



Chapter 7: Atoms & Spectra

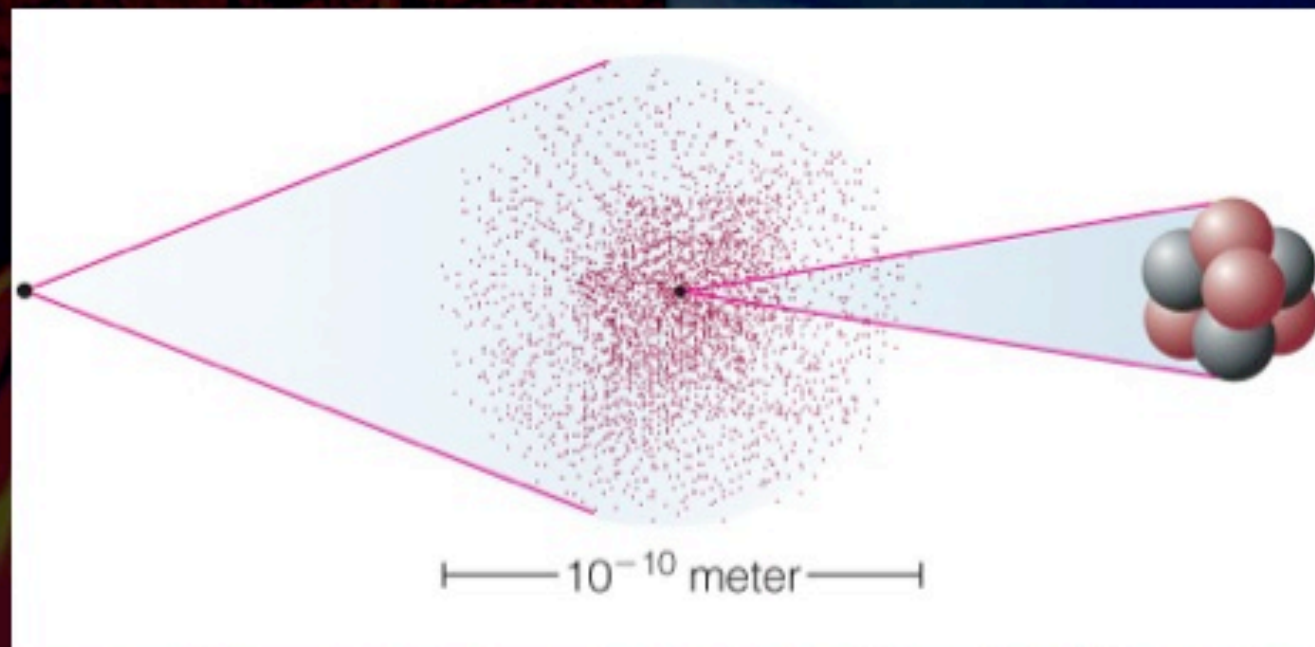
Prof. Evan Scannapieco

7.1 Atoms

Electron
Cloud

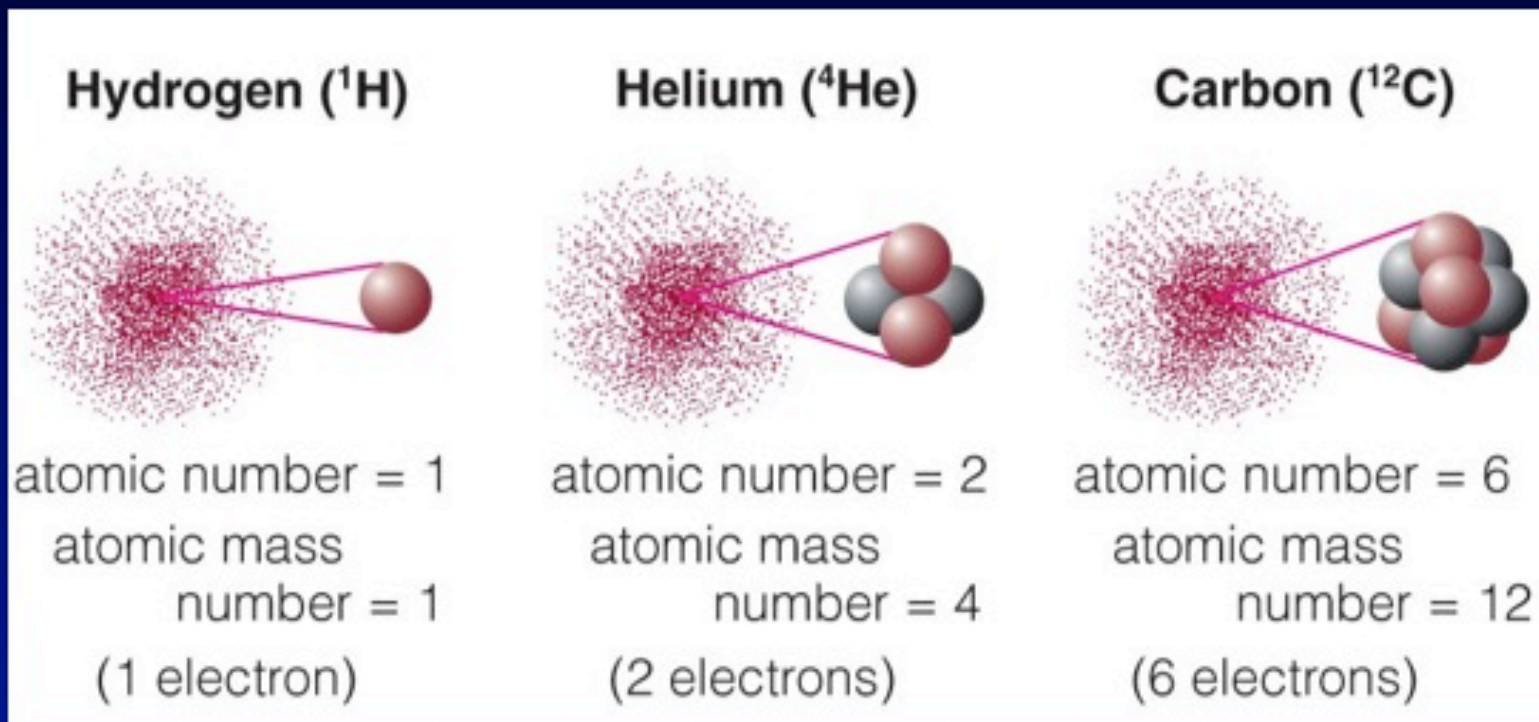
Nucleus

Atom



Atomic Terminology

- Atomic Number = # of protons in nucleus
- Atomic Mass Number = # of protons + neutrons



hydrogen 1 H 1.0079																		helium 2 He 4.0026					
lithium 3 Li 6.941	beryllium 4 Be 9.0122																	boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305																	aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078	scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80						
rubidium 37 Rb 85.468	strontium 38 Sr 87.62	yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29						
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]					
francium 87 Fr [223]	radium 88 Ra [226]	89-102 * *	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnium 110 Uun [271]	ununium 111 Uuu [272]	unubium 112 Uub [277]	ununquadium 114 Uuq [289]										

