Atomic Spectra

IB PHYSICS | ATOMIC PHYSICS

What is Light?

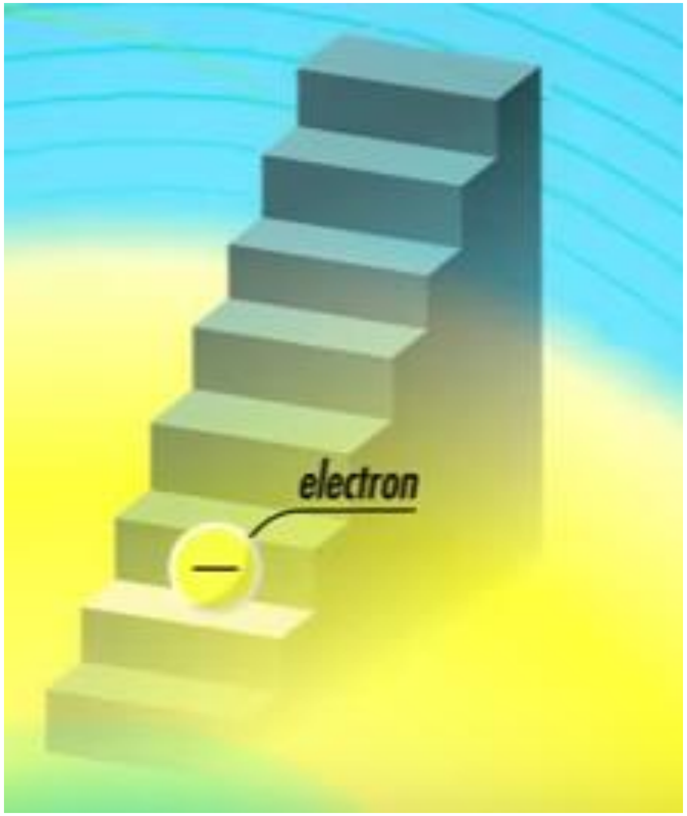
Energy

Wave

Particle
(photon)

Light is Quantized

Photons of light can only have certain ___discrete___ values of energy



Energy of a Photon

$$E = hf$$

Energy
[J]

Frequency
[Hz]

Planck's Constant	h	6.63×10^{-34} J s

Energy of a Photon

$$E = hf \qquad c = f\lambda$$

$$E = h\left(\frac{c}{\lambda}\right) \longleftarrow f = \frac{c}{\lambda}$$

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

$$c = 3.00 \times 10^{8}\ m\ s^{-1}$$

Quick Recap of eV

$$eV \rightarrow electron - volts$$

Unit of Energy

$$\{Energy\ in\ eV\} = \frac{\{Energy\ in\ J\}}{1.60 \times 10^{-19}}$$

IB Physics Data Booklet

Sub-topic 7.1 – Discrete energy and radioactivity	Sub-topic 7.2 – Nuclear reactions
$E = hf$ $\lambda = \frac{hc}{E}$	$\Delta E = \Delta m\, c^2$

Stefan–Boltzmann constant	σ	$5.67 \times 10^{-8}\ \mathrm{W\,m^{-2}\,K^{-4}}$
Coulomb constant	k	$8.99 \times 10^{9}\ \mathrm{N\,m^{2}\,C^{-2}}$
Permittivity of free space	ε_0	$8.85 \times 10^{-12}\ \mathrm{C^{2}\,N^{-1}\,m^{-2}}$
Permeability of free space	μ_0	$4\pi \times 10^{-7}\ \mathrm{T\,m\,A^{-1}}$
Speed of light in vacuum	c	$3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
Planck's constant	h	$6.63 \times 10^{-34}\ \mathrm{J\,s}$
Elementary charge	e	$1.60 \times 10^{-19}\ \mathrm{C}$

Try This...

Calculate the energy carried by one photon of microwaves of wavelength 9 cm (as might be used in wifi signals) in J and eV

↓

0.09 m

$$E = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{(0.09)} = \boxed{2.21 \times 10^{-24}\ \text{J}}$$

$$\frac{1.99 \times 10^{-24}}{1.60 \times 10^{-19}} = \boxed{1.38 \times 10^{-5}\ \text{eV}}$$

