Quantum Mechanics

At the end of this lecture you should:

- Have a qualitative understanding of the difference between quantum mechanics (QM) and classical physics and have an acquaintance with the origins of QM
- Understand the principles behind the *photoelectric effect* and be able to perform calculations which demonstrate your understanding
- Know what is meant by *Planck's constant, quantum, photon, work function, threshold frequency, stopping potential, electron volt*
- Have a qualitative understanding of *electron diffraction* and the ideas behind *Heisenberg's Uncertainty Principle*
- Know about *wave-particle duality* and the *De Broglie equation* which quantifies this

Quantum Physics – introduction
Getting 'into' the atom

Late in the 19th century, physicists explained properties of matter with particle model, light with wave model. Classical physics, which was continuous, had no theoretical limits on size of matter or radiation. Mechanics and electromagnetism together seemed to be enough.

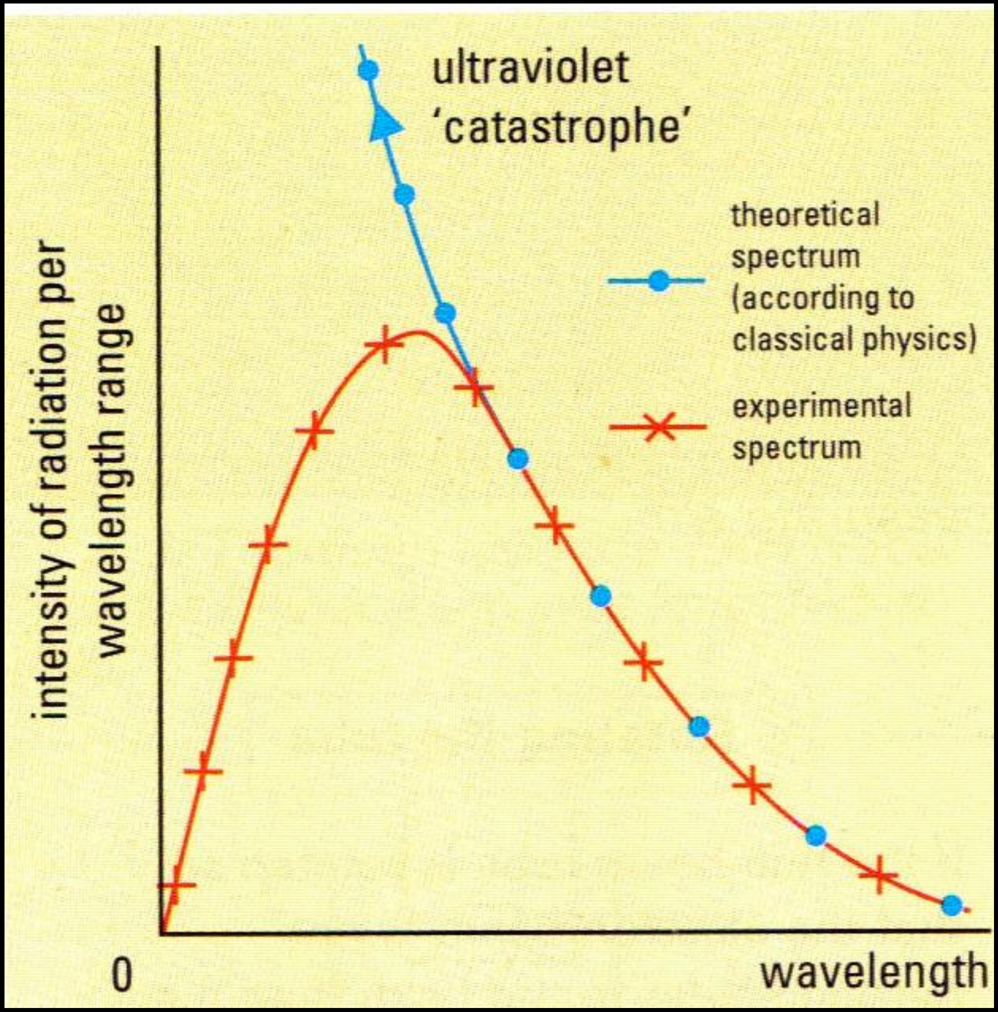
However…

Black-body radiation remained unexplained

All hot bodies radiate.