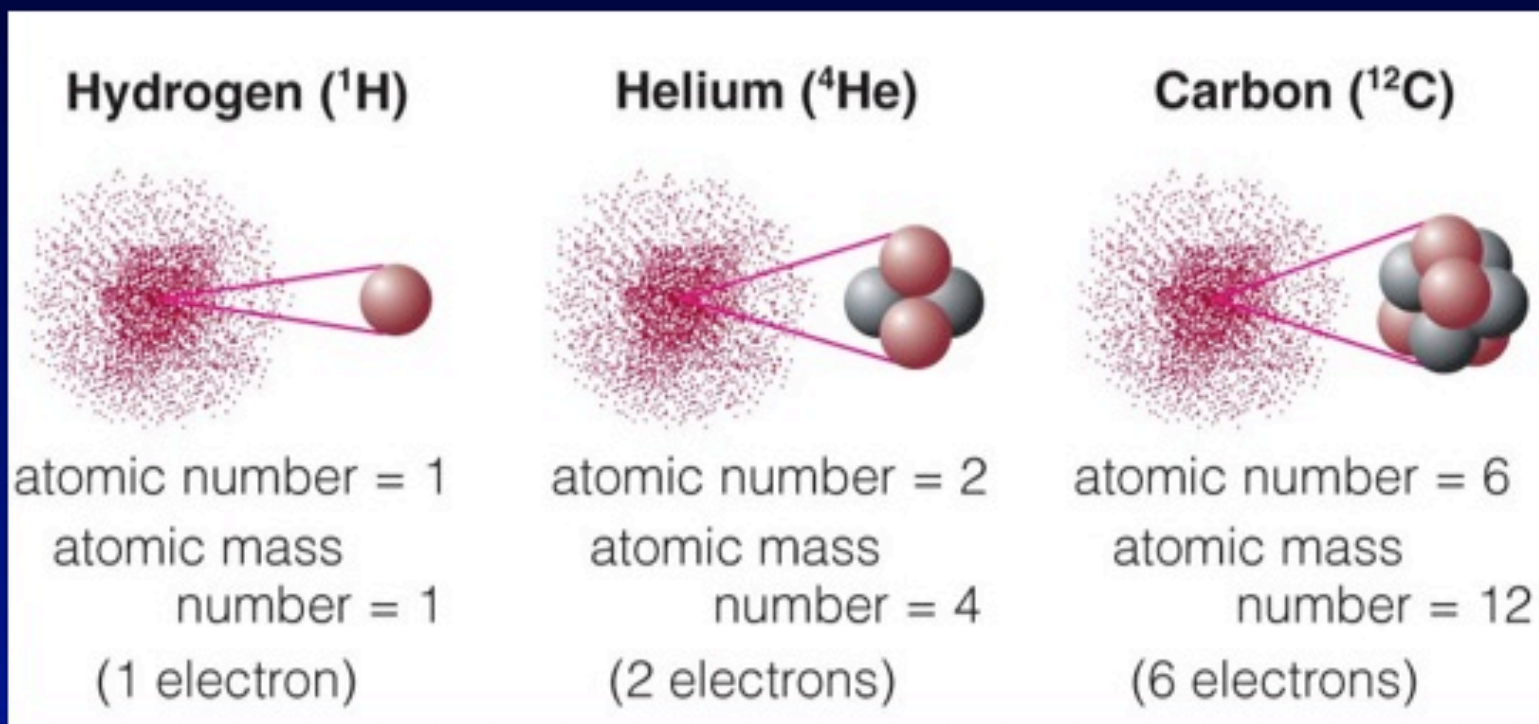
* Lanthanide series

* * Actinide series

lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

Atomic Terminology

- Atomic Number = # of protons in nucleus
- Atomic Mass Number = # of protons + neutrons



- Molecules: consist of two or more atoms (H_2O , CO_2)

Atomic Terminology

- **Isotope:** same # of protons but different # of neutrons. (^4He , ^3He)

Isotopes of Carbon

carbon-12



^{12}C

(6 protons
+ 6 neutrons)

carbon-13



^{13}C

(6 protons
+ 7 neutrons)

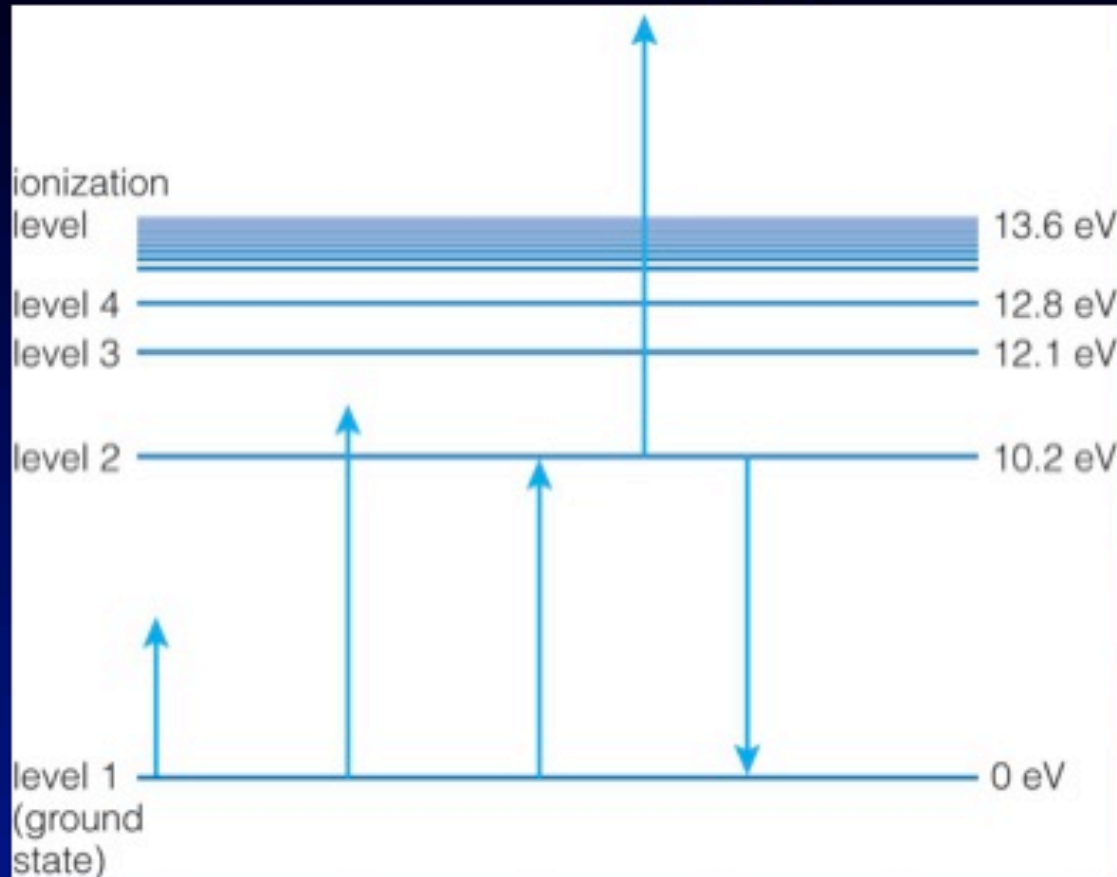
carbon-14



^{14}C

(6 protons
+ 8 neutrons)

How is energy stored in atoms?