Shortcut time ☺

Unit conversions

1 radian (rad) $\equiv \frac{180°}{\pi}$

Temperature (K) = temperature (°C) + 273

1 light year (ly) = 9.46×10^{15} m

1 parsec (pc) = 3.26 ly

1 astronomical unit (AU) = 1.50×10^{11} m

1 kilowatt-hour (kWh) = 3.60×10^{6} J

$hc = 1.99 \times 10^{-25}$ J m $= 1.24 \times 10^{-6}$ eV m

Since *h* and *c* are both constants, *hc* acts as a constant as well

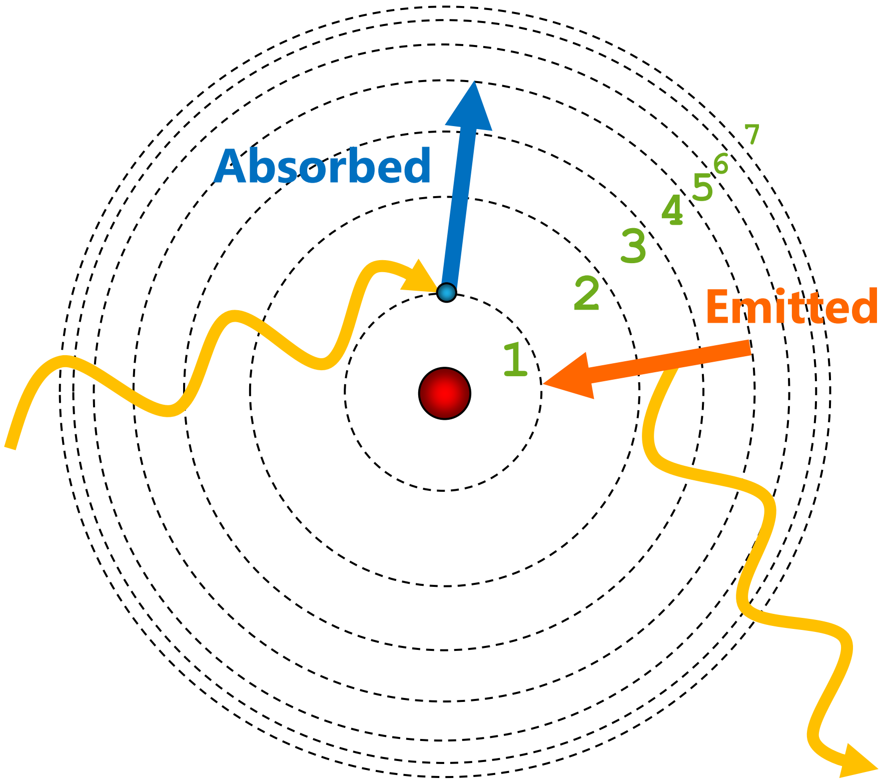
$$E = \frac{hc}{\lambda}$$

$$\frac{1.99 \times 10^{-25}\ \text{J m}}{0.09\ \text{m}} = 2.21 \times 10^{-24}\ \text{J}$$

$$\frac{1.24 \times 10^{-6}\ \text{eV m}}{0.09\ \text{m}} = 1.38 \times 10^{-5}\ \text{eV}$$

