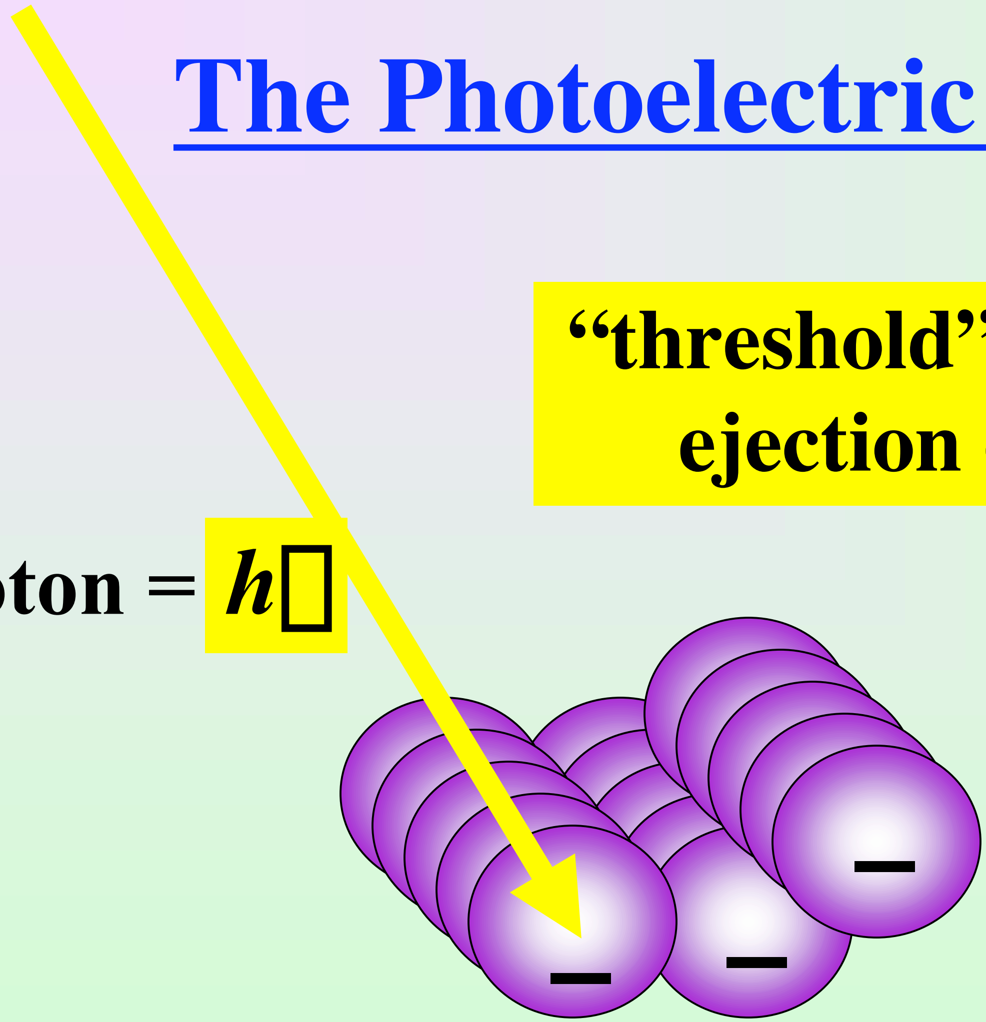
$$h\nu = \text{kinetic energy } e^- + \text{binding energy}$$

