

Flame Test

- an **analytic procedure** used in chemistry to **detect the presence of certain elements**, primarily metal ions.



The idea:

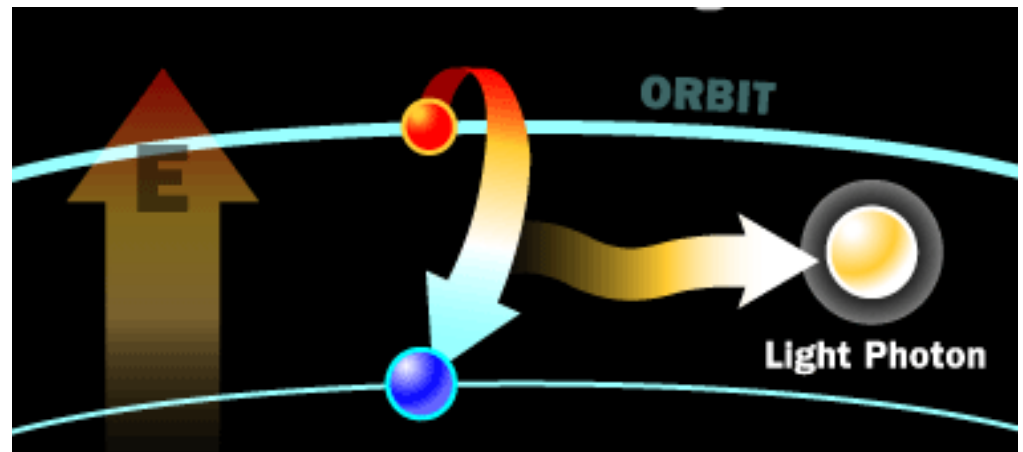
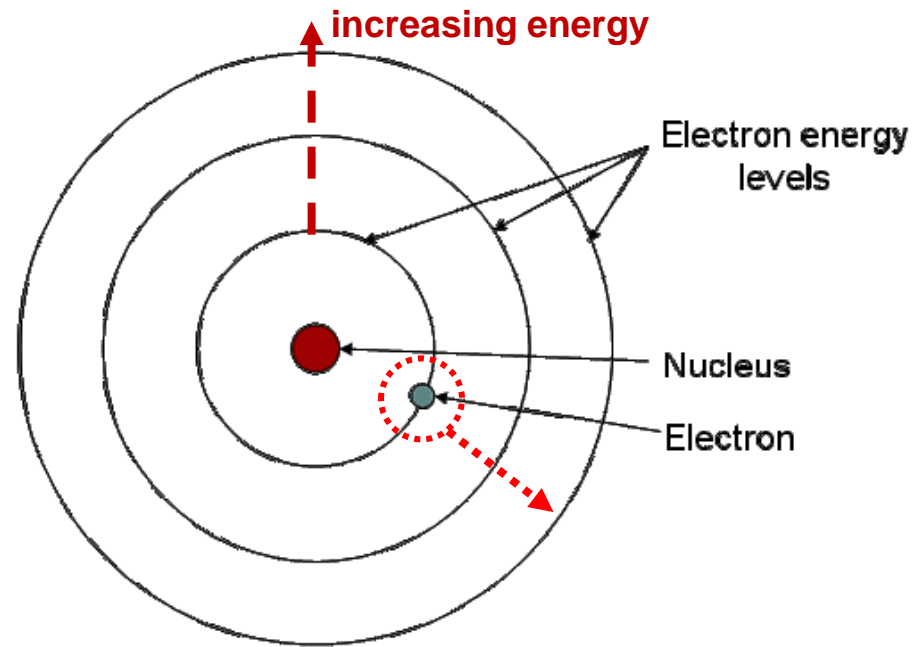
- introduce a sample into flame to *heat*
- sample atoms *sublimate* (get *isolated*)
- since they are *hot*, they emit light
- specific colors are observed...

WHY?

Electrons in Atoms

Electrons in atoms exist in one or more energy levels (orbitals) around the nucleus.

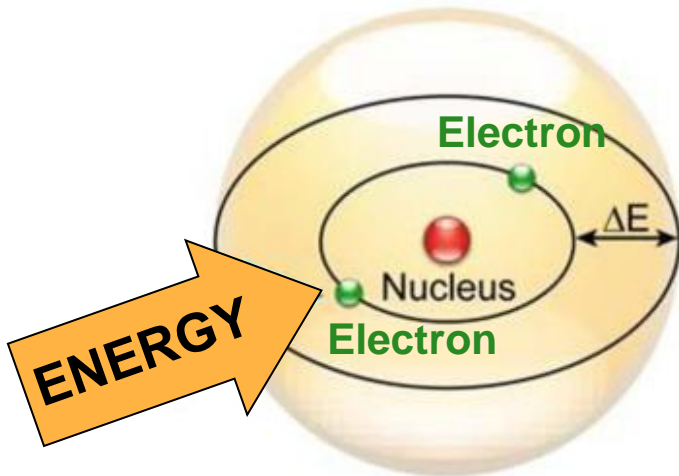
- When matter gains energy, for example by **being heated**, the additional energy pushes the electrons in atoms to higher energy orbitals.
- Electrons tend to return back to their initial orbitals; their “extra” **energy is emitted** in the form of a *particle-like packet of electromagnetic radiation* called a **photon**.



