

# Photoelectric Effect

**When light of sufficient energy  
shines on a metal surface,  
electrons are emitted from the  
surface**

# Light acts as a wave and as a particle

## Wave properties

- Periodic electric and magnetic fields (wavelength, frequency, speed, amplitude)
- Diffraction
- Double Slit Interference
- Doppler Effect

## Particle properties

- Light interacts with matter
- Light with a frequency above some minimum value and incident on metals causes electrons to be emitted.

# Does light act like a wave for photoelectrons?

- If light intensity is increased, the number of electrons ejected and the max KE should be increased because higher intensity means greater electric field amplitude and greater electric field means ejecting electrons with higher speed.
- The frequency of light should not matter. Only the intensity of the light.

# Does light act as photons (“particles” or “quanta” or “packages”)?

- An increase in intensity of light means more photons are incident, so more electrons will be ejected (more electrons means more current flowing); but since the energy of each photon is the same, the max KE of the electrons is not changed.
- If the frequency is increased, the max KE of the electrons increases linearly.
- $KE(\text{max of photoelectrons}) = hf - \text{Work}$
- There is a cutoff frequency below which no electrons will be ejected.

# Robert Millikan (1913 – 1914)

- The photon theory of light as a particle was upheld as a result of the photoelectric effect.
- The color of the light determines how energetic the electrons are ( $KE(\max)$ )
- The intensity determines the rate at which the electrons are ejected (the current)

$$\text{KE}(\text{max of photoelectrons}) = hf - \text{Work}$$

- Work function is amount of energy just sufficient to emit electrons.
- $hf$  is the energy of incident light ( $h = \text{Planck's constant} = 6.63 \times 10^{-34} \text{ Joule second}$ )

# Example

- A photon with a frequency of  $7 \times 10^{14}$  Hertz strikes a metal surface whose work function is  $1.5 \times 10^{-19}$  Joule. Calculate the KE(max) and the threshold frequency of the metal.
- $KE(\text{max}) = hf - \text{Work}$   
 $= (6.63 \times 10^{-34} \text{ J s})(7 \times 10^{14} \text{ Hertz}) - 1.5 \times 10^{-19} \text{ J} = 3.14 \times 10^{-19} \text{ J}$   
Threshold  $f = 1.5 \times 10^{-19} \text{ J} / 6.63 \times 10^{-34}$   
 $= 2.26 \times 10^{14} \text{ Hertz}$

# Group Activity

- Using  $E = hf$  where  $h = 6.63 \times 10^{-34}$  J s
- Determine the energy of the following colors of light:
- Red at  $4.3 \times 10^{14}$  Hertz
- Orange at  $4.9 \times 10^{14}$  Hertz
- Yellow at  $5.1 \times 10^{14}$  Hertz
- Green at  $5.8 \times 10^{14}$  Hertz
- Blue at  $6.3 \times 10^{14}$  Hertz