The known spectrum did not coincide with the theoretical spectrum

Indeed, classical physics violated the law of conservation of energy.



In 1900, Planck postulated that

All oscillators that emit radiation can only emit *discrete energies*. That is, radiation comes in *packets* or *quanta* (plural of quantum). These quanta are proportional to frequency:

$$E = hf$$

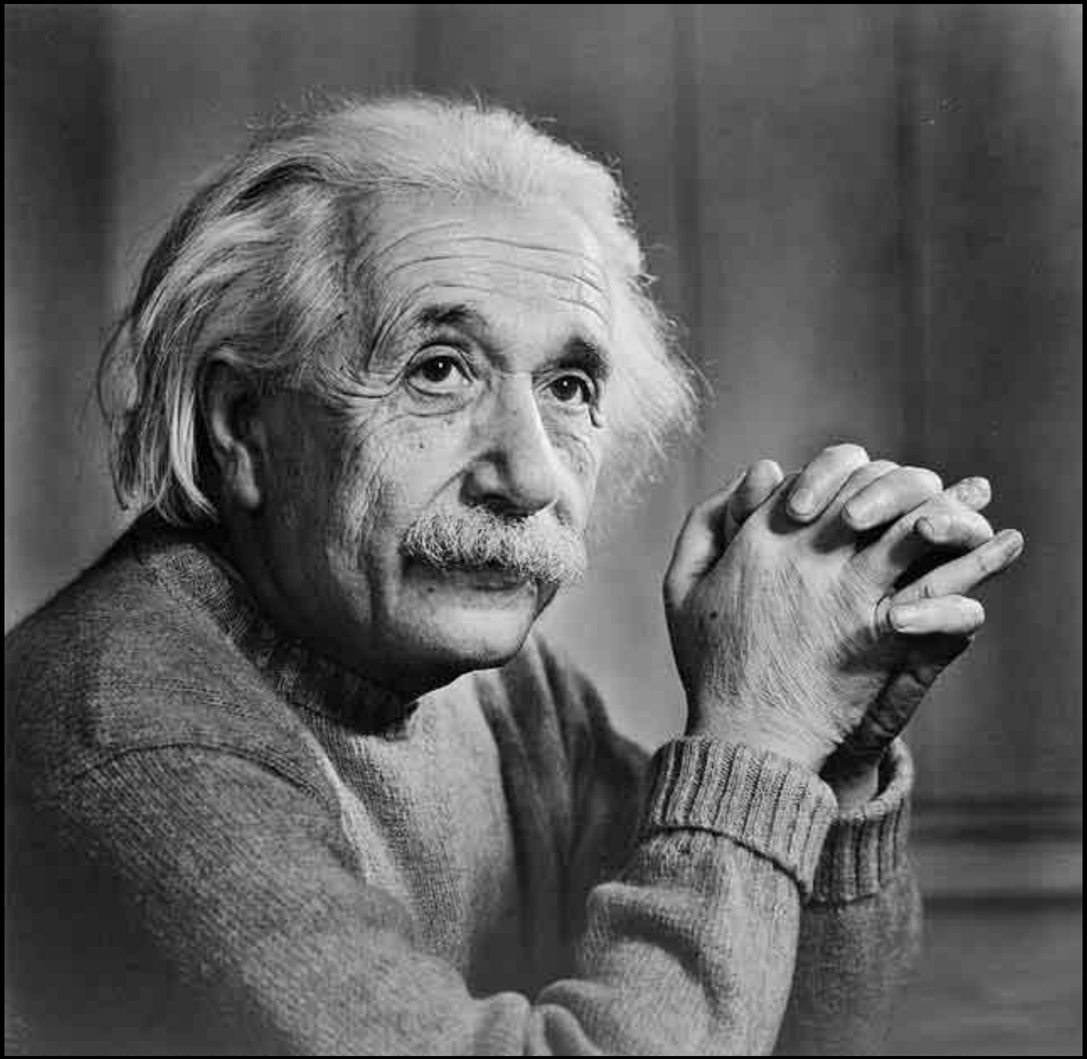
where $h = 6.63 \times 10^{-34}$ Js $= 4.14 \times 10^{-15}$ eV-s