Emission of Light

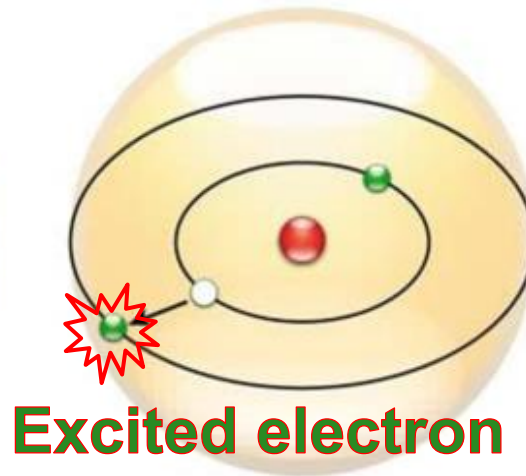
results from **oscillations of electrons** (“jumps” back and forth between energy levels in atoms)

ground state
 (“cool”)

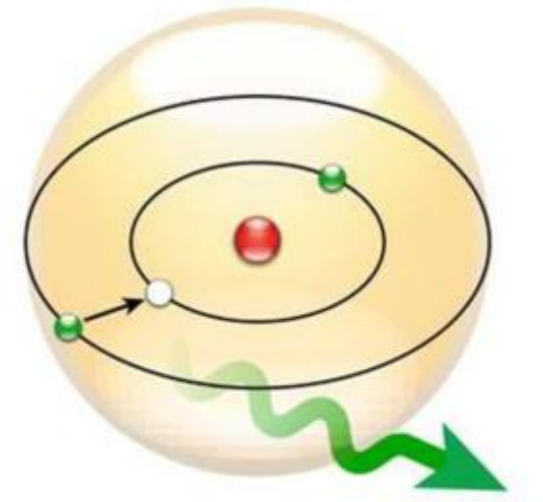


(ANY ENERGY: heat,
kinetic/collision, chemical,
electromagnetic)

excited state
 (“hot”)



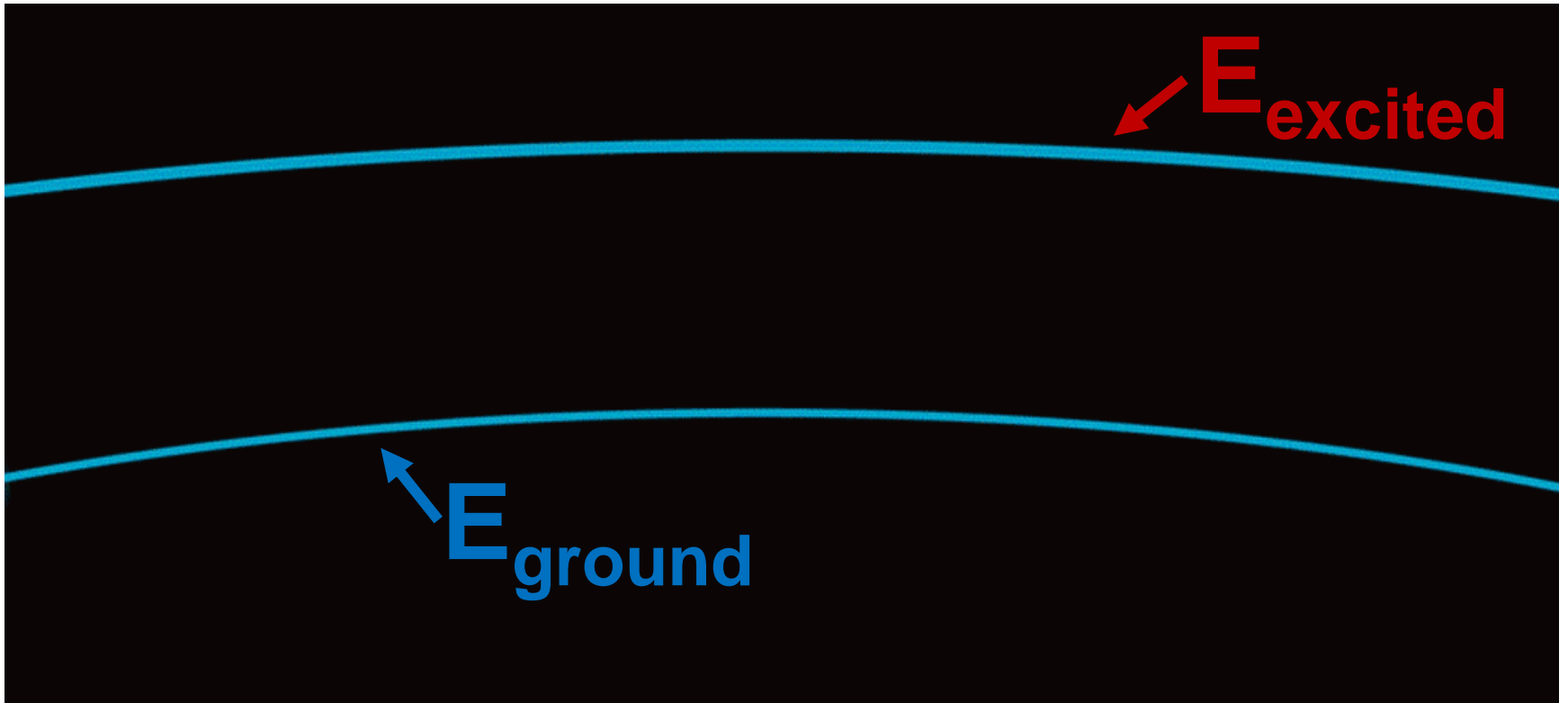
back to
ground state



LIGHT
(ENERGY!)