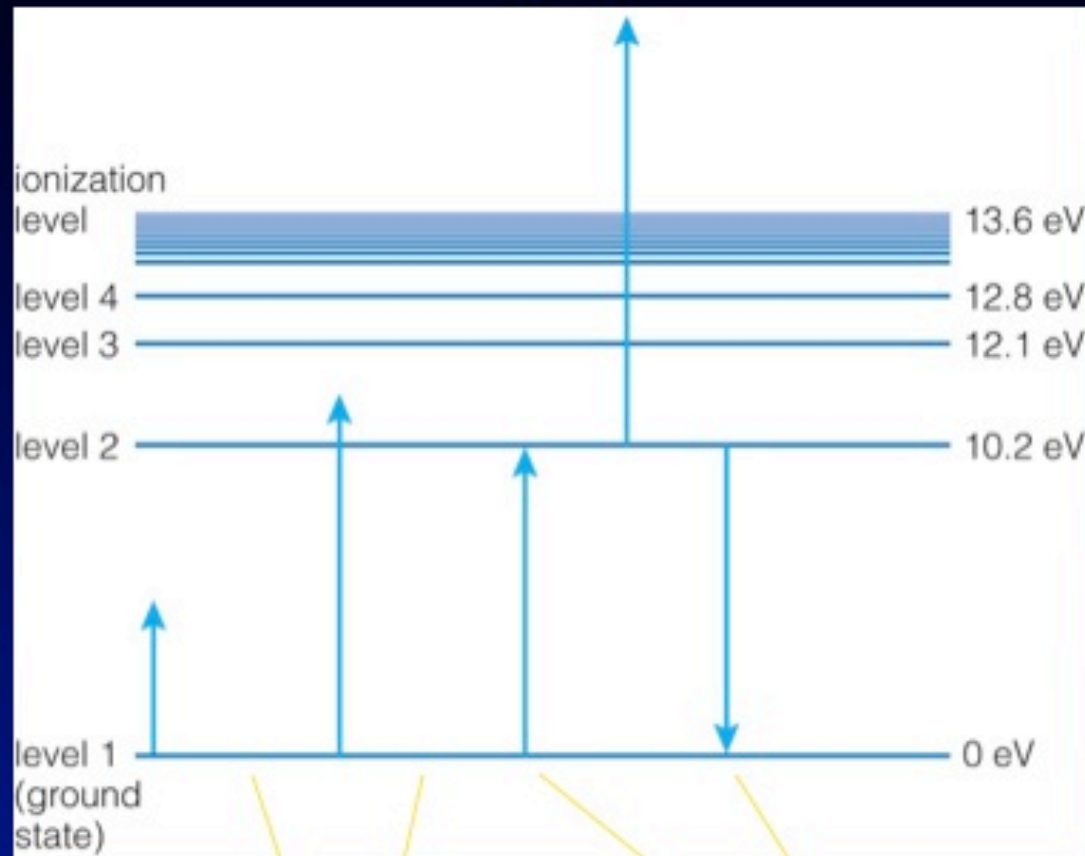


Excited States

Ground State

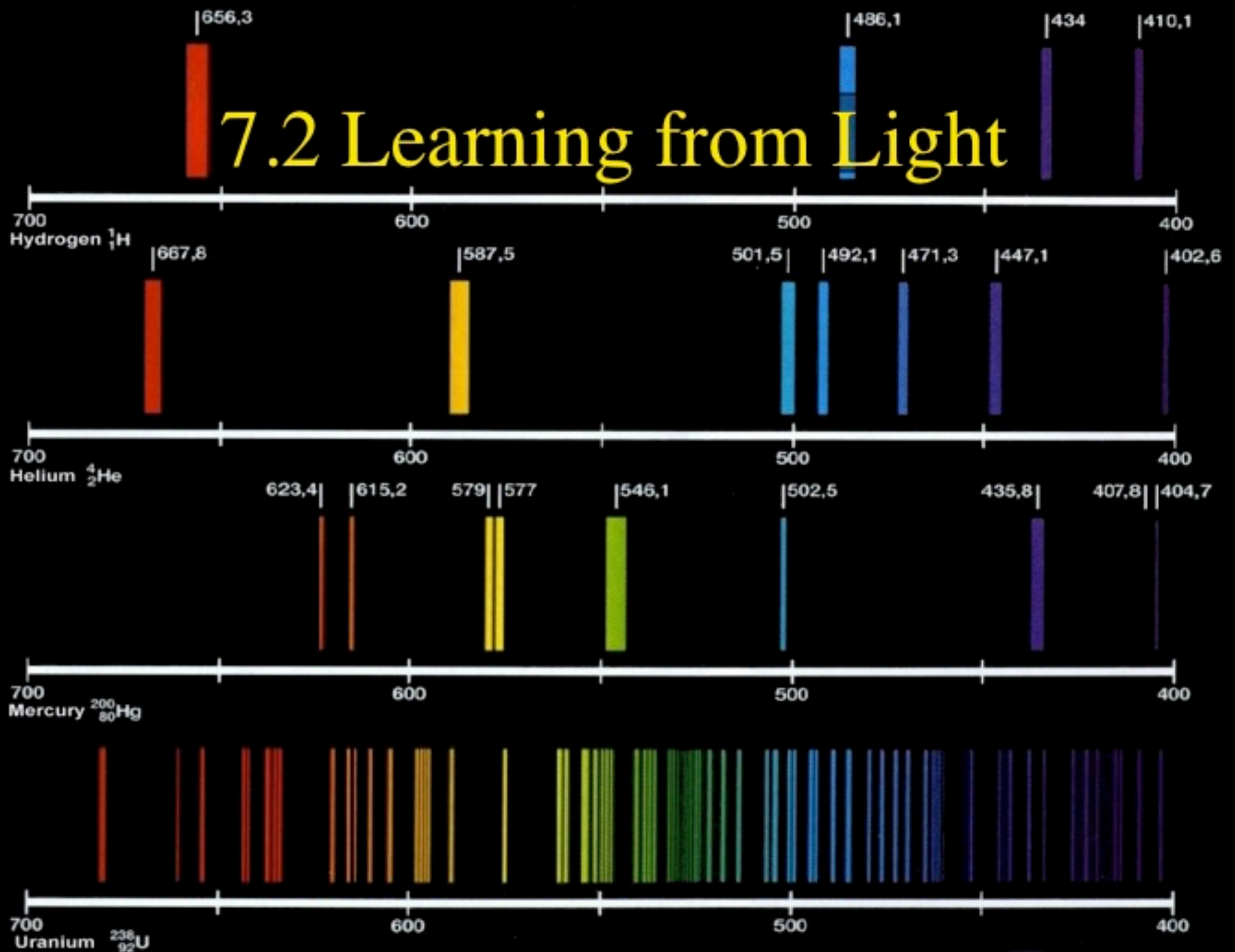
- Electrons in atoms are restricted to particular energy levels

Energy Level Transitions



- The only allowed changes in energy are those corresponding to a transition between energy levels

7.2 Learning from Light



Three Types of Spectra

Show

Continuous Spectrum



The light bulb produces light with a continuous spectrum

The spectrum shows a smooth, continuous rainbow of light.

A graph of the spectrum is also continuous, notice that intensity varies slightly at different wavelengths.

Show

Emission Line Spectrum



The cloud also emits its own light, but only at specific wavelengths determined by its composition

We see bright emission lines at specific wavelengths (color), but no other light.

The graph shows an upward spike at the wavelength of each emission line.

Show

Absorption Line Spectrum

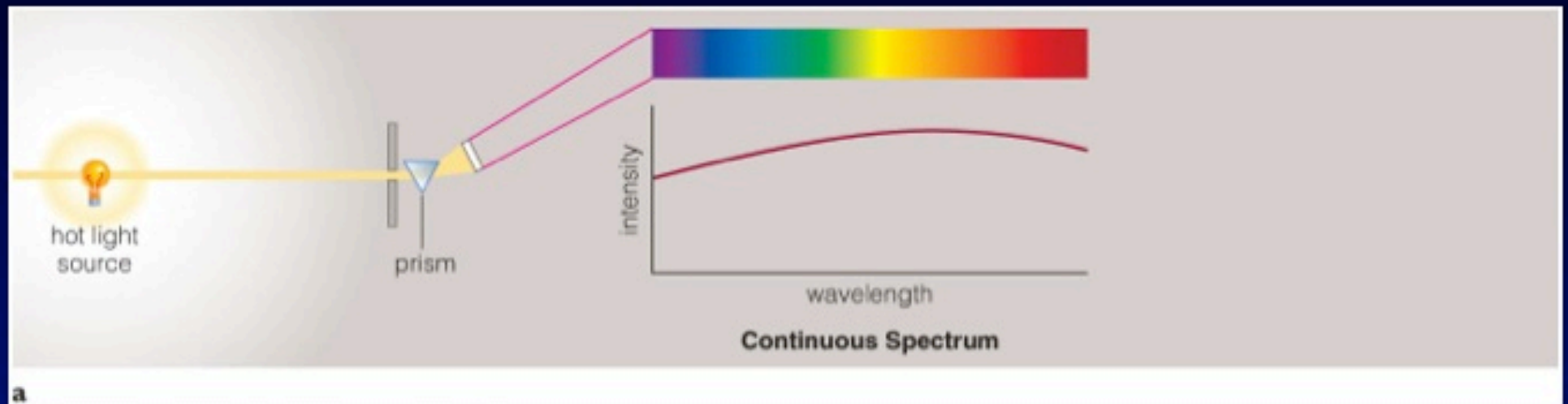


The cloud absorbs light at specific wavelengths determined by its composition

We see dark absorption lines where the cloud has absorbed lights of specific wavelengths (colors).

The graph shows a dip in intensity at the wavelength of each absorption line.

