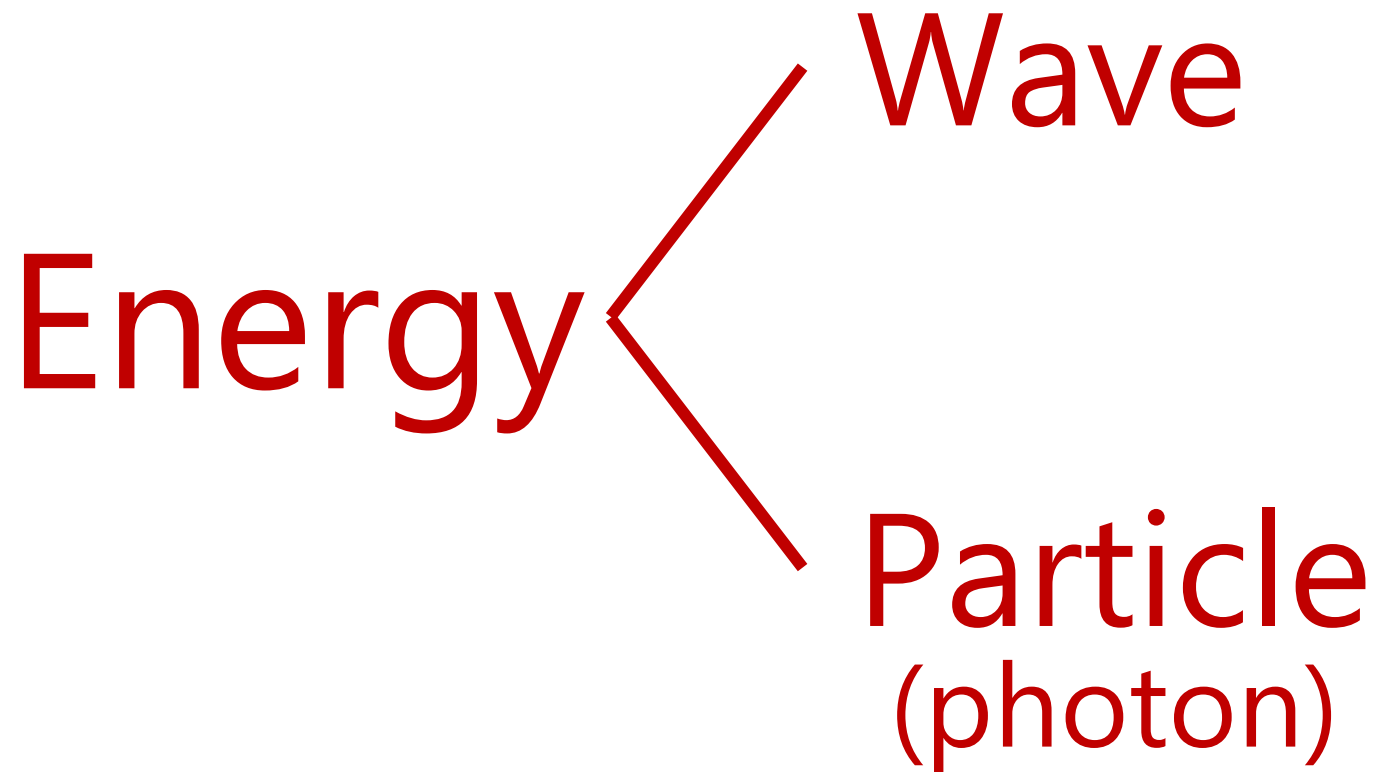


# Atomic Spectra

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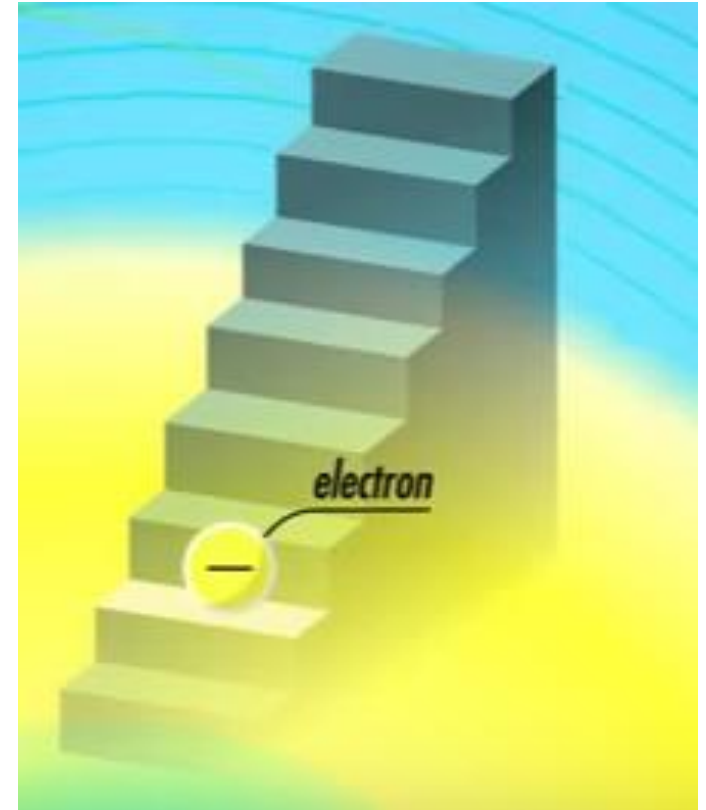
IB PHYSICS | ATOMIC PHYSICS