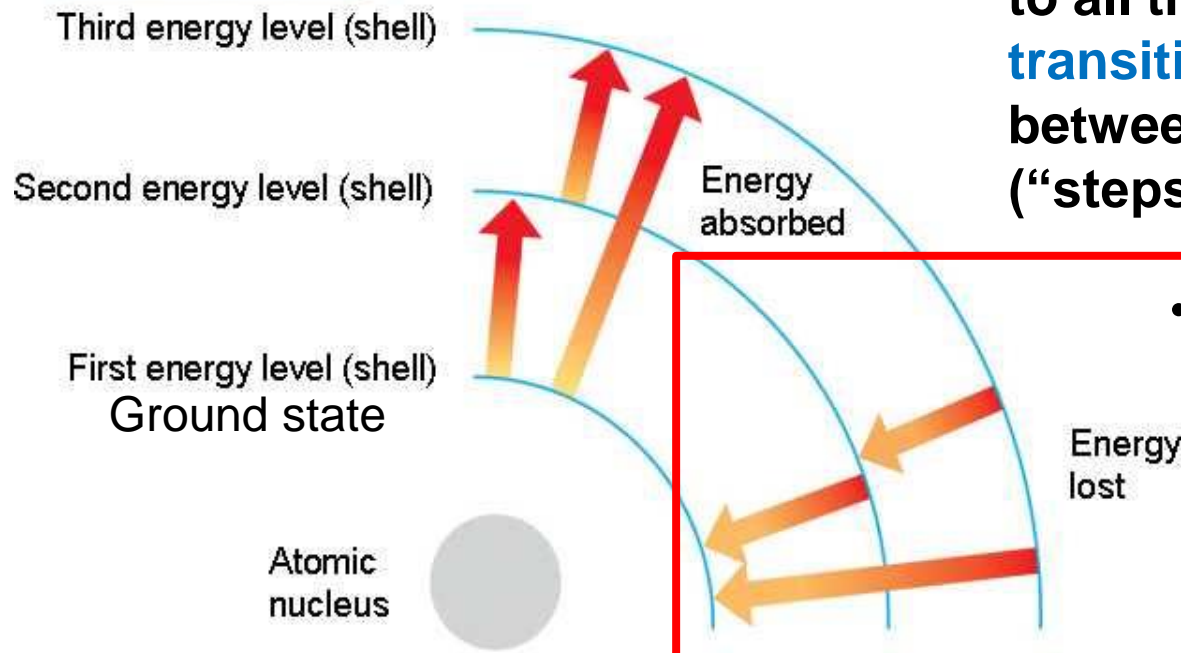
Color of Light

is defined by electron transition



$$\text{Photon Frequency} \sim E_{\text{photon}} = E_{\text{excited}} - E_{\text{ground}}$$