Continuous Spectrum



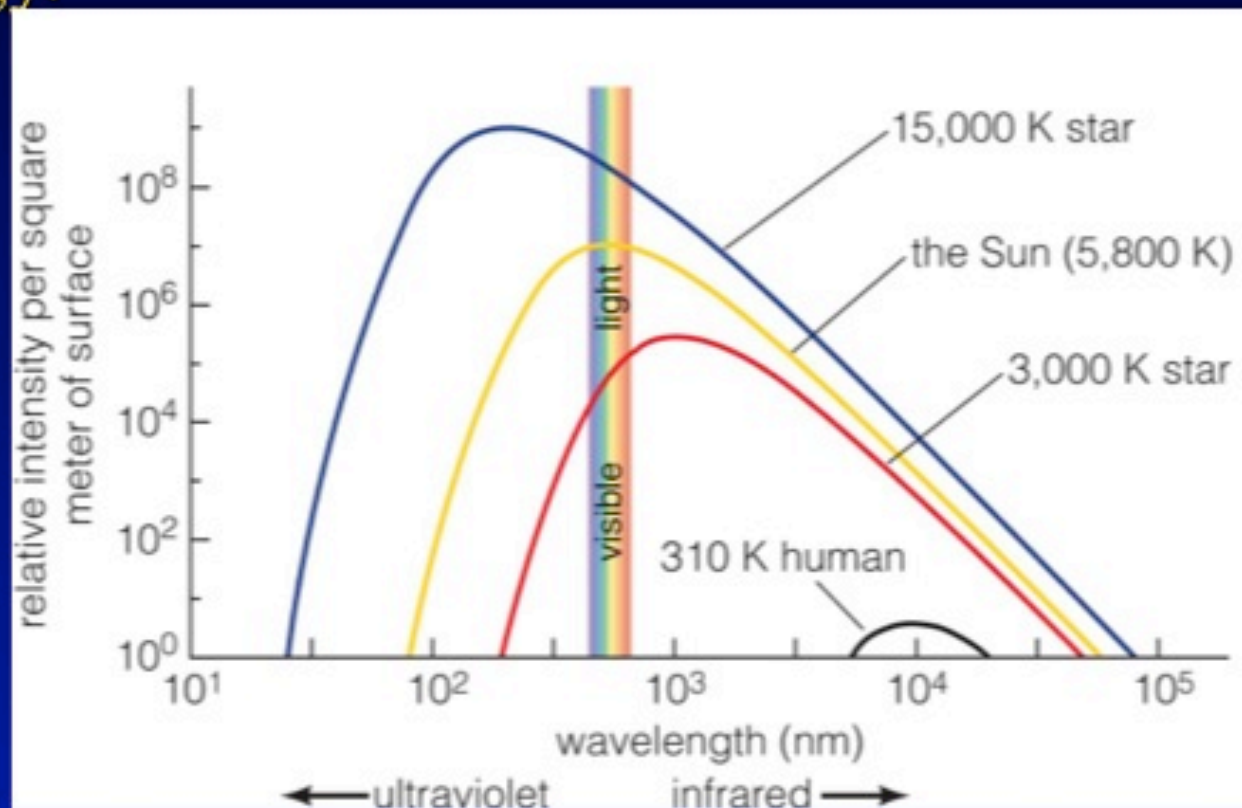
- The spectrum of a common (incandescent) light bulb spans all visible wavelengths, without interruption

Thermal Radiation

- Nearly all large or dense objects emit thermal radiation, including stars, planets, you...
- An object's thermal radiation spectrum depends on only one property: its **temperature**

Properties of Thermal Radiation

1. Hotter objects emit more light at all frequencies per unit area.
2. Hotter objects emit photons with a higher average energy.



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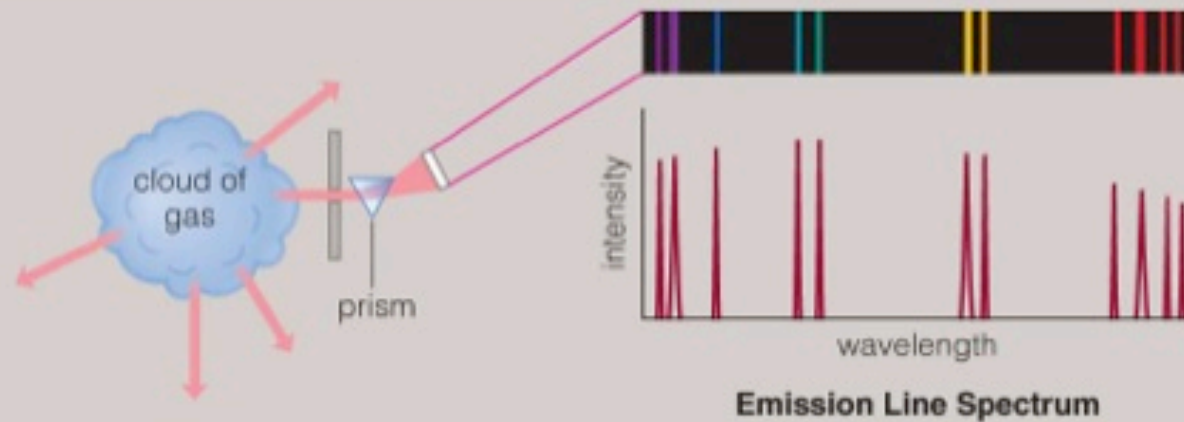
The graph shows a dip in intensity at the wavelength of each absorption line.

Thought Question

Which is hotter?

- a) A blue star.
- b) A red star.
- c) A planet that emits only infrared light.

Emission Line Spectrum



b

- A thin or low-density cloud of gas emits light only at specific wavelengths that depend on its composition and temperature, producing a spectrum with bright emission lines

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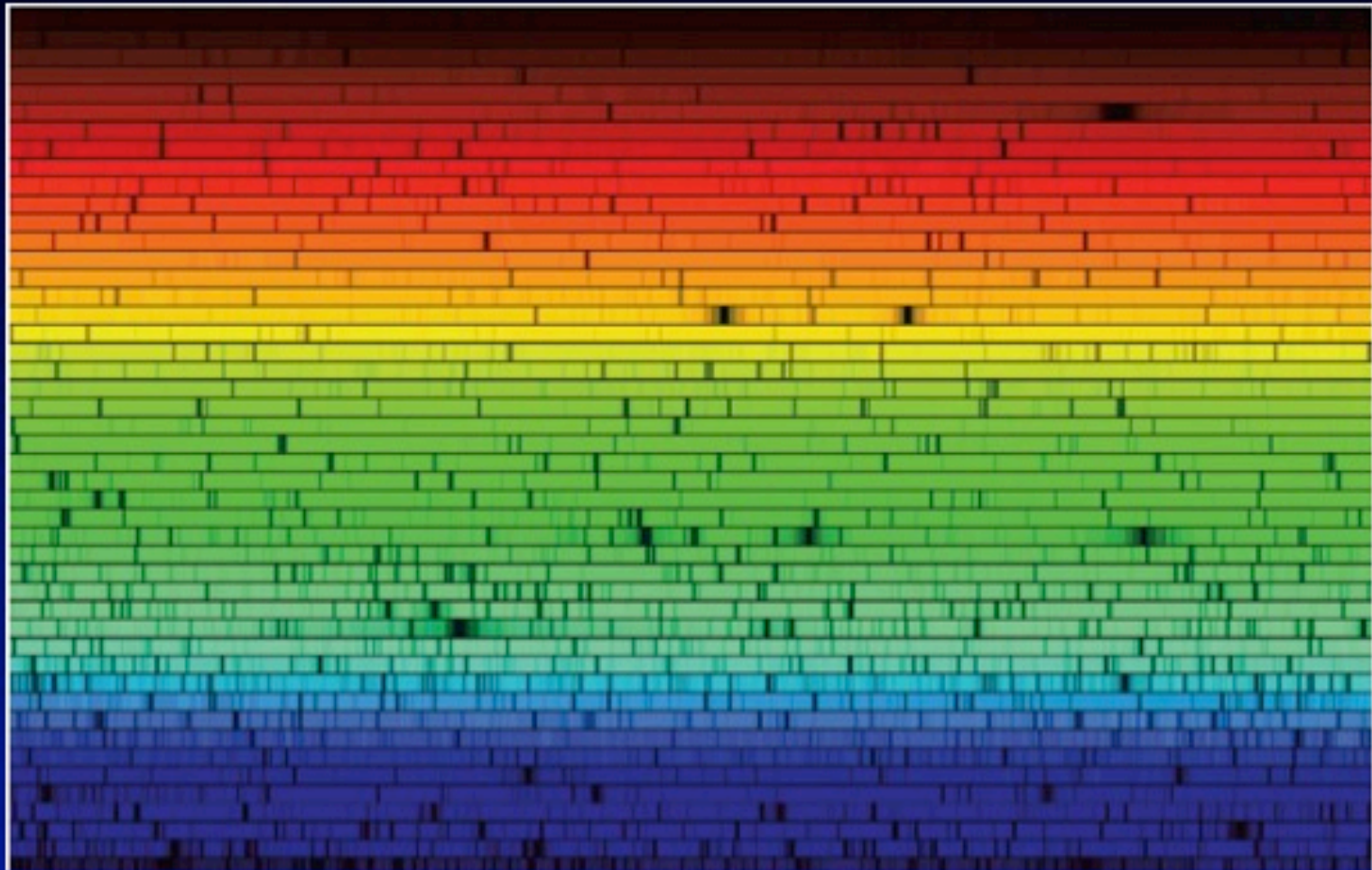