h is known as *"Planck's constant"*

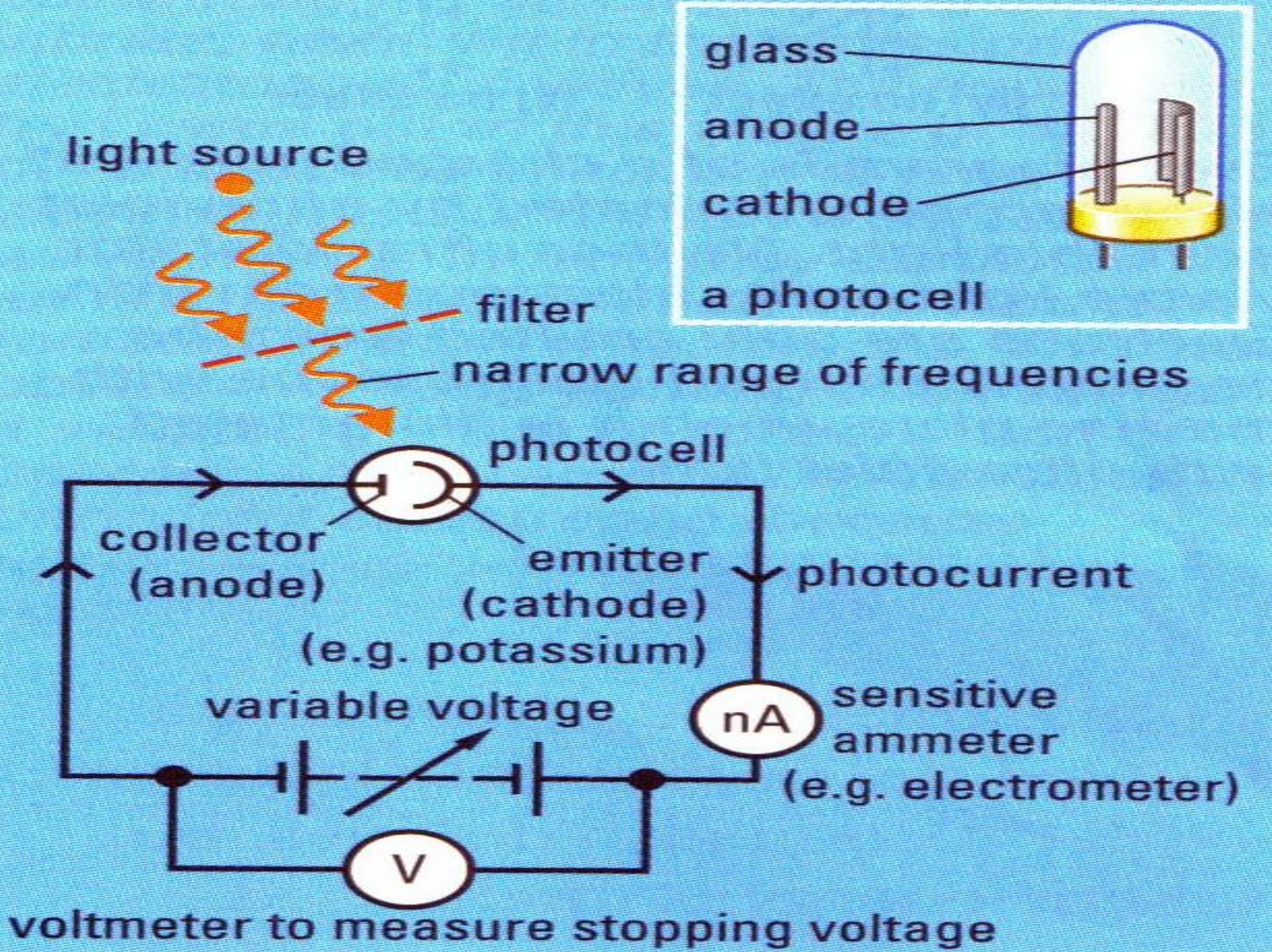
Definition

What is one electronvolt?