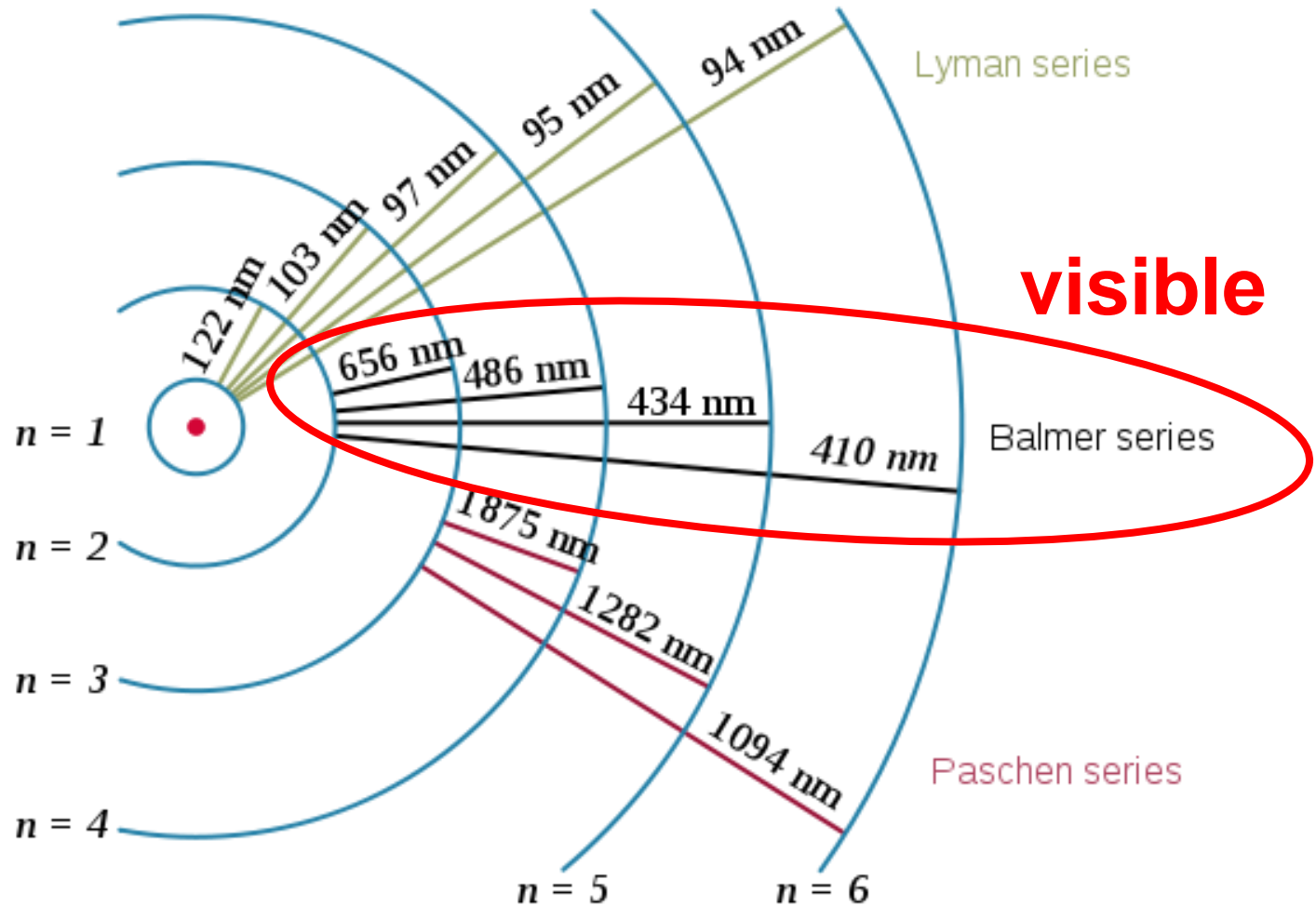
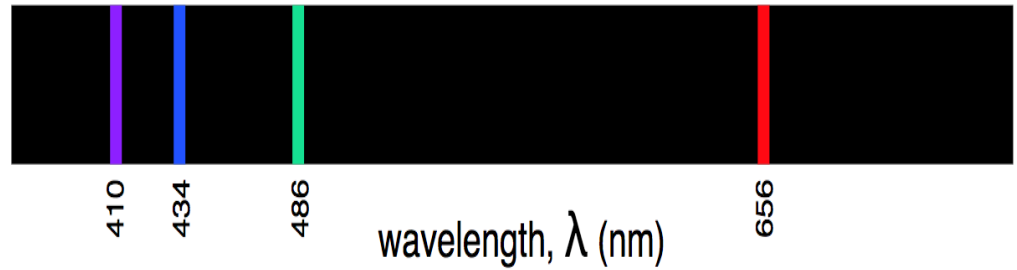
A ***ball bouncing down a flight of stairs*** provides an analogy for energy levels of electrons in atoms: it can only rest on each step, not between steps; the lowest possible step is “ground”.



- An isolated atom will only have light emissions of **certain colors** corresponding to all the **allowed transitions** of electrons between energy levels (“steps”).

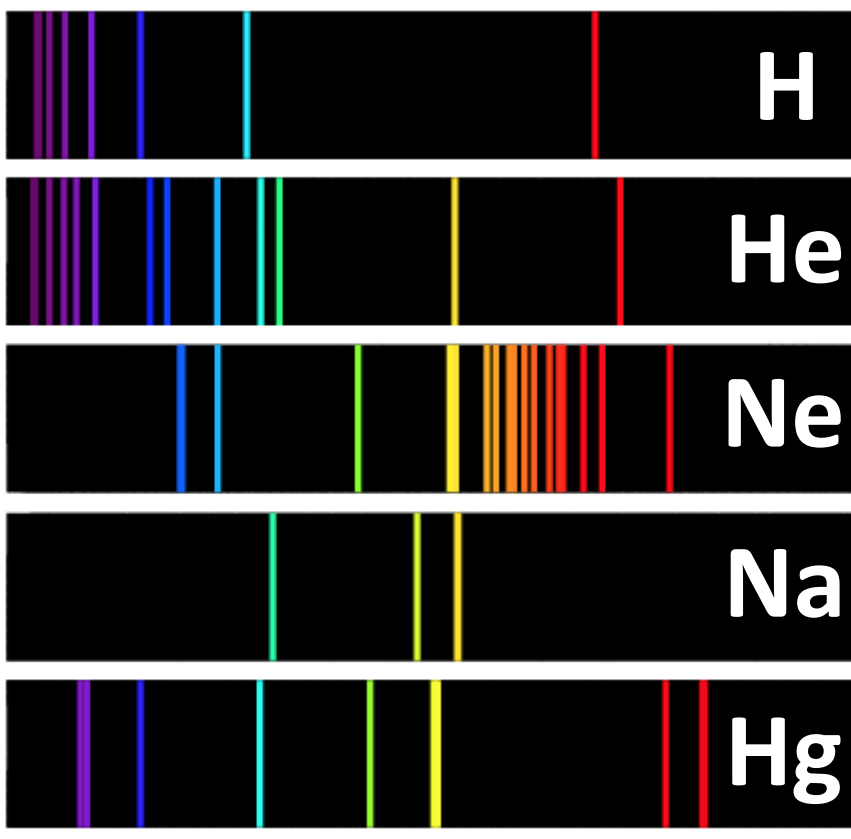
- This set of distinct colors is called **line emission spectrum**