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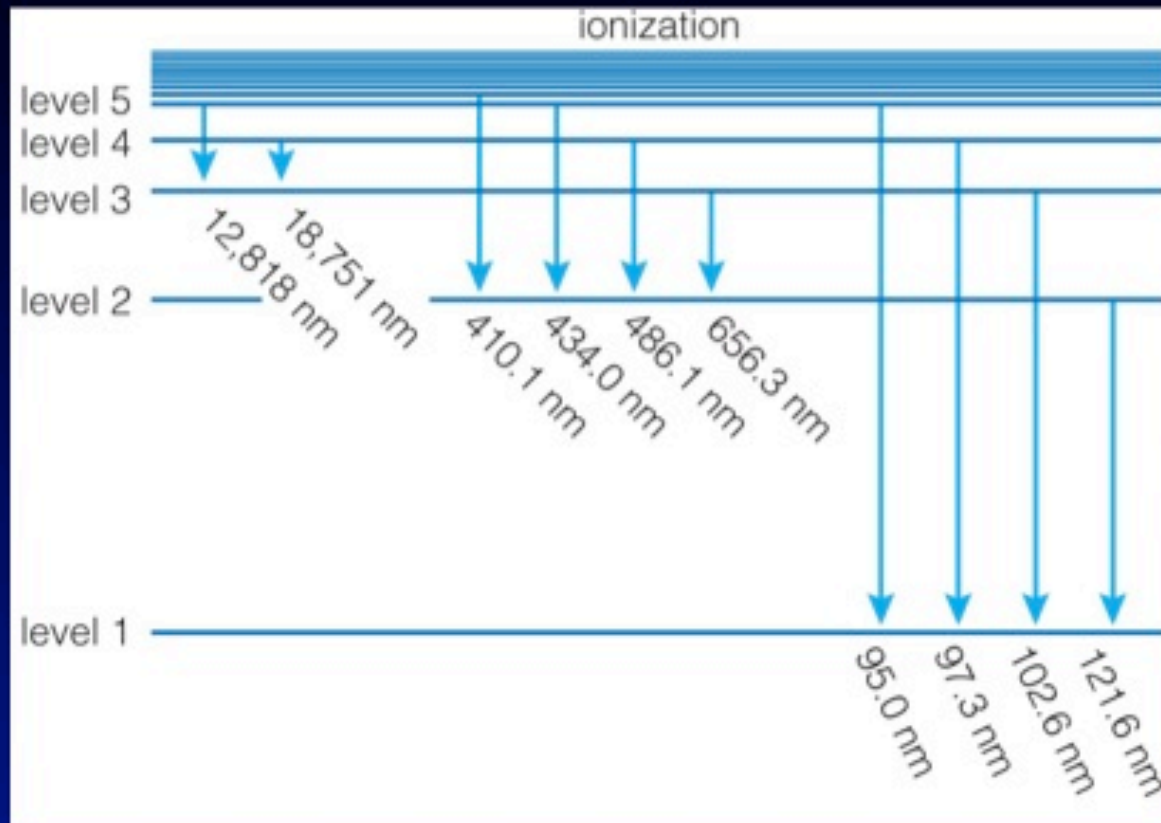
The graph shows a dip in intensity at the wavelength of each absorption line.

How does light tell us what things are made of?



Spectrum of the Sun

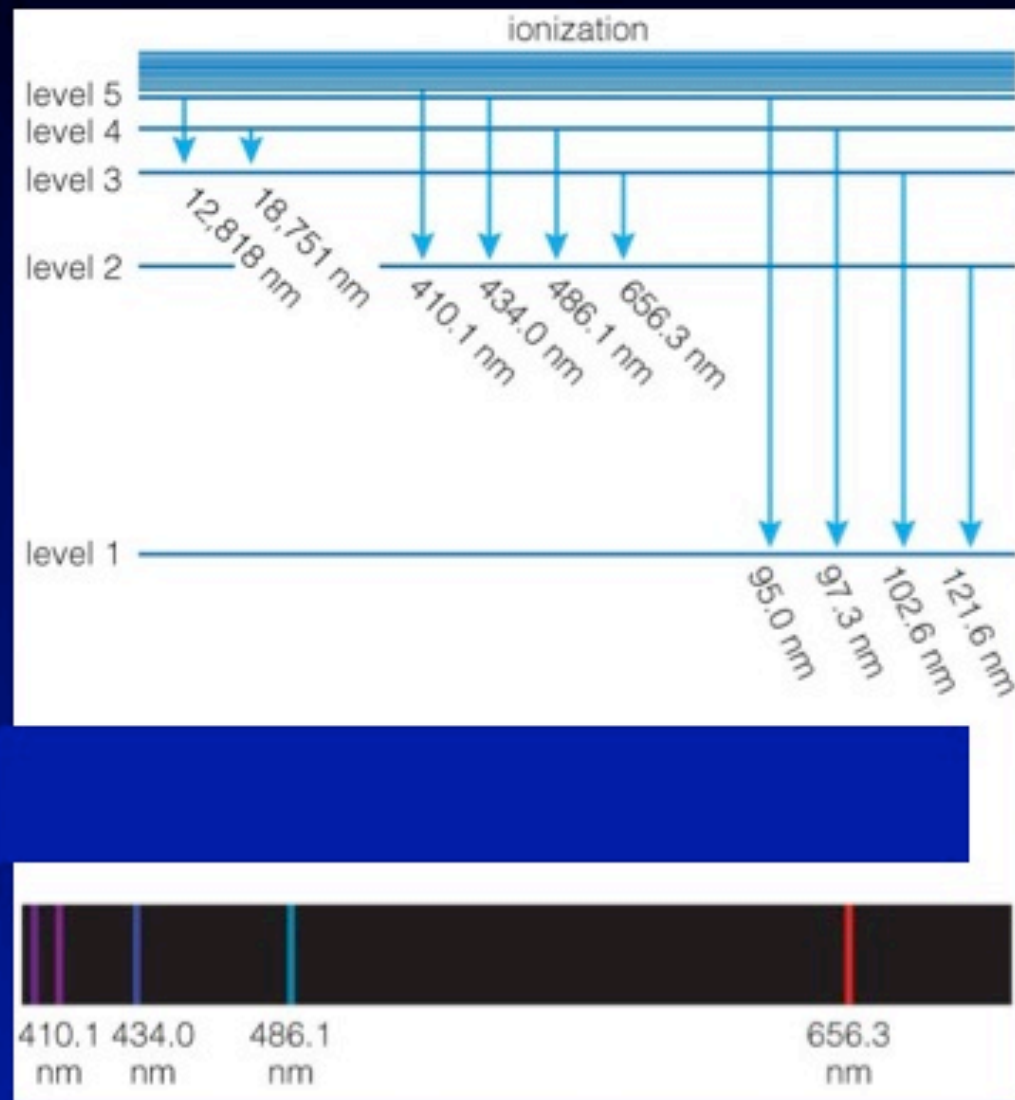
Chemical Fingerprints



Energy levels of Hydrogen

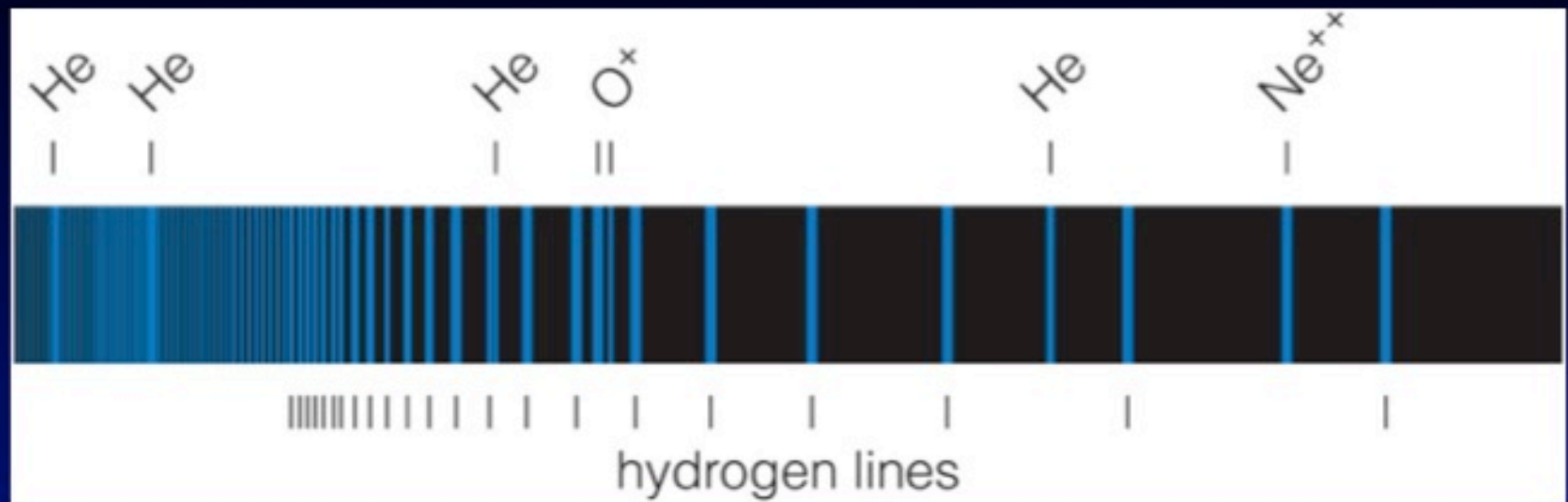
- Each type of atom has a unique set of energy levels
- Each transition corresponds to a unique photon energy, frequency, and wavelength