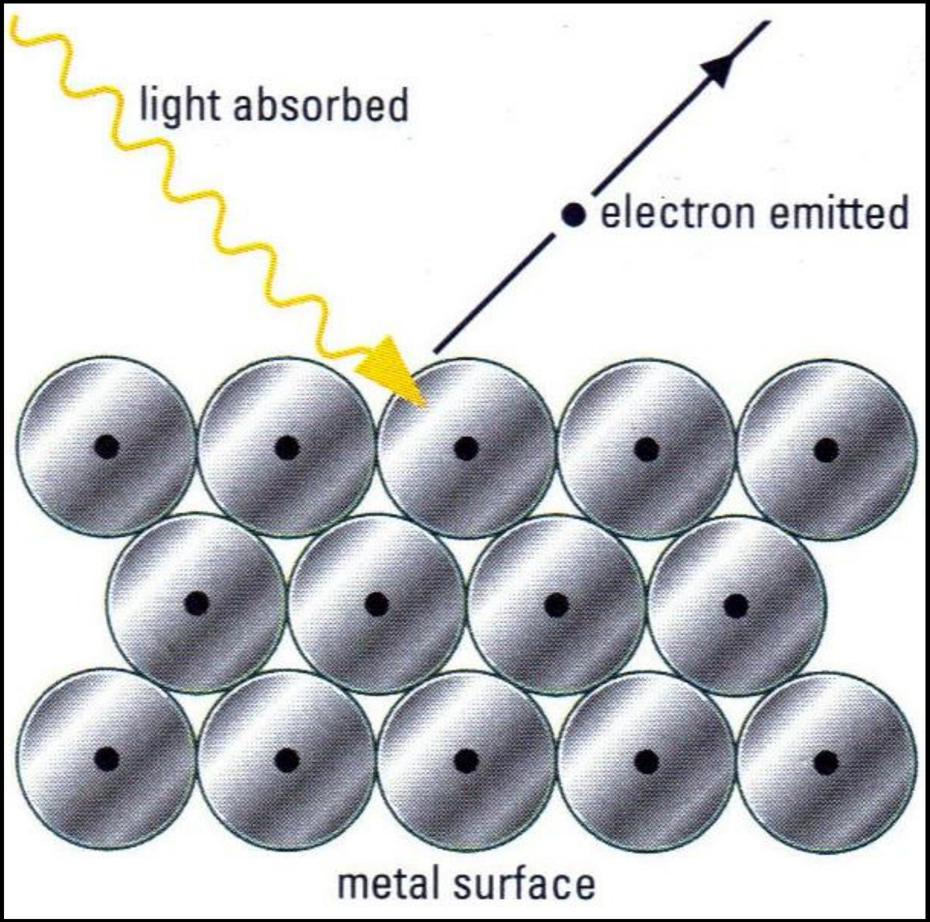
Along comes Albert…



Photoelectric effect


glass
anode
cathode
a photocell
light source
filter
narrow range of frequencies
photocell
collector
(anode)
emitter
(cathode)
(e.g. potassium)
photocurrent
variable voltage
nA
sensitive
ammeter
(e.g. electrometer)
V
voltmeter to measure stopping voltage

Photoelectric effect



This equation explained

1) For each metal, there is a threshold frequency below which no electrons are emitted.

2) The number of electrons emitted is proportional to intensity of radiation.

3) Emitted electrons have KE up to a maximum value which depends on frequency of radiation*.

(* unexplained by classical physics)

For his work on the photoelectric Effect, Einstein was awarded the Nobel Prize in 1921

Example 1

a) Find the longest wavelength beyond which no electrons are emitted from a caesium surface if $\Phi_{caesium} = 1.80$ eV.

b) If the surface is illuminated with monochromatic light of wavelength $\lambda = 450$ nm, calculate KE_{max} of emitted photoelectrons.

c) What is the *stopping potential* which just prevents photoemission in this situation?

De Broglie equation

During his PhD work, de Broglie proposed that electrons might behave as waves.