Hydrogen Atom



Atomic Spectrum

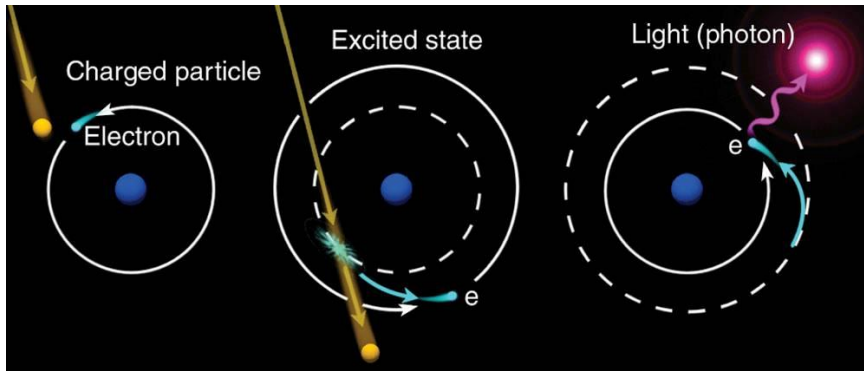
Each particular chemical element has a unique electron configuration and hence its own **unique line emission spectrum**, also called atomic spectrum.



- **Spectroscopy** can be used to **identify the elements** in matter of unknown composition.
- Similarly, the **emission spectra of simple molecules** can be used in **chemical analysis of substances**.
- Emission spectra are given by **matter in a gaseous state**: the atoms or molecules are so far apart that they behave like they are isolated.

Aurora (Northern Lights)

The aurora forms when **charged particles** emitted from the Sun (solar wind) get caught up in the Earth's magnetic field and **collide with atoms and molecules** in the top of the atmosphere.

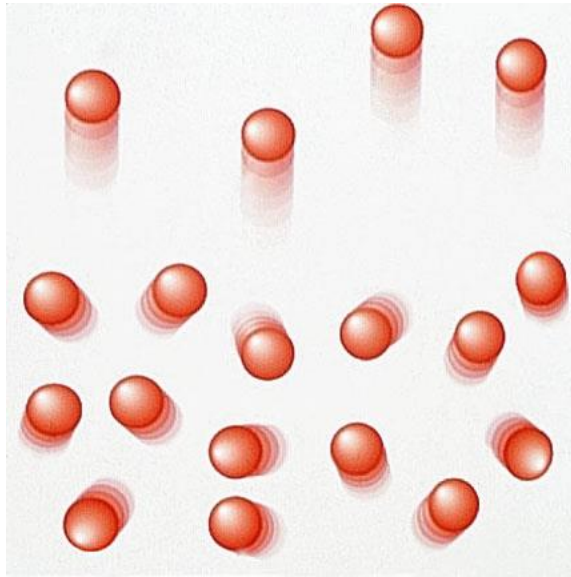


Different colors of the aurora are produced by different atmospheric components:

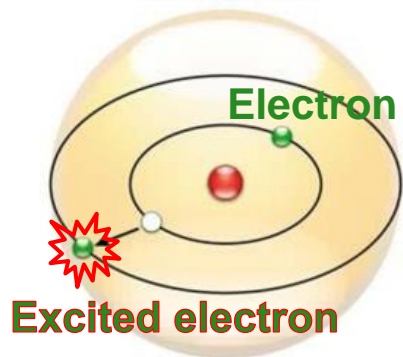
- **Red** – oxygen atoms at ~200 miles high
- **Blue** – ionized nitrogen molecules
- **Green-Yellow** – oxygen atoms at ~60 miles high – most common!
- **Pink/crimson/purple** – mix of the above