$$\text{kinetic energy } e^- = (1/2\, mv^2)\, e^- = h\nu - h\nu_0$$

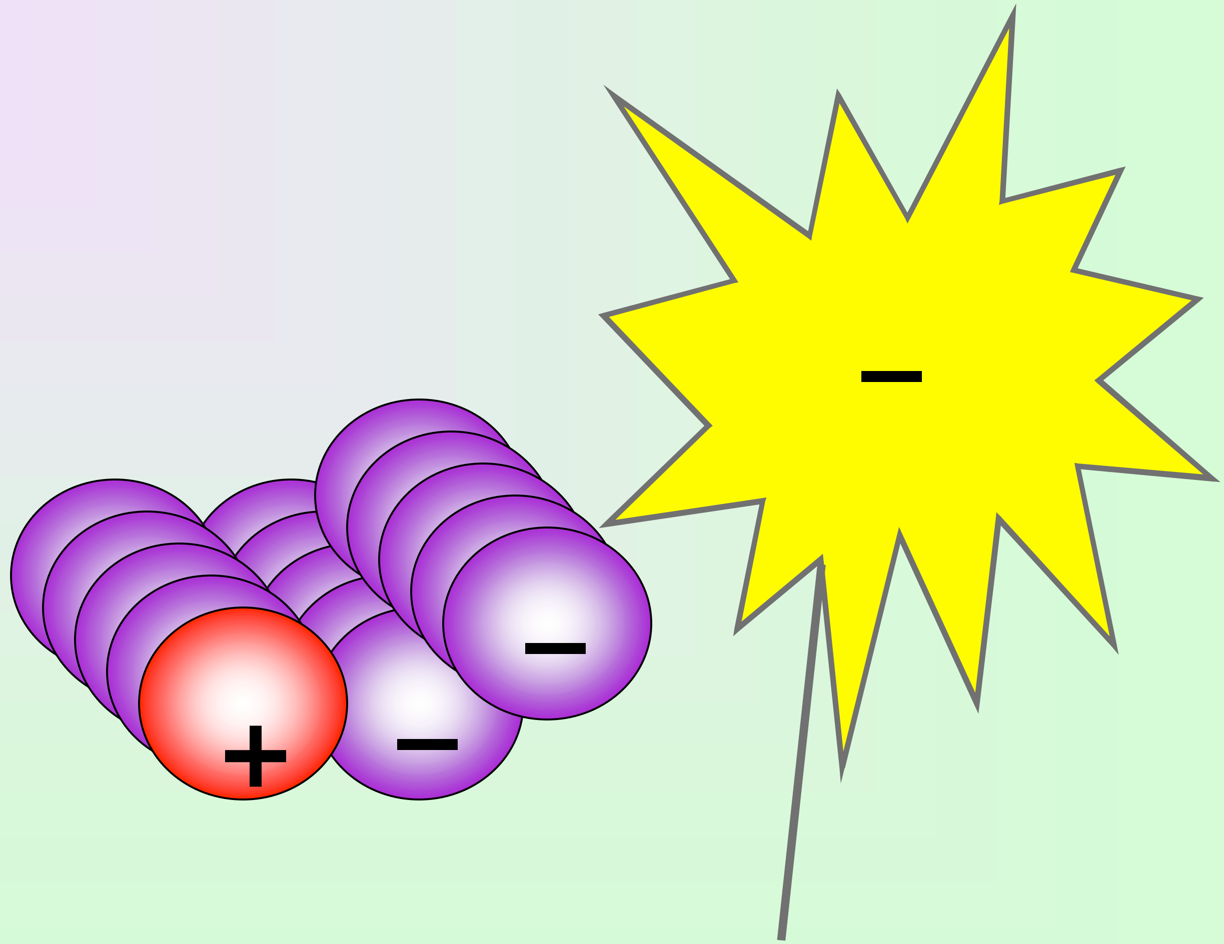
The Photoelectric Effect

"threshold" frequency for ejection of electrons

Photon = $h\nu$



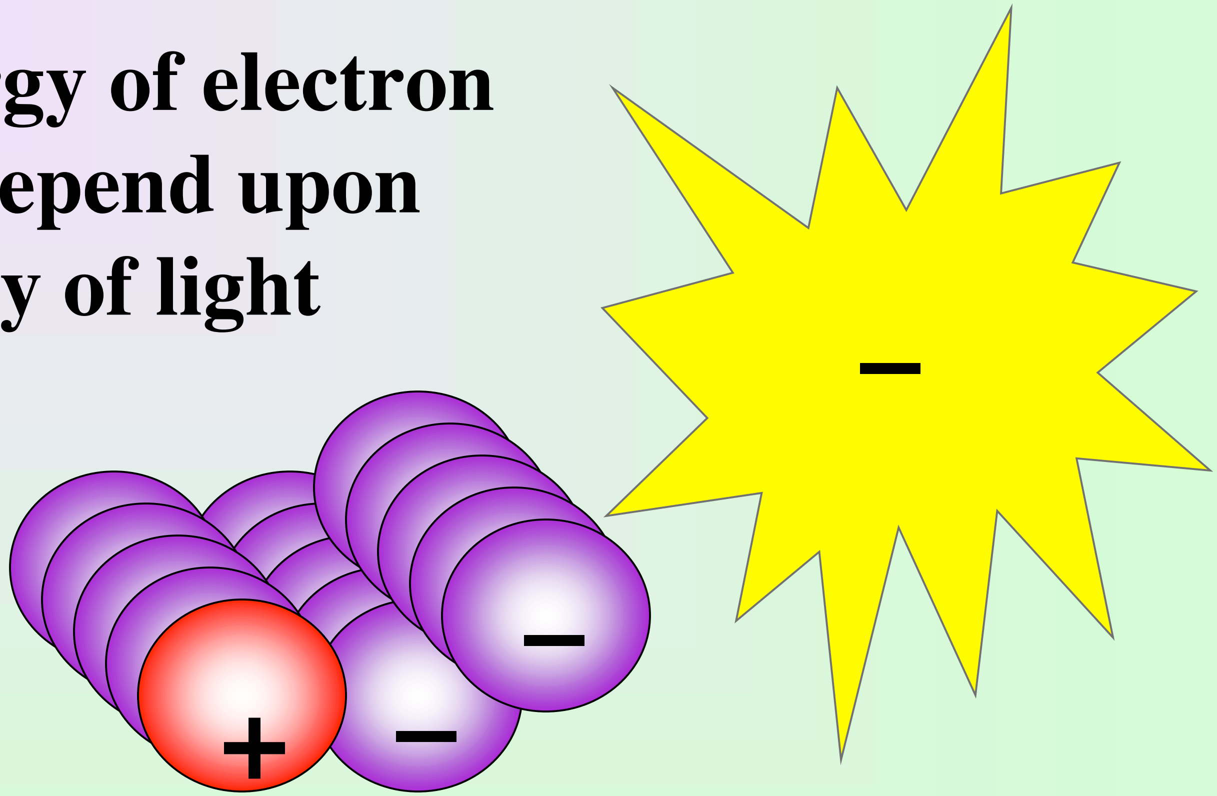
The Photoelectric Effect



KE = $h\nu$ **- BE**

The Photoelectric Effect

Kinetic energy of electron does not depend upon intensity of light



it depends on the frequency

Mass of a Photon

$$\mathrm{E} = h\nu$$

$$\mathrm{E} = mc^2$$

$$mc^2 = h\nu$$

$$\nu = \frac{c}{\lambda}$$

$$m = \frac{h\,\frac{c}{\lambda}}{c^2}$$

$$m = \frac{h}{c\,\lambda}$$

Mass of a Photon is relativistic

Depending on the experiment:

light behaves either as a wave or as a stream of particles

wave /particle duality

Example

Calculate the energy(in joules)of a photon with a wavelength 5.00 x 10^4 nm (infrared region).

$$\Delta E = h\nu$$

$$\nu = \frac{c}{\lambda}$$

$$\Delta E = \frac{hc}{\lambda}$$

$$\Delta E = \frac{(6.63 \times 10^{-34}\ \mathrm{J \cdot s})\ (3.00 \times 10^{8}\ \mathrm{m/s})}{5.00 \times 10^{4}\ \mathrm{nm} \times \dfrac{1 \times 10^{-9}\ \mathrm{m}}{1\ \mathrm{nm}}} = 3.98 \times 10^{-21}\ \mathrm{J}$$