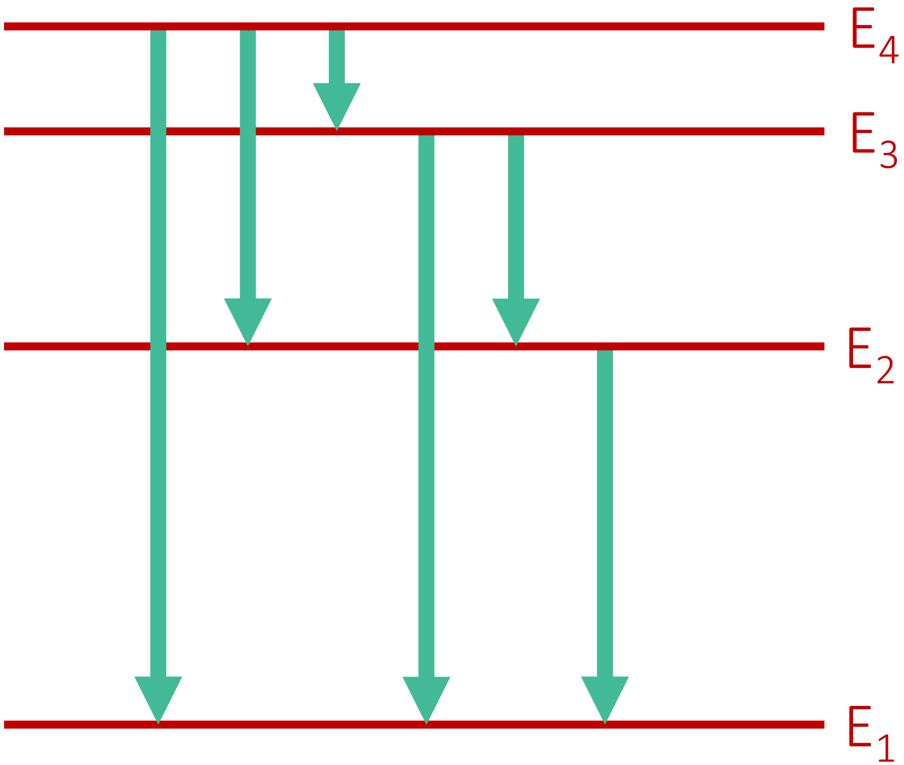
Energy Levels

Electrons in an atom exist at discrete energy levels



Energy Levels

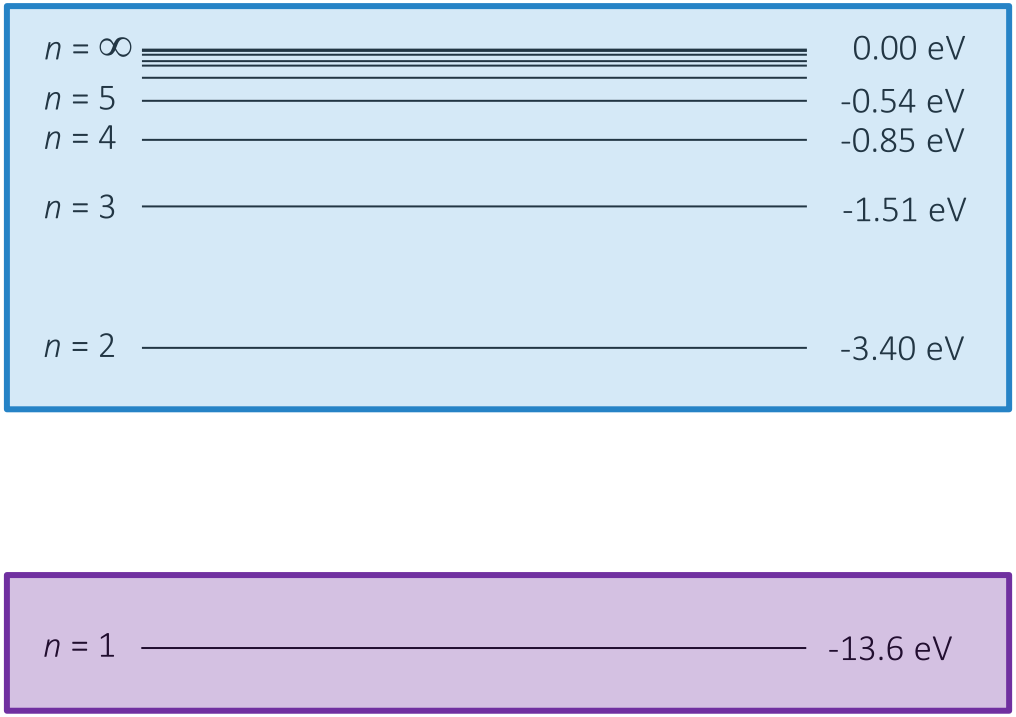
A photon is emitted whenever an electron transitions from one energy level down to a lower energy level



How many different transitions are possible between these four energy levels?