Gases

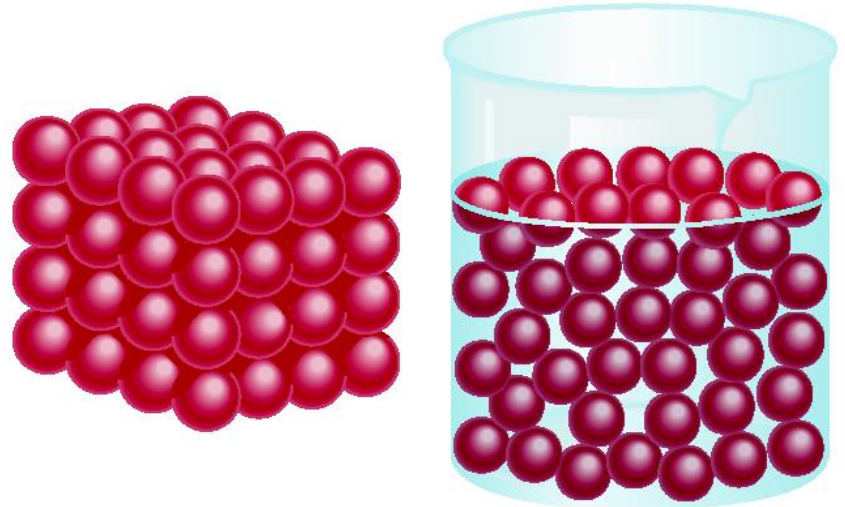


atoms far apart

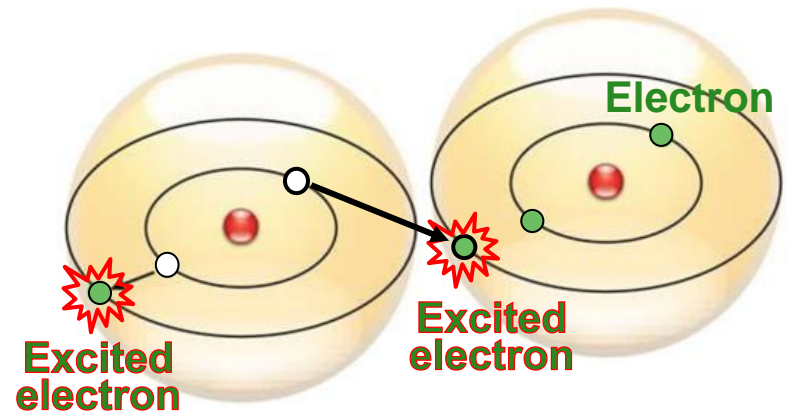


VS

Solids/Liquids

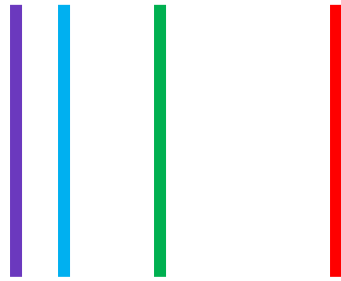


atoms close to each other

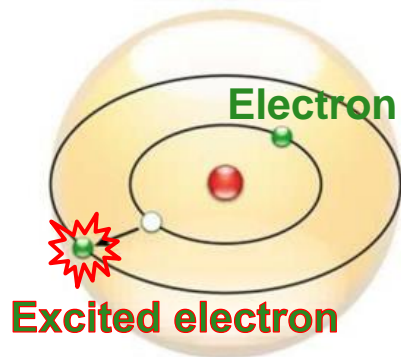


Gases

atoms far apart

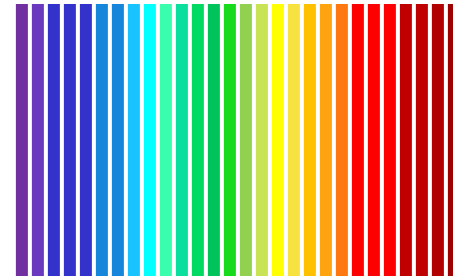


limited set of distinct colors

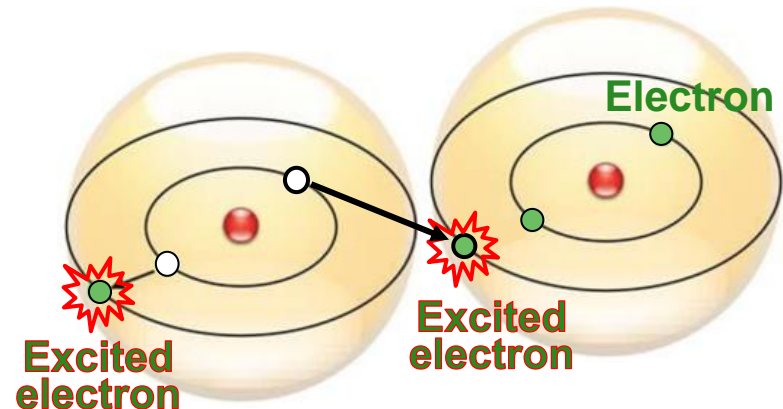


Solids/Liquids

atoms close to each other



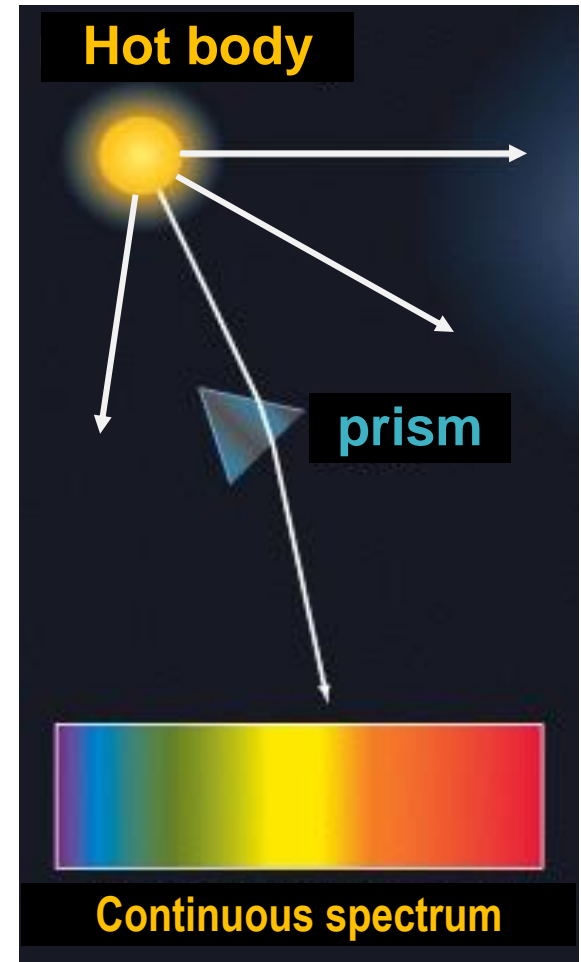
much greater number of possible colors



Thermal Radiation

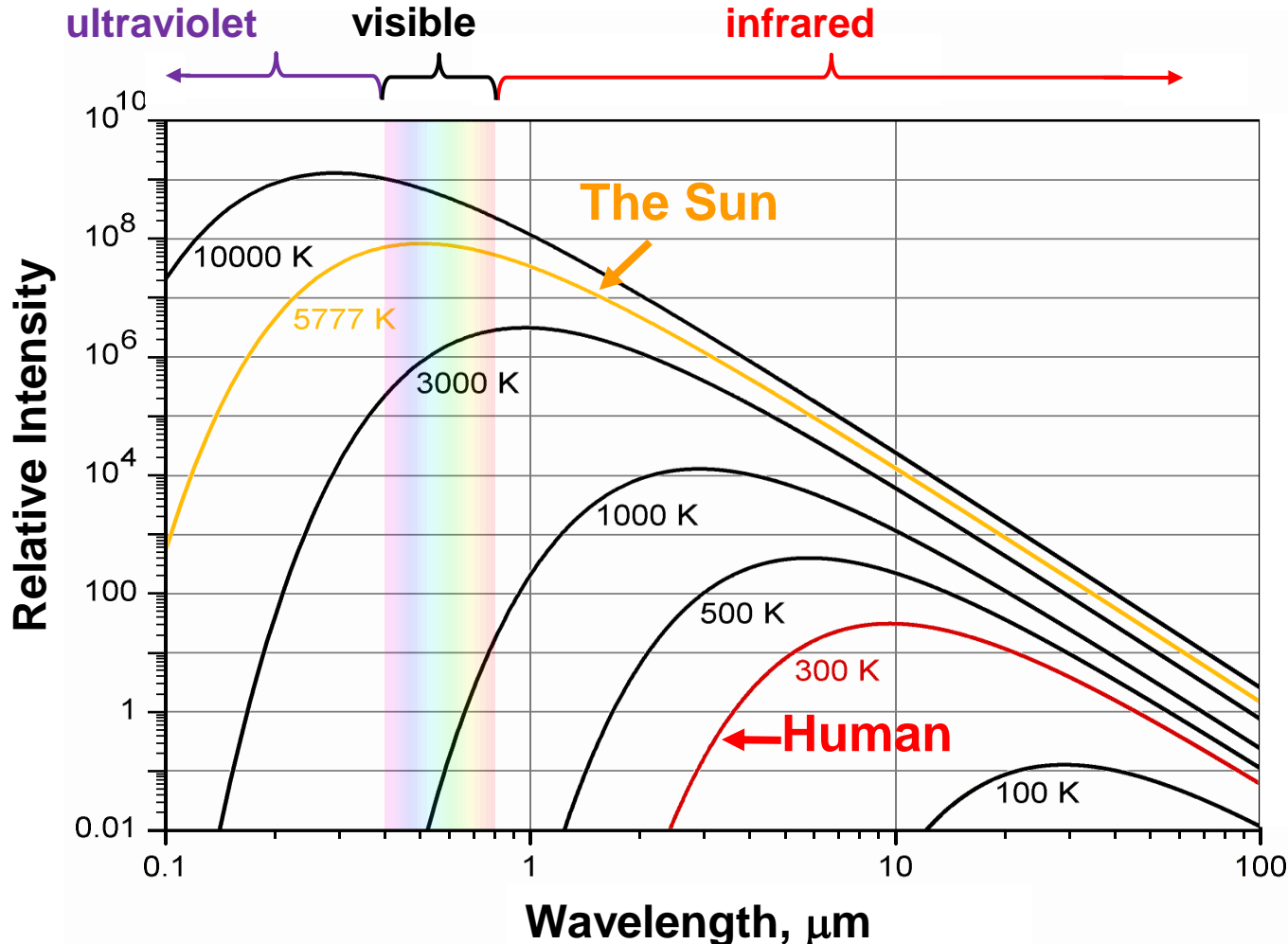
All normal matter emits electromagnetic radiation when it has a temperature above absolute zero.

- This radiation represents a conversion of a body's thermal (heat) energy into electromagnetic energy, and is therefore called **thermal radiation**.