# What is Light?



# 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

$h$

$6.63 \times 10^{-34} \text{ J s}$

# Energy of a Photon

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

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

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

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

# Quick Recap of eV

$eV \rightarrow$  *electron – volts*

Unit of Energy

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

# 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	$\sigma$	$5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$
Coulomb constant	$k$	$8.99 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$
Permittivity of free space	$\epsilon_0$	$8.85 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$
Permeability of free space	$\mu_0$	$4\pi \times 10^{-7} \text{ T m A}^{-1}$
Speed of light in vacuum	$c$	$3.00 \times 10^8 \text{ m s}^{-1}$
Planck's constant	$h$	$6.63 \times 10^{-34} \text{ J s}$
Elementary charge	$e$	$1.60 \times 10^{-19} \text{ C}$

# 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

$$1 \text{ radian (rad)} \equiv \frac{180^\circ}{\pi}$$

$$\text{Temperature (K)} = \text{temperature (}^\circ\text{C)} + 273$$

$$1 \text{ light year (ly)} = 9.46 \times 10^{15} \text{ m}$$

$$1 \text{ parsec (pc)} = 3.26 \text{ ly}$$

$$1 \text{ astronomical unit (AU)} = 1.50 \times 10^{11} \text{ m}$$

$$1 \text{ kilowatt-hour (kWh)} = 3.60 \times 10^6 \text{ J}$$