6

Energy Levels

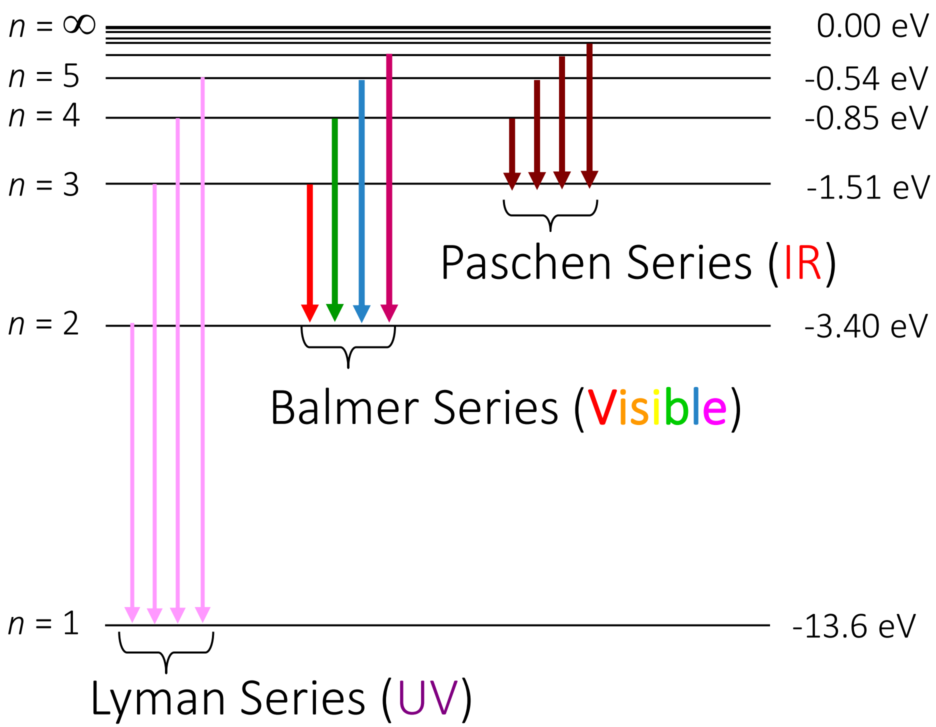


Excited States

Ground State

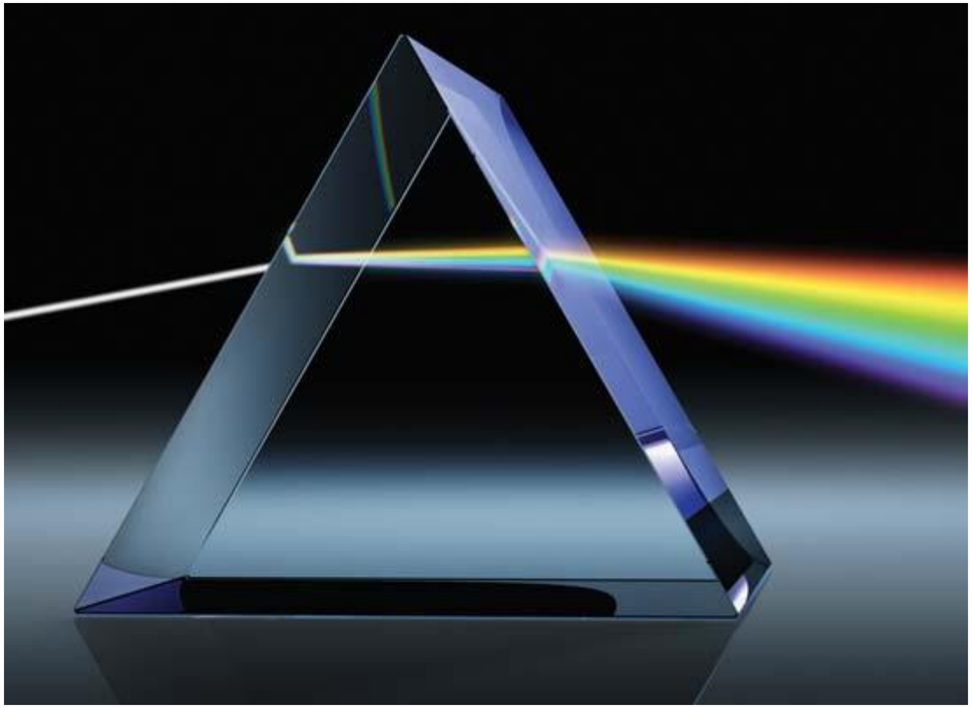
Energy Transitions

Different Energy transitions result in different energies (wavelengths) of light that are absorbed or emitted



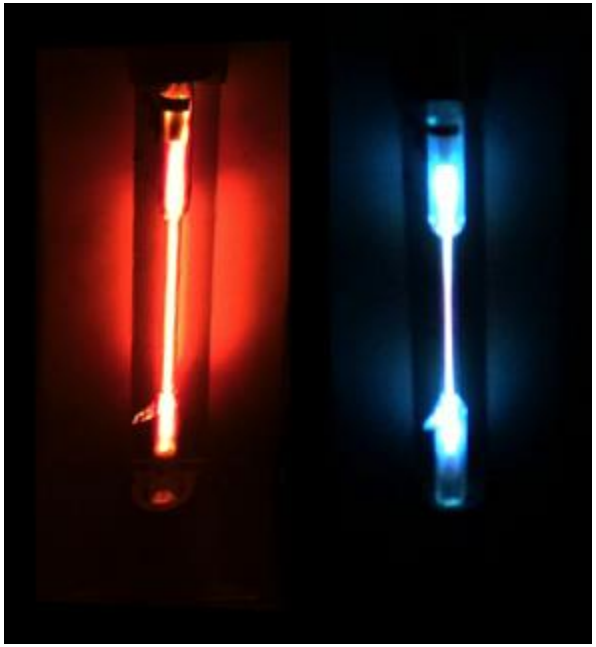
Continuous Spectrum

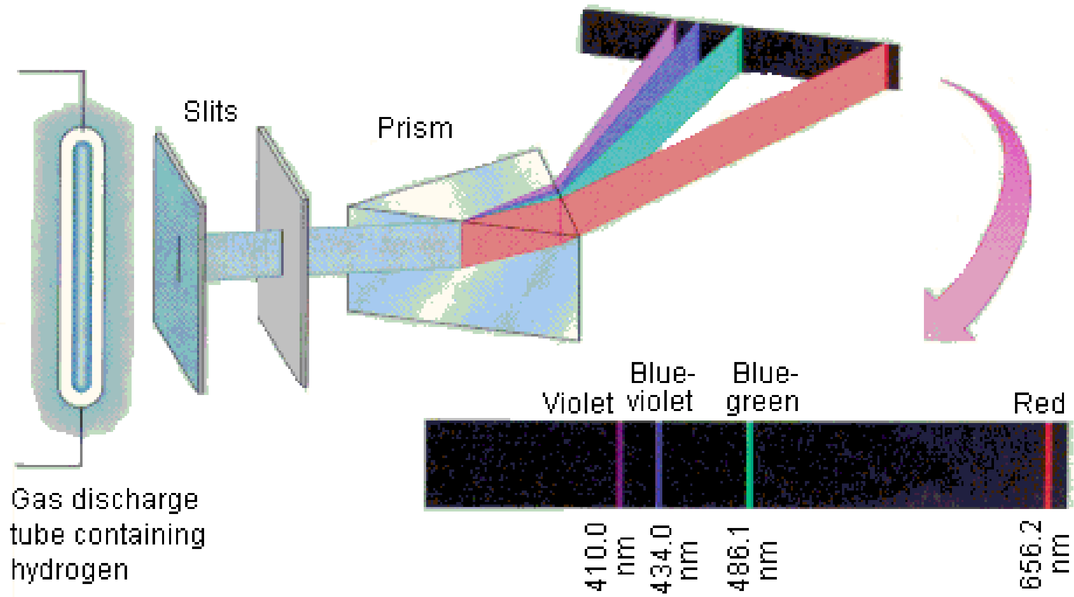
When white light from the sun passes through a prism, the light is dispersed into its component colors in a continuous spectrum