- When the atoms are in a condensed state (solid or liquid matter), the “hot” electrons can make transitions not only within the energy levels of their own atom, but also between the levels of neighboring atoms (that can be of same or different kind).
- This results in a **much larger number of possible transitions** with corresponding frequencies of radiant energy, producing a **continuous color spectrum**.



Thermal Radiation Spectrum

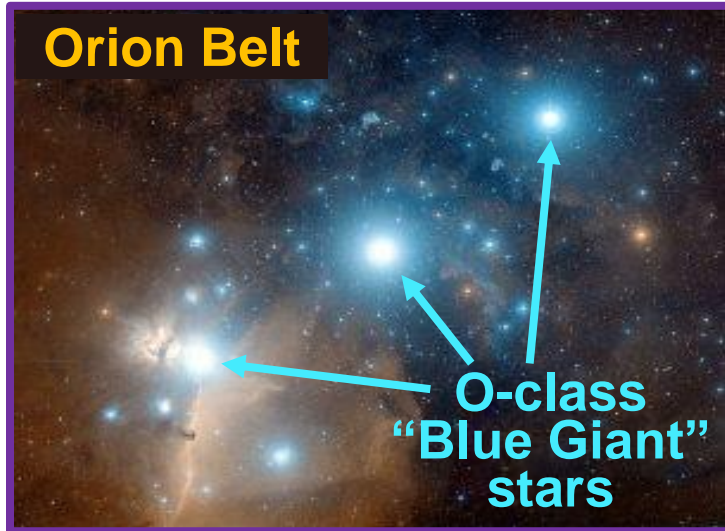
The exact thermal radiation spectrum depends upon **properties of the material** and the **temperature**.



In general, as the temperature increases, the peak of the radiation curve moves to higher intensities and shorter wavelengths.