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

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

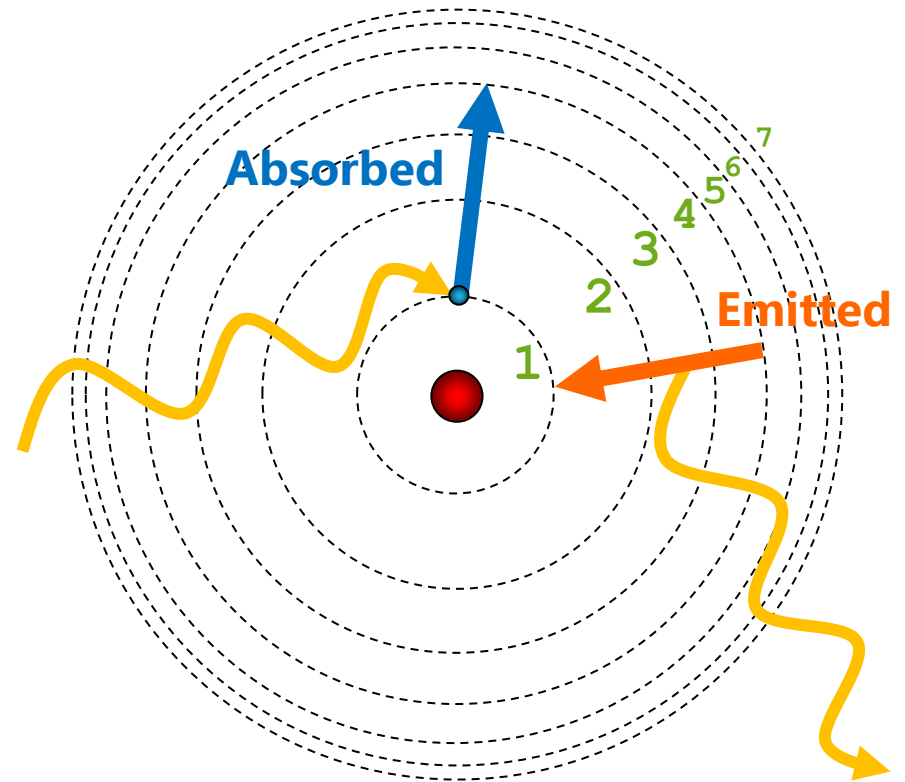
$$E = \frac{hc}{\lambda}$$

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

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

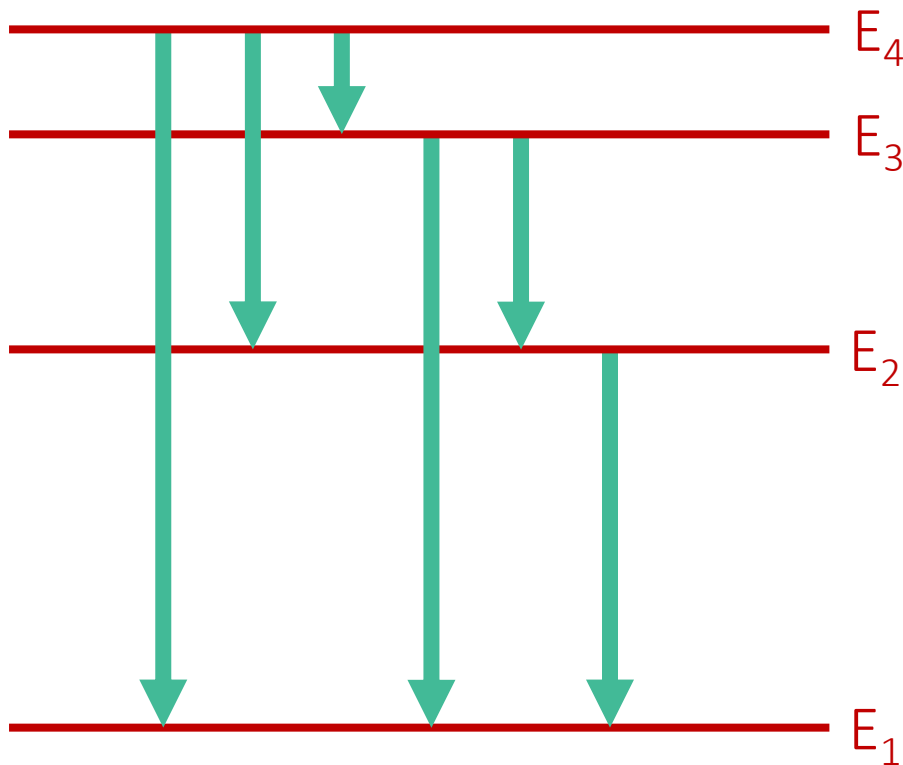
# Energy Levels

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



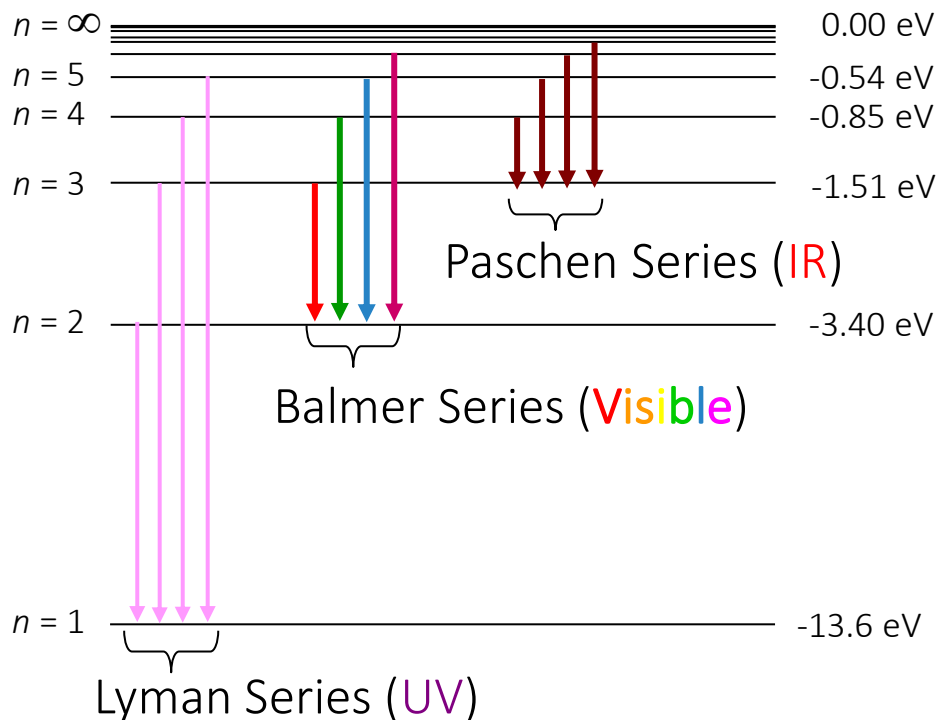
Excited States



Ground State

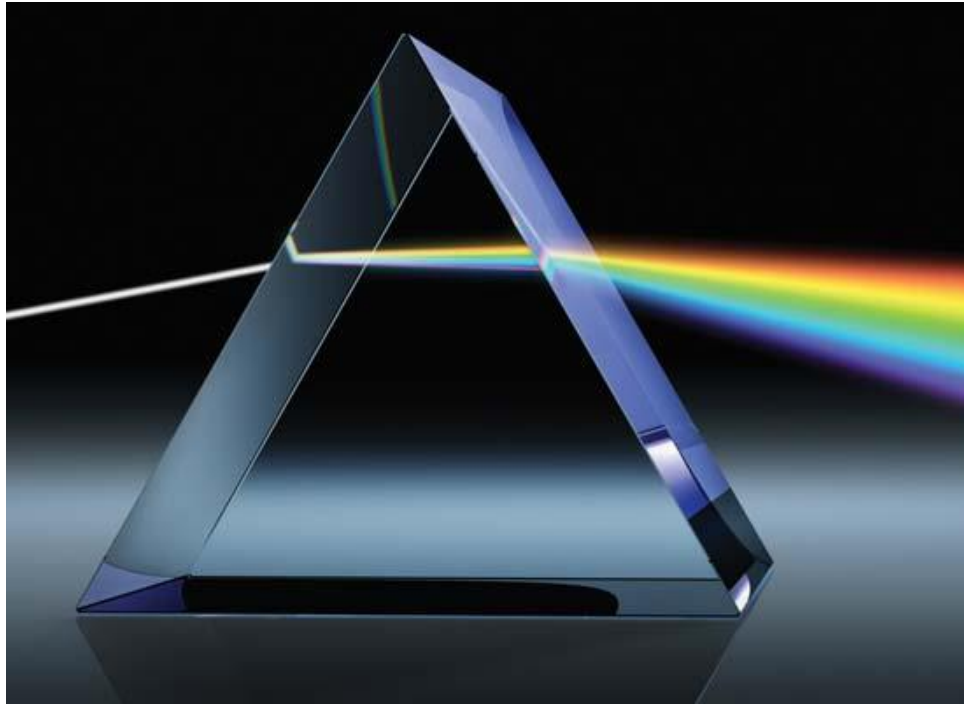
# Energy Transitions

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



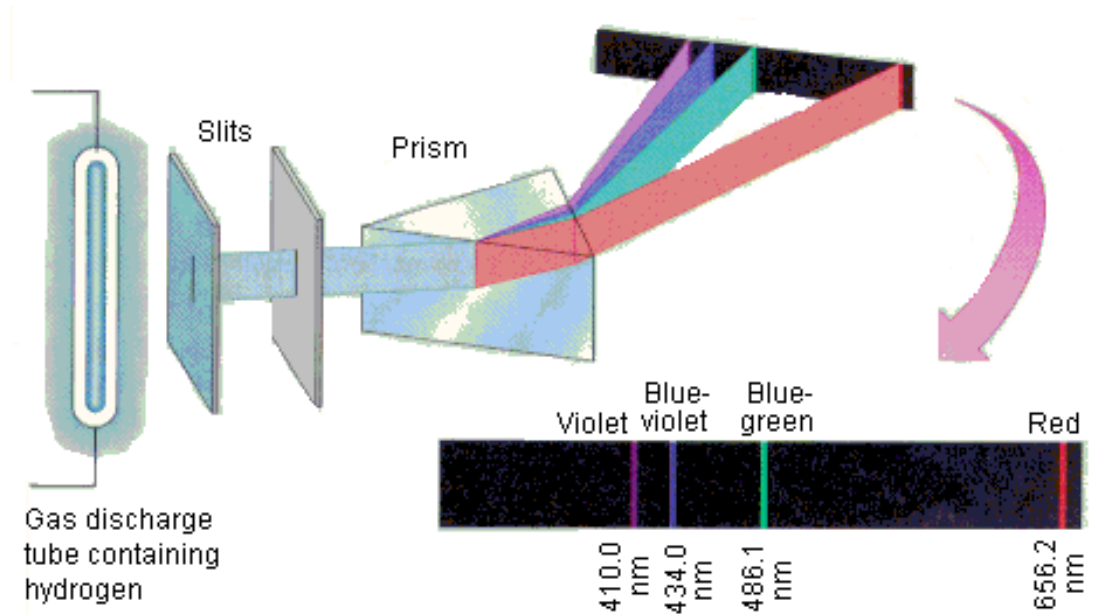
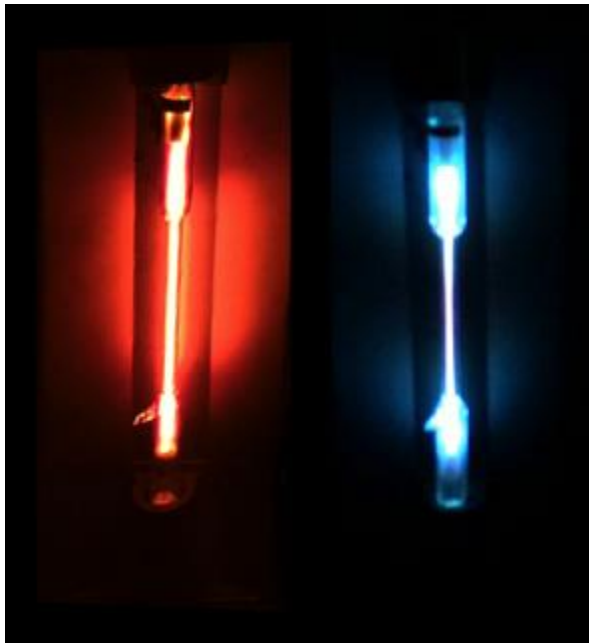
# Continuous Spectrum