Emission Spectrum

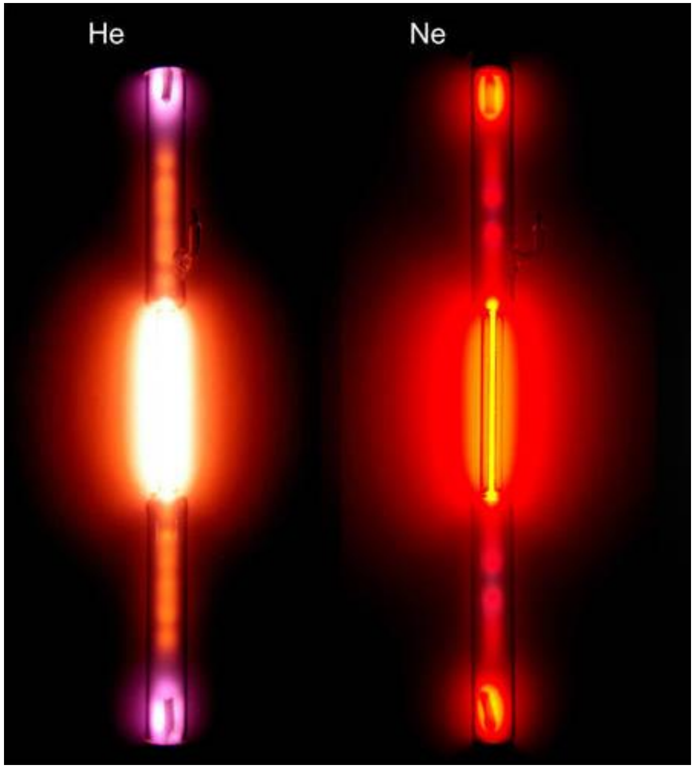
If an electric current is passed through an element in the form of a low-pressure gas, it will produce its own unique emission spectrum