Chemical Fingerprints



- Downward transitions produce a unique pattern of emission lines

Chemical Fingerprints



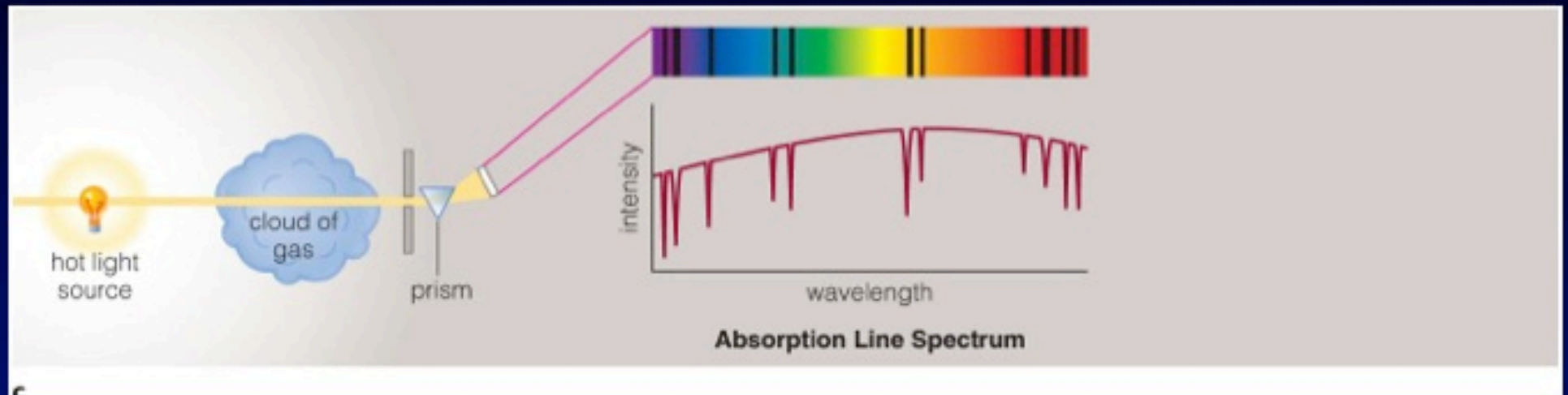
- Observing the fingerprints in a spectrum tells us which kinds of atoms are present

Chemical Fingerprints



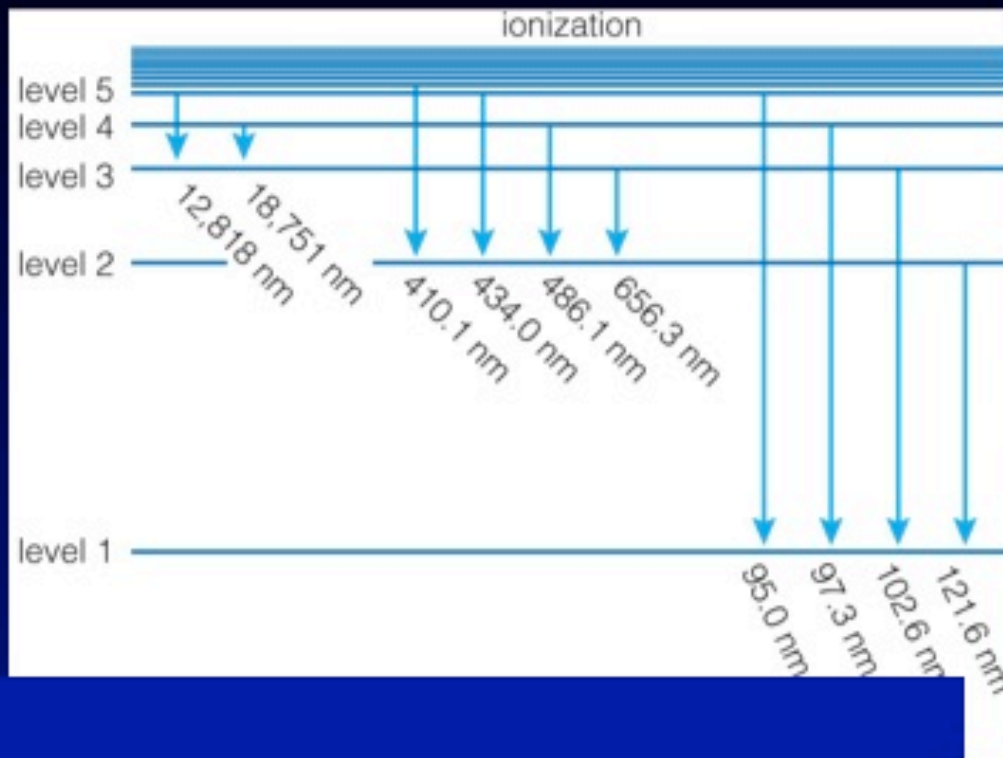
- Each type of atom has a unique spectral fingerprint

Absorption Line Spectrum



- A cloud of gas between us and a light bulb can absorb light of specific wavelengths, leaving dark absorption lines in the spectrum

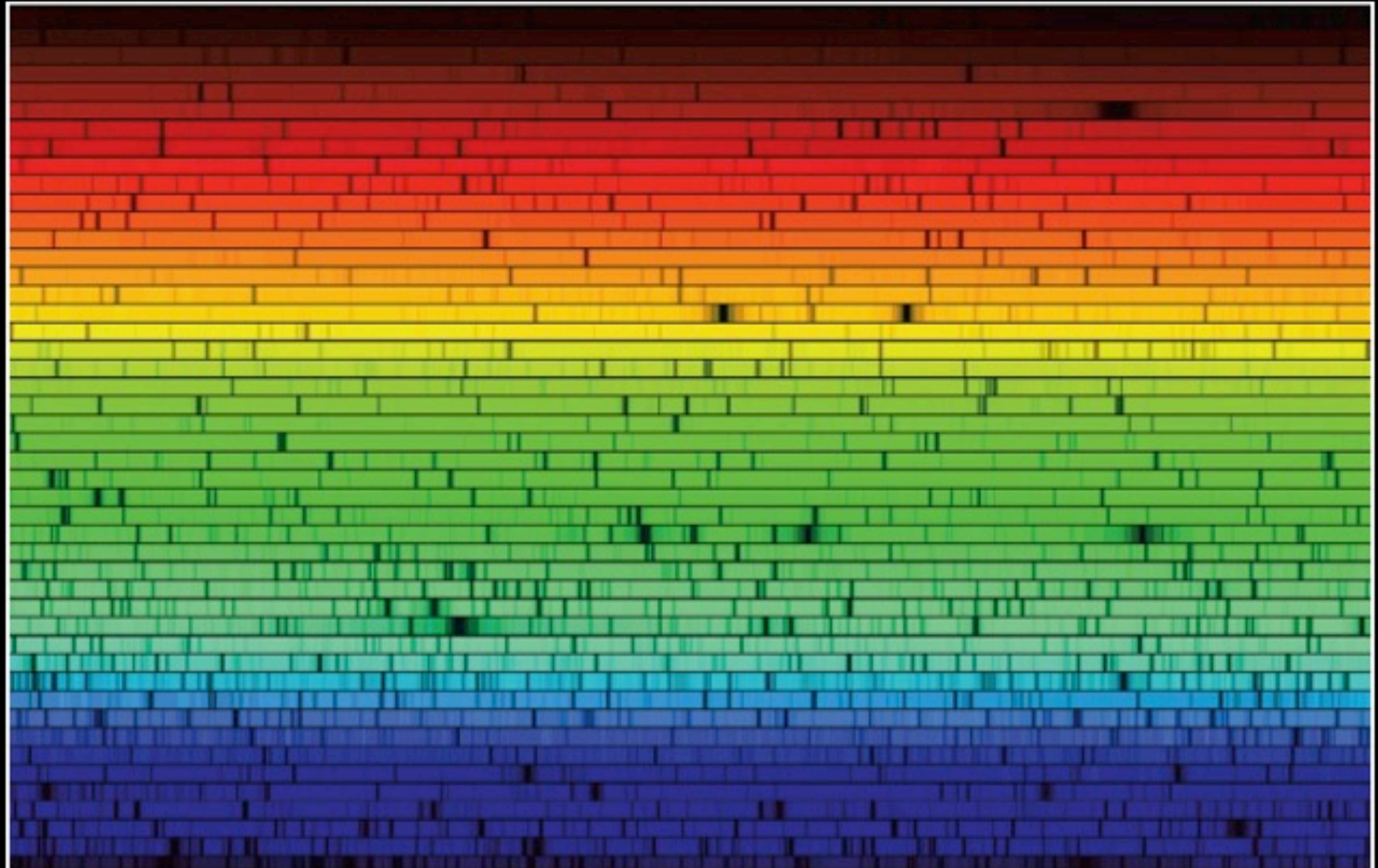
Chemical Fingerprints



- Because those atoms can absorb photons with those same energies, upward transitions produce a pattern of absorption lines at the same wavelengths