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



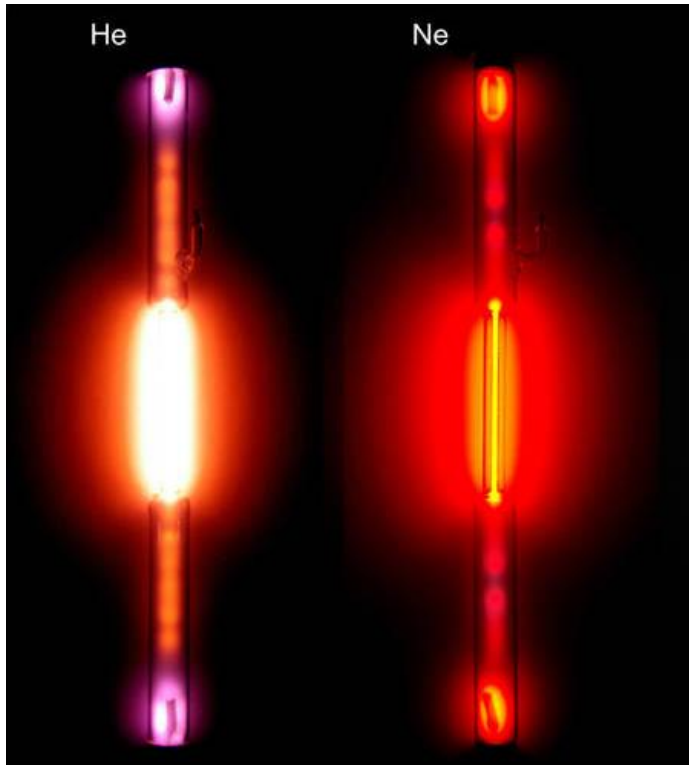
# Emission Spectrum

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

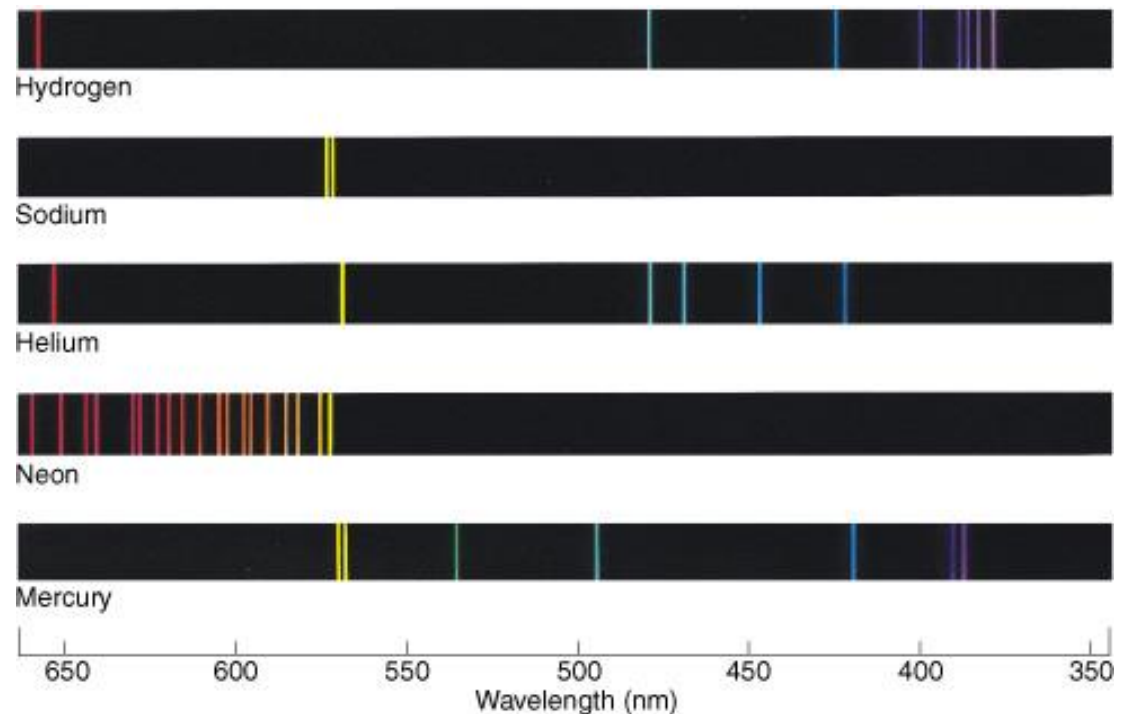


# Emission Spectrum

These spectra can be used to identify elements like a fingerprint



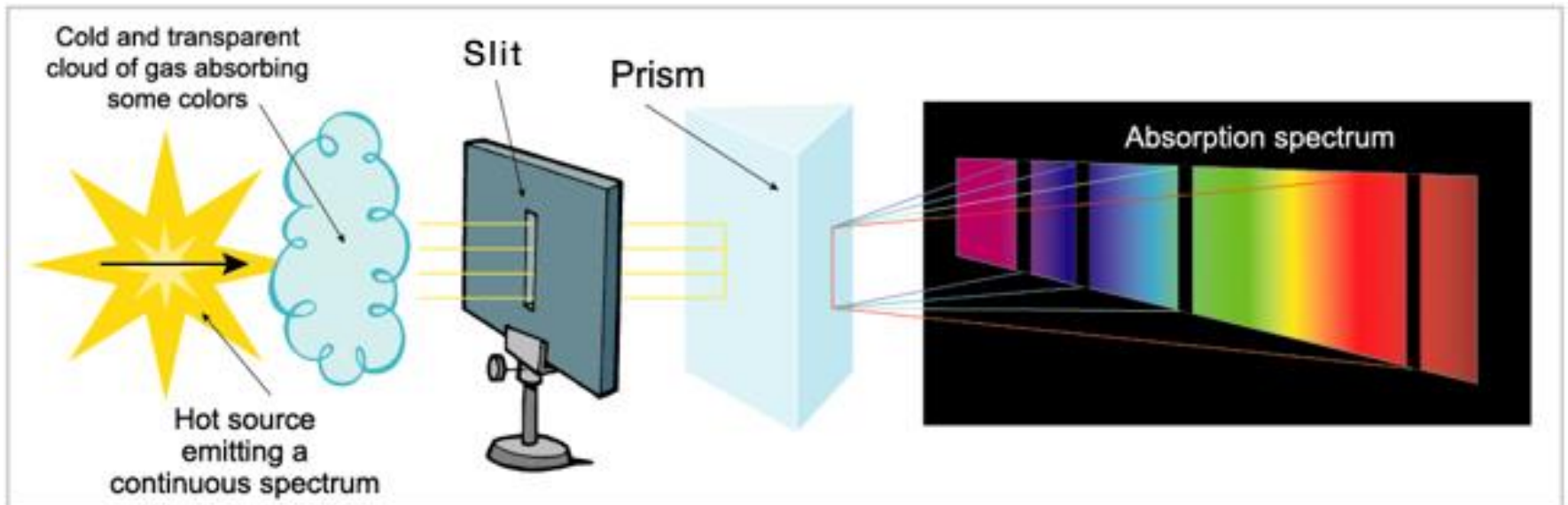
These are known as Line Spectra



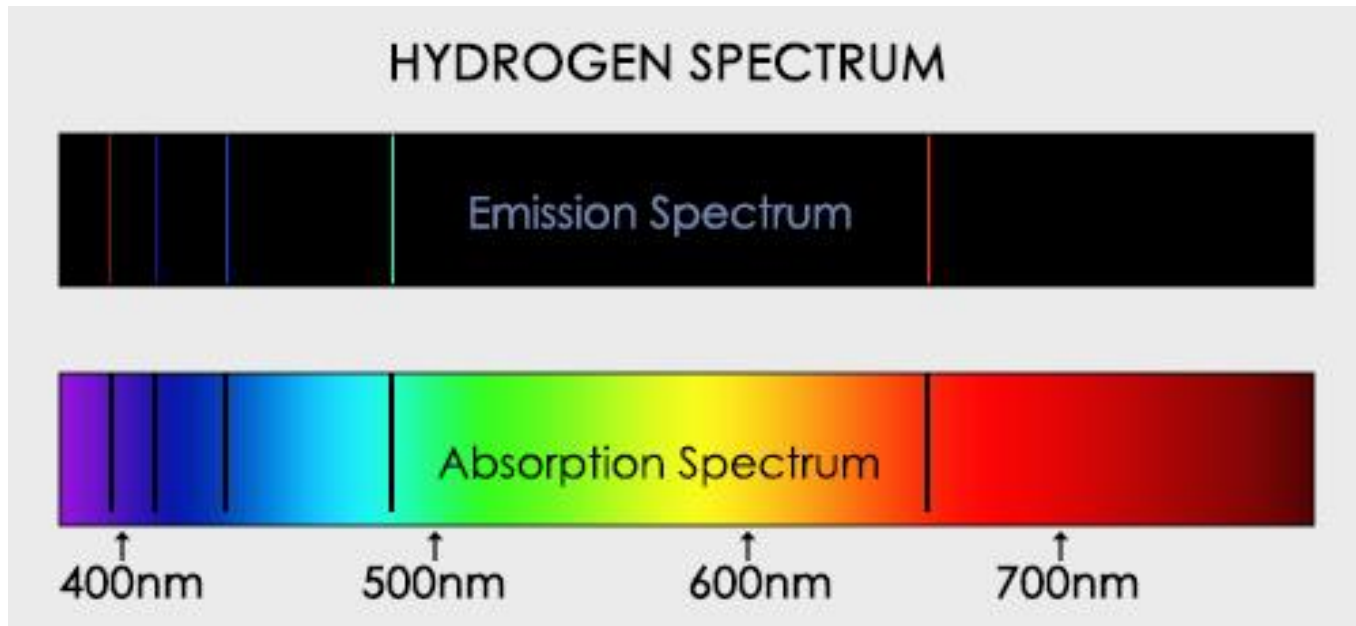