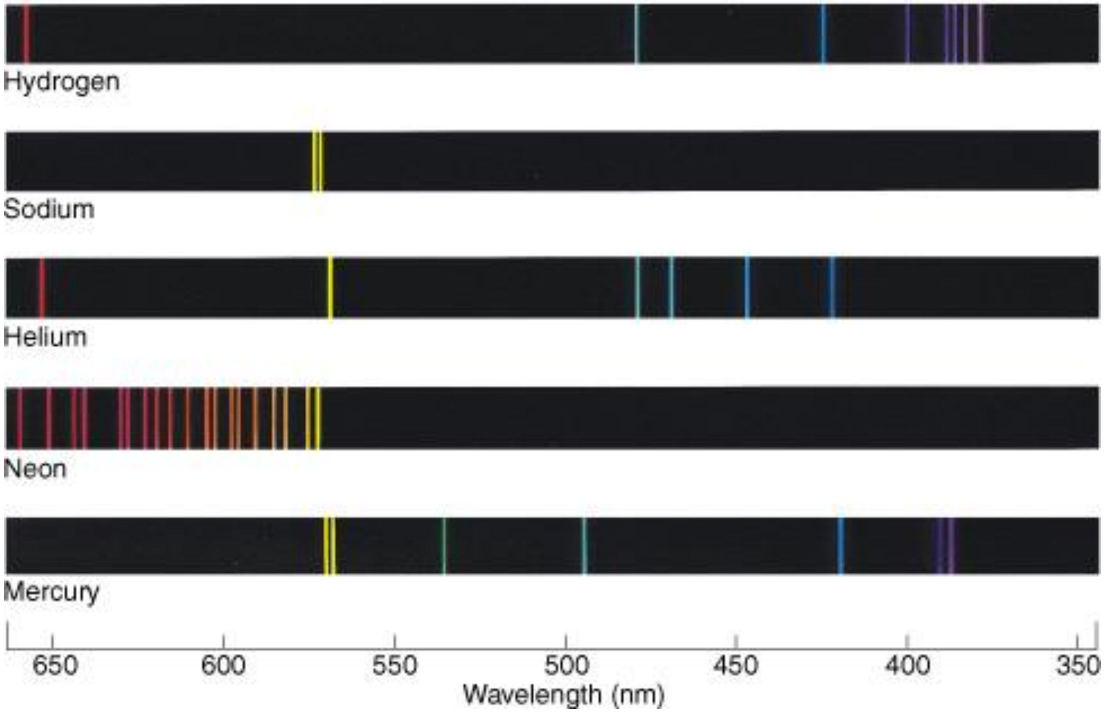


Emission Spectrum

These spectra can be used to identify elements like a fingerprint

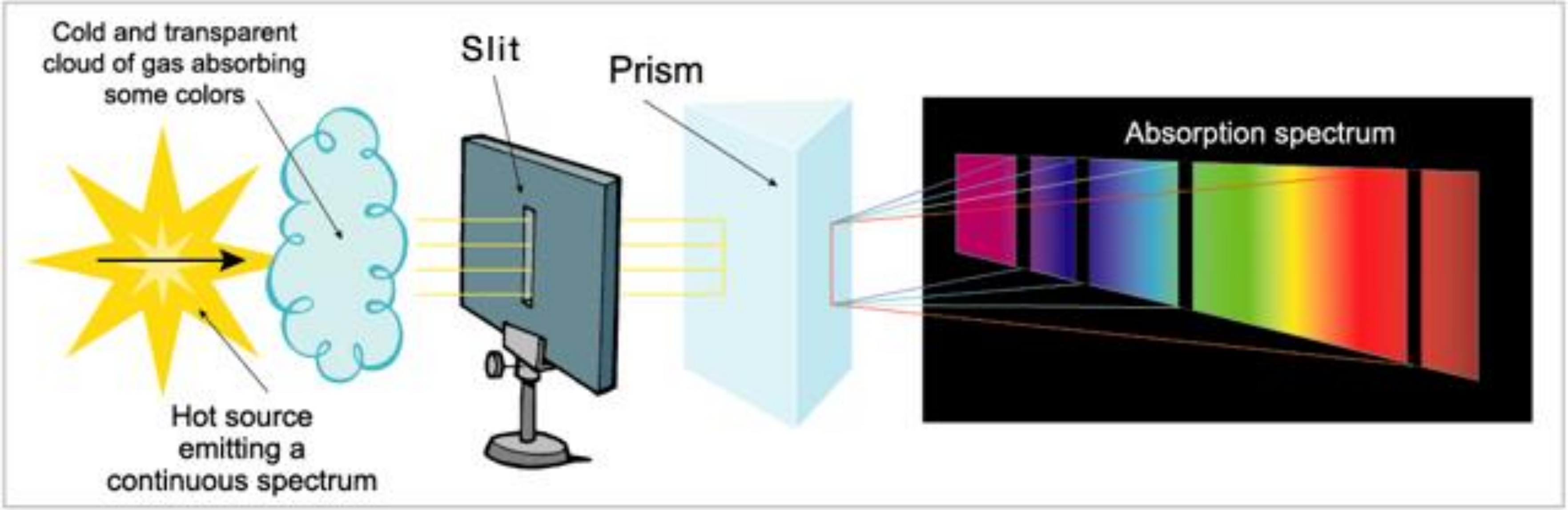


These are known as Line Spectra

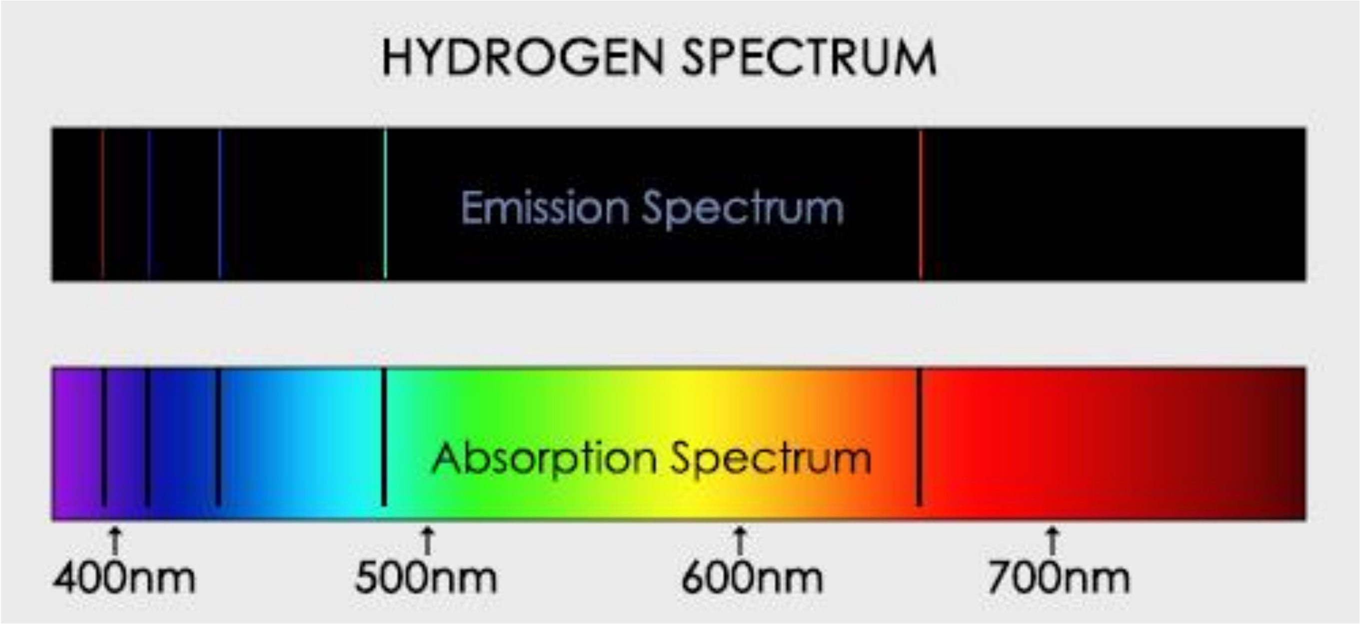


Absorption Spectrum

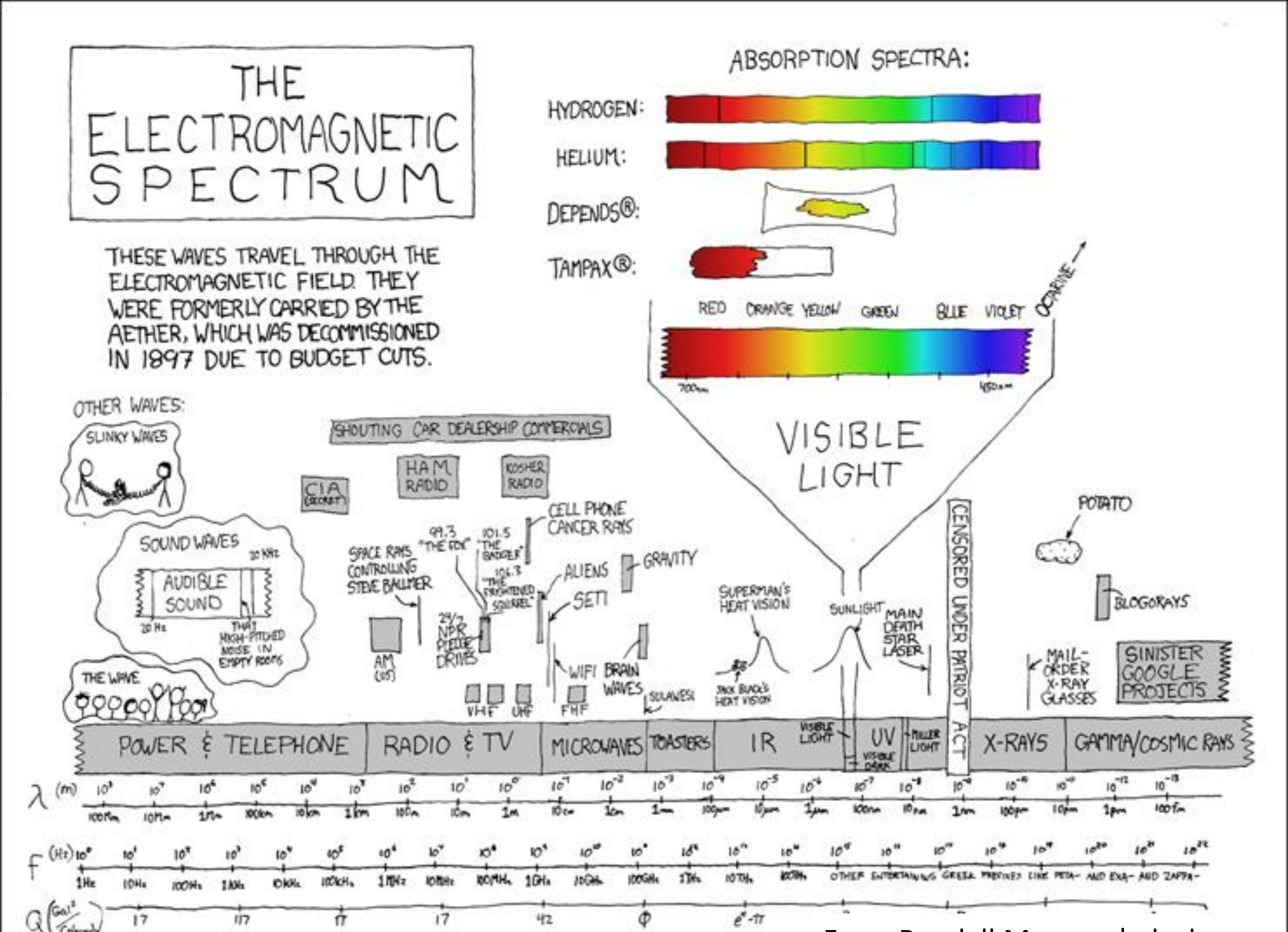