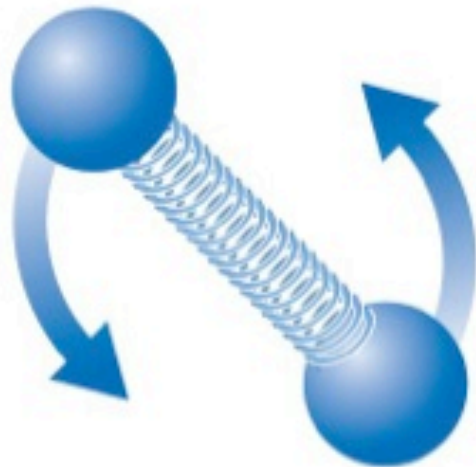


Example: Solar Spectrum

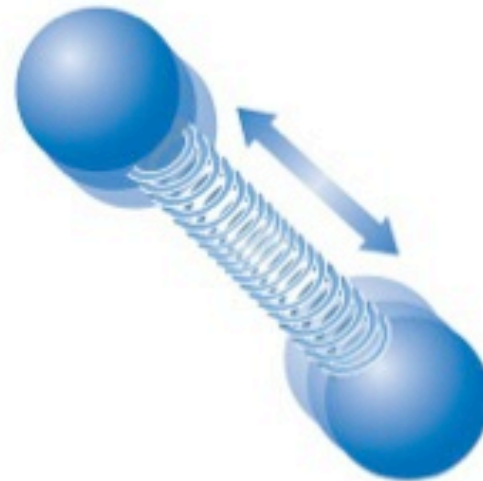


Energy Levels of Molecules

rotation

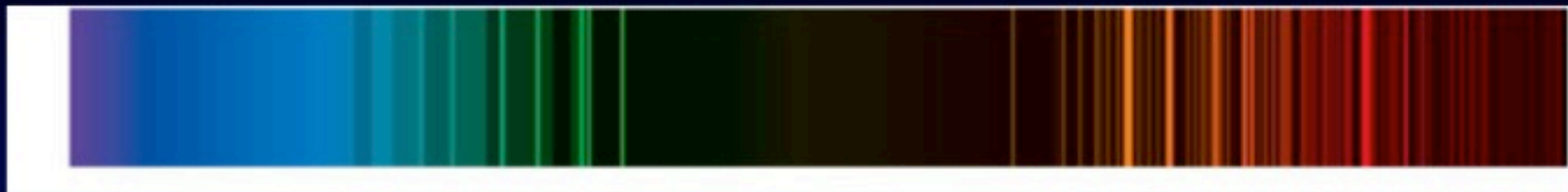


vibration



- Molecules have additional energy levels because they can vibrate and rotate

Energy Levels of Molecules



- The large numbers of vibrational and rotational energy levels can make the spectra of molecules very complicated
- Many of these molecular transitions are in the infrared part of the spectrum

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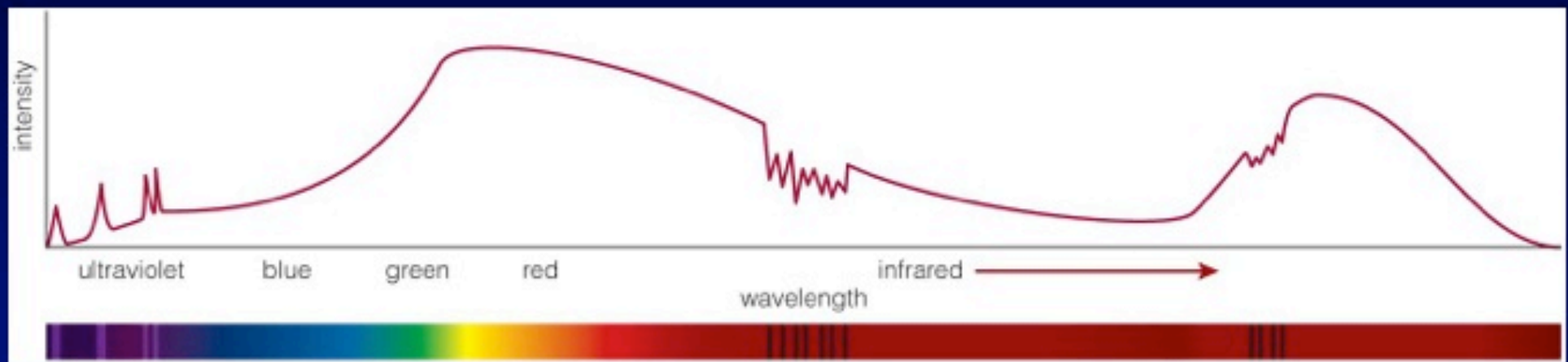


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The graph shows a dip in intensity at the wavelength of each absorption line.

Which letter labels absorption lines?



A

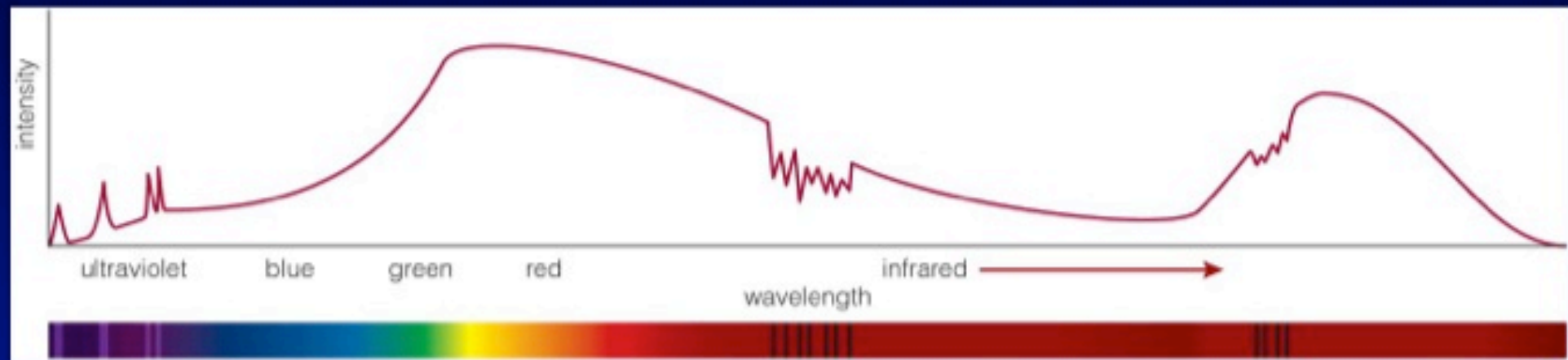
B

C

E

Thought Question

Which letter(s) labels emission lines?