# Absorption Spectrum

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

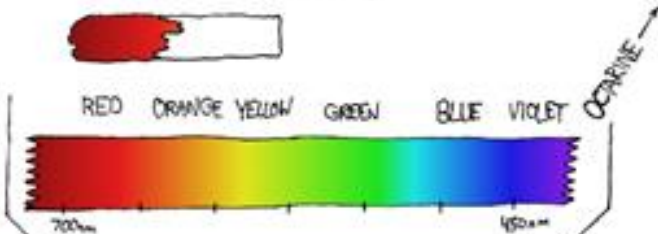
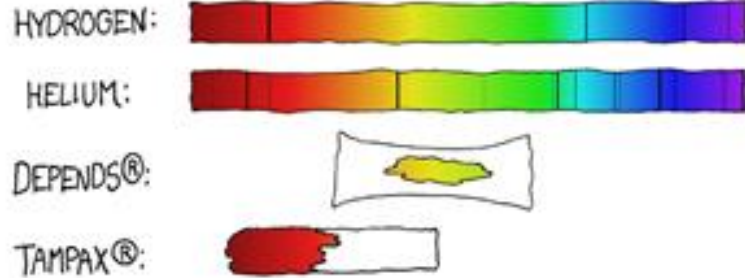


The emission and absorption spectra are negative images of each other

# THE ELECTROMAGNETIC SPECTRUM

THESE WAVES TRAVEL THROUGH THE ELECTROMAGNETIC FIELD. THEY WERE FORMERLY CARRIED BY THE AETHER, WHICH WAS DECOMMISSIONED IN 1897 DUE TO BUDGET CUTS.

## ABSORPTION SPECTRA:



## VISIBLE LIGHT

### OTHER WAVES:

**Slinky Waves**  
[Illustration of two people on a slinky]

**SOUND WAVES**  
30 kHz  
AUDIBLE SOUND  
30 Hz  
THAT HIGH-PITCHED NOISE IN EMPTY ROOMS

**THE WAVE**  
[Illustration of a wave]

SHOUTING CAR DEALERSHIP COMMERCIALS

CIA (SECRET)

HAM RADIO

KOSHER RADIO

CELL PHONE CANCER RAYS

99.3 "THE FOX"

101.5 "THE BADGER"

104.3 "THE FRIGHTENED SQUIREL"

24/7 NPR PLEDGE DRIVES

AM (US)