If white light is passed through a sample of gaseous atoms or molecules, it is found that the light of certain wavelengths is missing



Absorption Spectrum

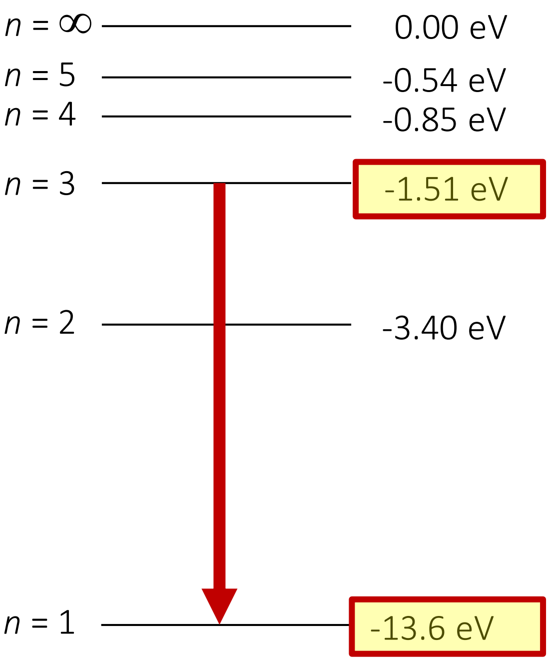


The emission and absorption spectra are negative images of each other



From Randall Monroe | xkcd.com

Calculating Wavelength Emitted



What is the wavelength emitted?