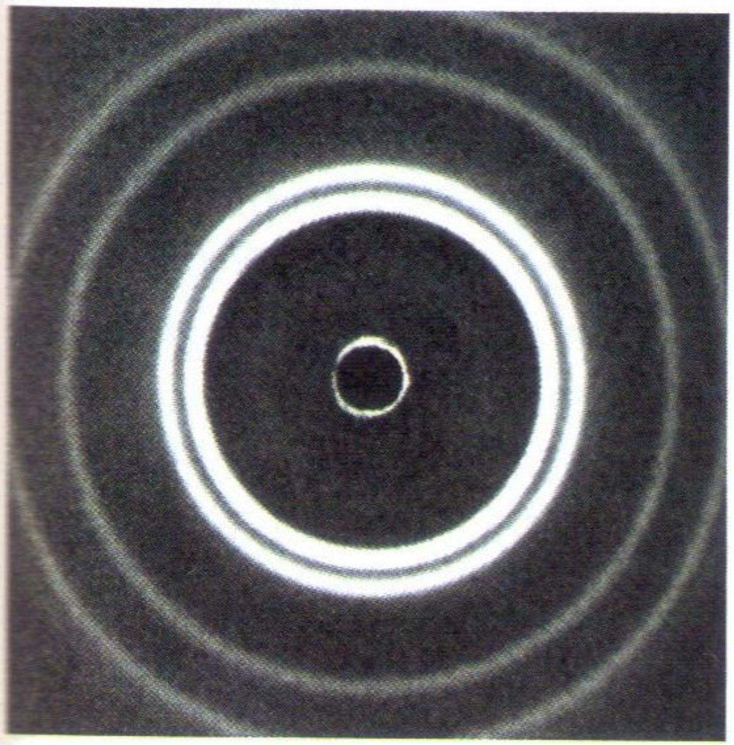
Electron diffraction

Using de Broglie equation for electrons accelerated through 1kV gives a wavelength of about _<u>0.0388 nm</u>_.

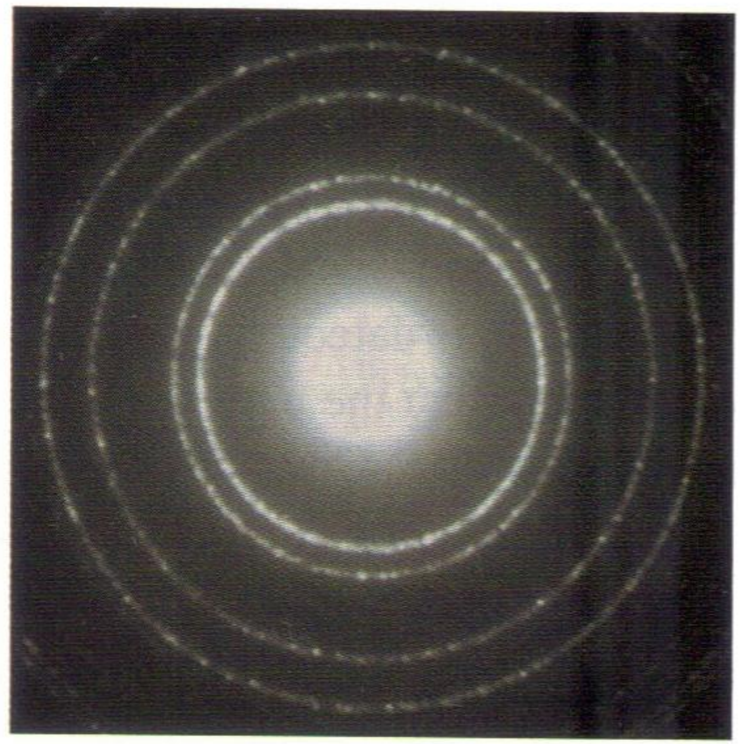
This is comparable to the wavelength of X-Rays.

Why are electrons easier to use than X-Rays when studying crystalline structures?

Diffraction patterns due to X-Ray and Electrons passing through aluminium foil



X-ray



Electrons

If all moving objects have an associated wave, why can’t we see the waves associated with buses?

Wave-particle duality

Sometimes light behaves like a wave, sometimes light behaves like a particle.

Wave-particle duality exists in the universe!

How accurately physical properties can be measured is limited.

Heisenberg’s uncertainty principle

CHECK LIST

READING Adams and Allday: 8.4, 8.5, 8.6, 8.7.

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