Everything Glows!

- The temperature at which all solids glow a **dim red** is about **800 K** (over 500°C or 900°F).



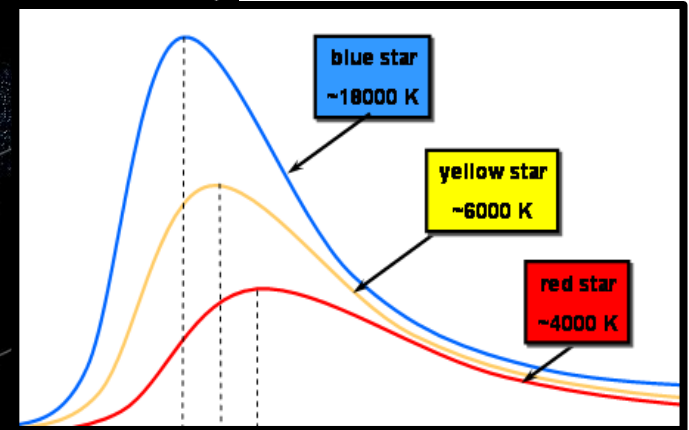
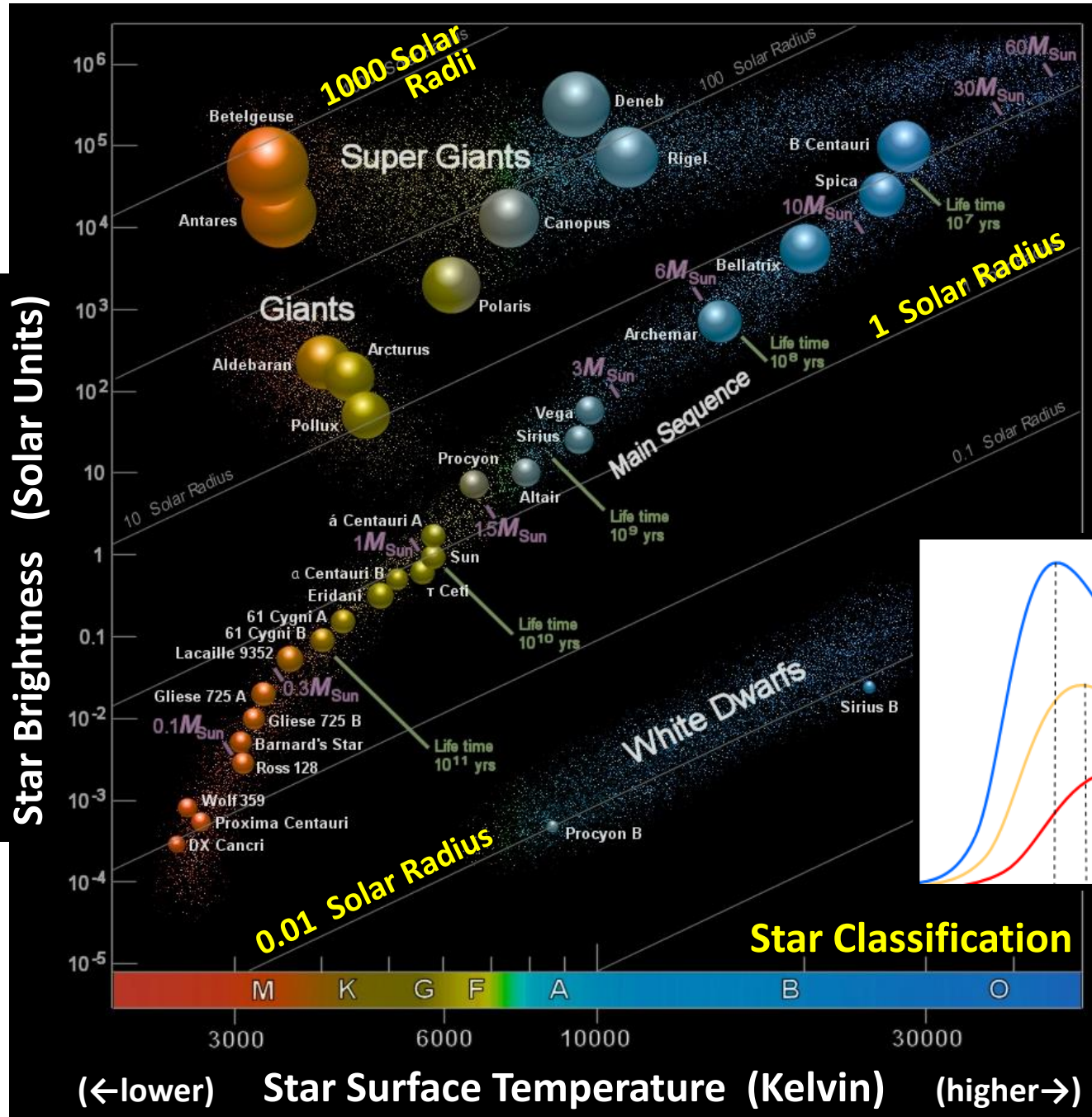
- A very hot object (**10,000 K**) would emit a significant amount of energy in the **ultraviolet and x-ray region** of the spectrum.

- People are emitters of light in the **infrared region** (peak $\sim 9.5\mu\text{m}$).



Colors of the Stars

are defined by how hot their *surfaces* are



The Sun surface is about 5700 K