A

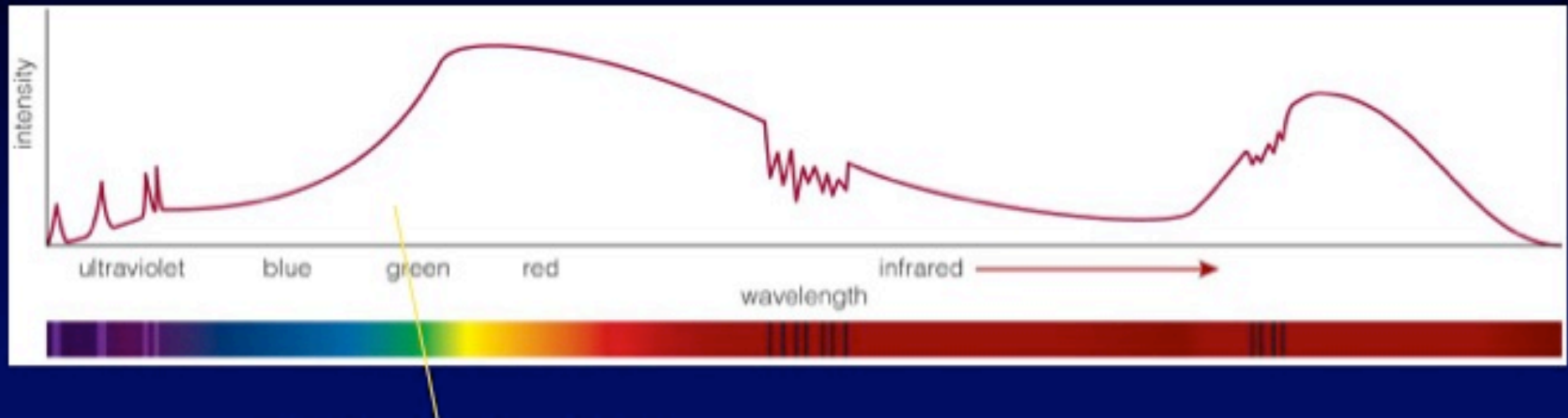
B

C

D

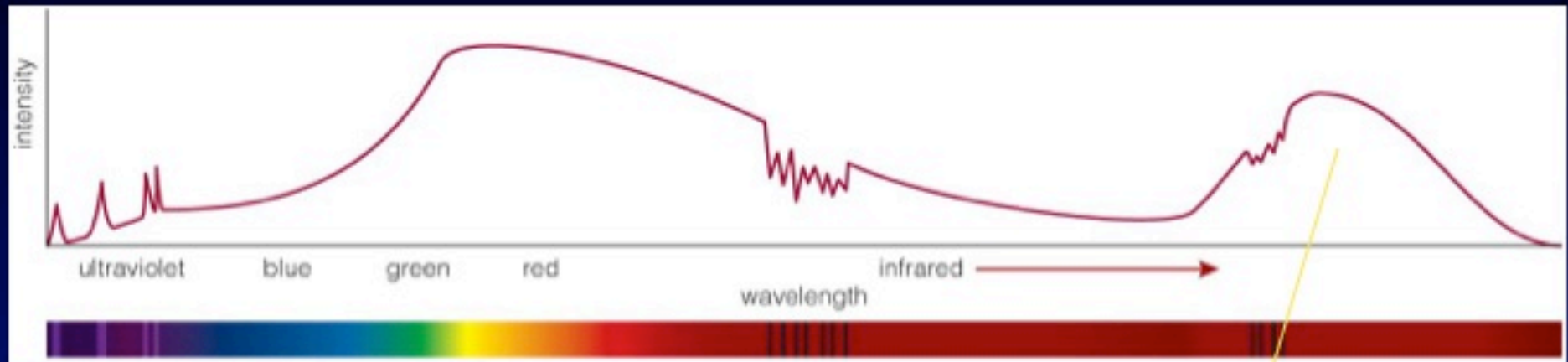
E

What is this object?



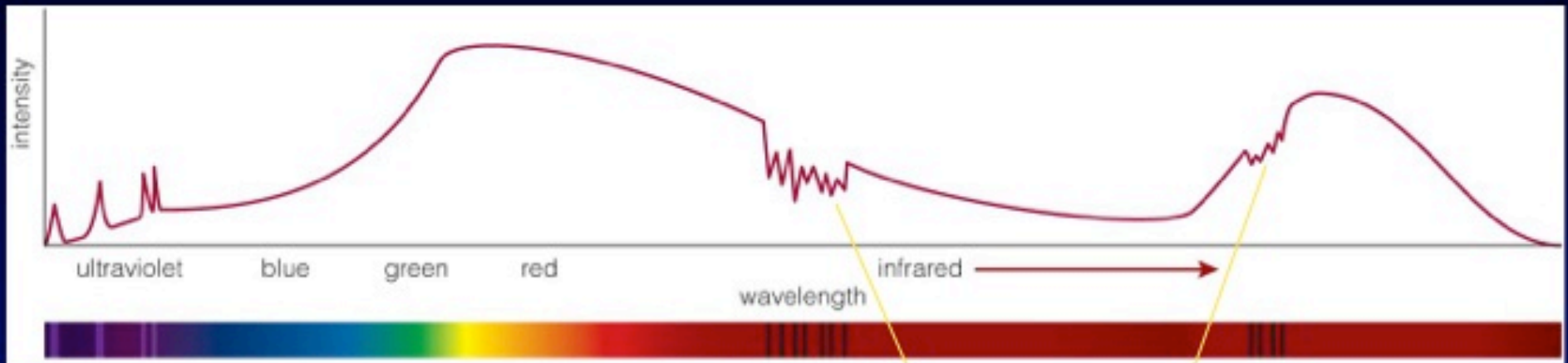
Reflected Sunlight:
Continuous spectrum of
visible light is like the
Sun's except that some
of the blue light has been
absorbed - object must
look red

What is this object?



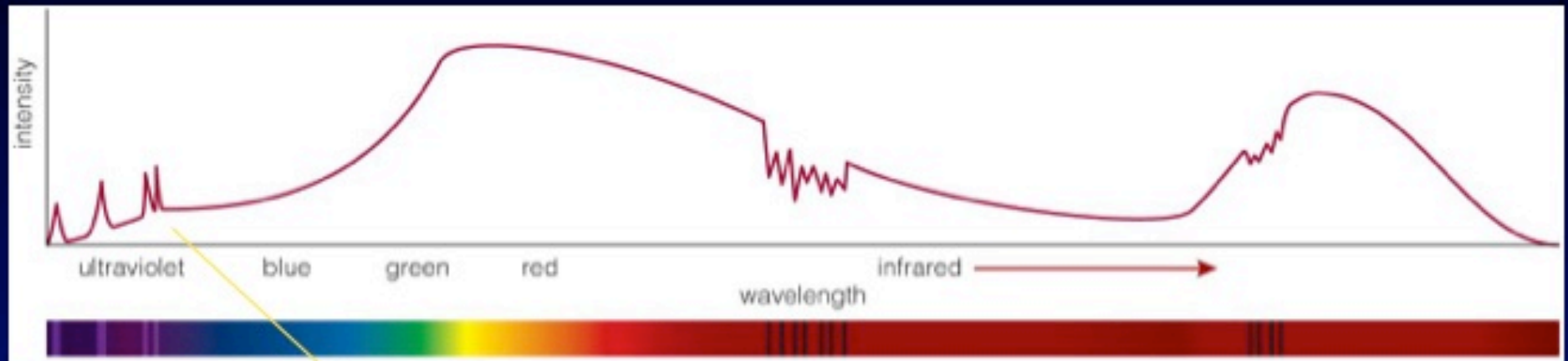
Thermal Radiation:
Infrared spectrum peaks
at a wavelength
corresponding to a
temperature of 225 K

What is this object?



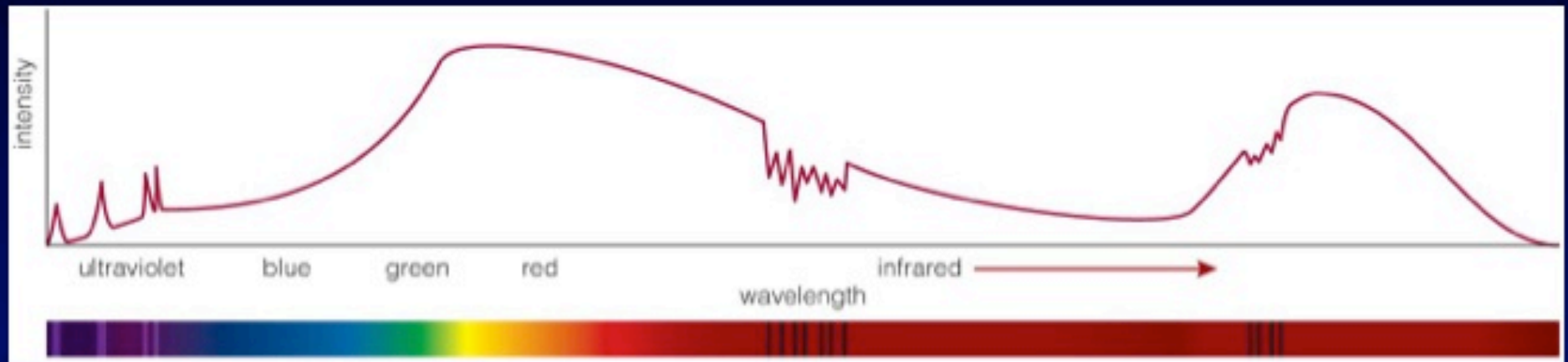
Carbon Dioxide:
Absorption lines are the
fingerprint of CO₂ in the
atmosphere

What is this object?



Ultraviolet Emission Lines:
Indicate a hot upper
atmosphere

What is this object?



Mars!