VHF UHF

FHF

ALIENS SETI

BRAIN WAVES

WIFI

GRAVITY

SUNSHINE

SUPERMAN'S HEAT VISION

JACK BLACK'S HEAT VISION

SUNLIGHT

MAIN DEATH STAR LASER

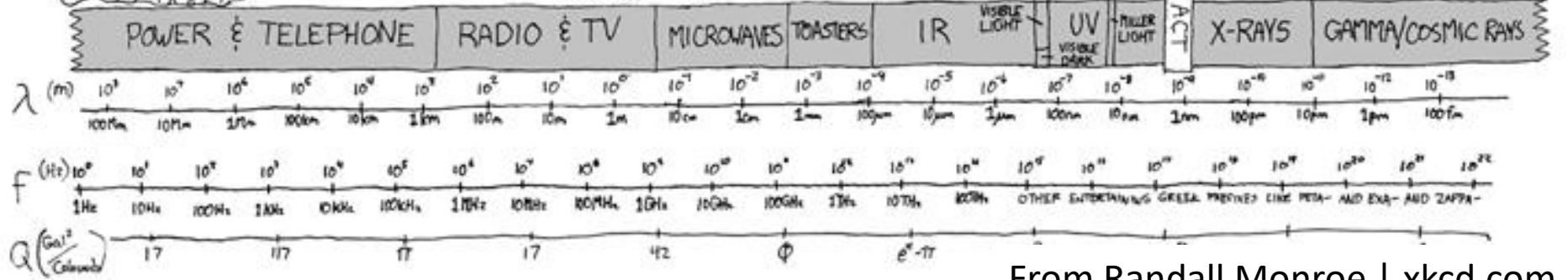
POTATO

BLOGORAYS

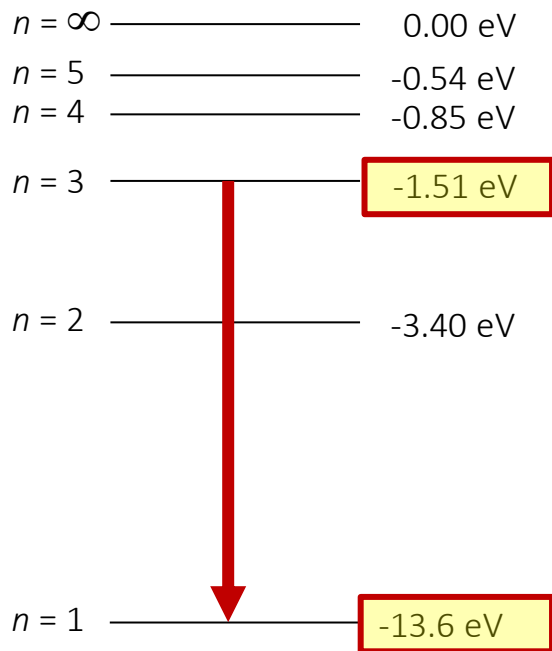
MAIL-ORDER X-RAY GLASSES

SINISTER GOOGLE PROJECTS

CENSORED UNDER PATRIOT ACT



# Calculating Wavelength Emitted



What is the wavelength emitted?

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

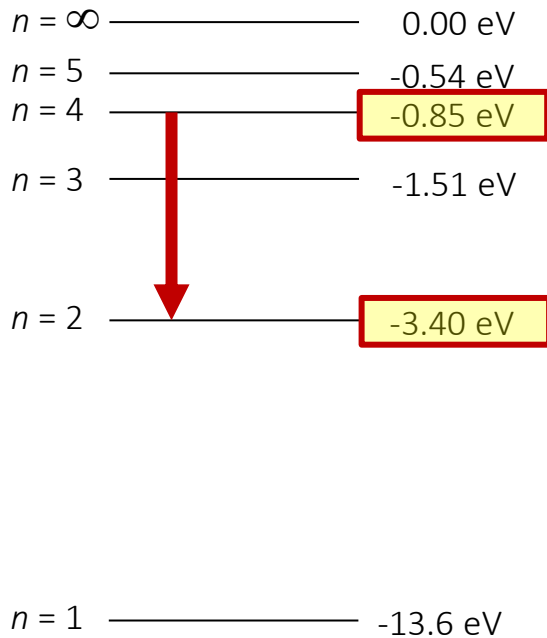
$$\lambda = \frac{1.24 \times 10^{-6} \text{ eV m}}{12.09 \text{ eV}} = 1.03 \times 10^{-7} \text{ m}$$

103 nm

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

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

# 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

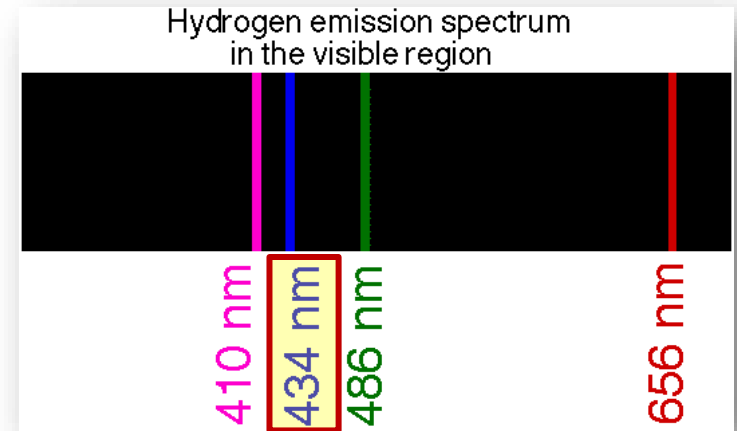
$$\lambda = \frac{hc}{E}$$

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

# Working Backwards...

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

↓  
 $434 \times 10^{-9} \text{ m}$

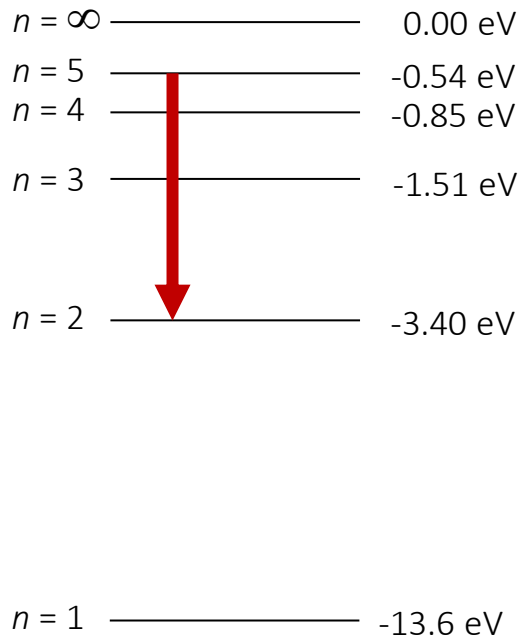


$$E = \frac{hc}{\lambda} = \frac{1.24 \times 10^{-6} \text{ eV m}}{434 \times 10^{-9} \text{ m}} = 2.86 \text{ eV}$$

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

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

# Working Backwards...



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

*What transition has an energy difference of 2.86 eV?*

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