$$E = 13.6 - 1.51 = 12.09 \text{ eV}$$

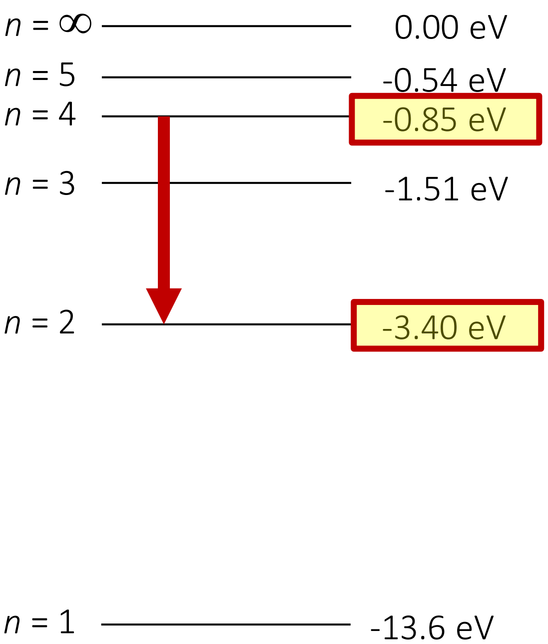
$$\lambda = \frac{1.24 \times 10^{-6} \text{ eV m}}{12.09 \text{ eV}} = 1.03 \times 10^{-7} \text{ m}$$

103 nm

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

hc	1.99×10^{-25} J m	1.24×10^{-6} eV m

Try This...



What is the wavelength emitted?

$$E = 3.40 - 0.85 = 2.55\ \text{eV}$$

$$\lambda = \frac{1.24 \times 10^{-6}\ \text{eV m}}{2.55\ \text{eV}} = 4.86 \times 10^{-7}\ \text{m}$$

486 nm

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

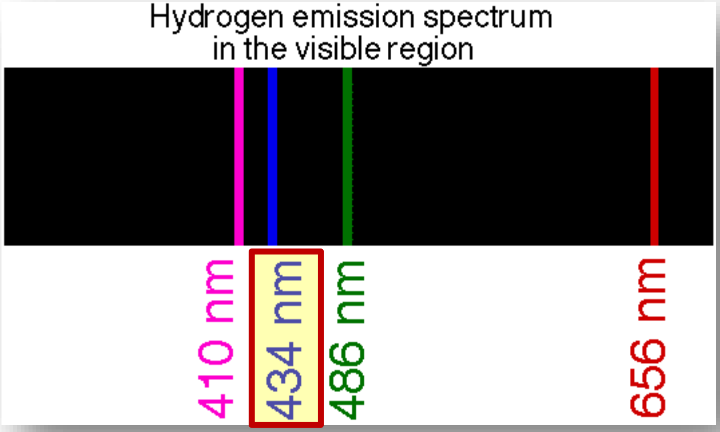
hc	1.99×10^{-25} J m	1.24×10^{-6} eV m

Working Backwards…

What is the energy in eV for a 434 nm blue emission line?

↓

434×10^{-9} m

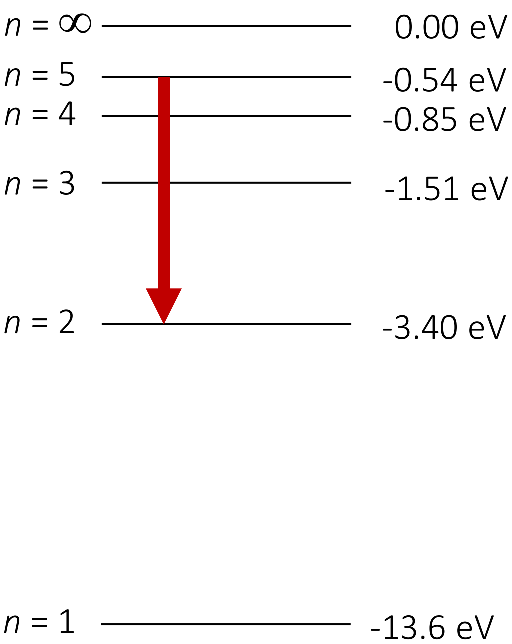


$$E = \frac{hc}{\lambda} = \frac{1.24 \times 10^{-6}\ \text{eV}\ \cancel{\text{m}}}{434 \times 10^{-9}\ \cancel{\text{m}}} = \boxed{2.86\ \text{eV}}$$

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

hc	1.99×10^{-25} J m	1.24×10^{-6} eV m

Working Backwards…



Draw in the Energy Transition for a 434 nm blue emission line?

What transition has an energy difference of 2.86 eV?

$$E = 3.40 - 0.54 = 2.86\text{ eV}$$