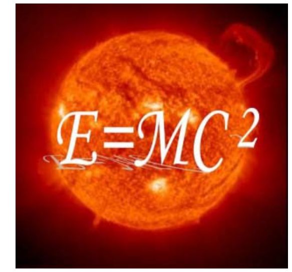
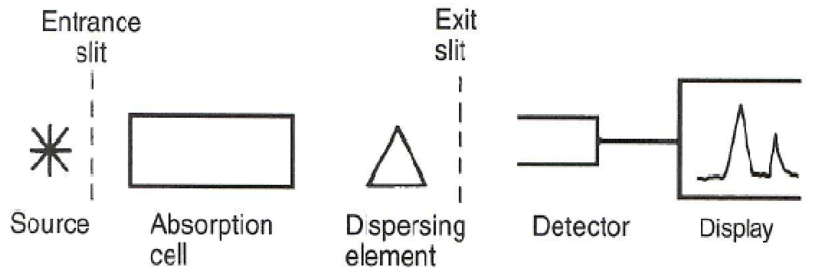
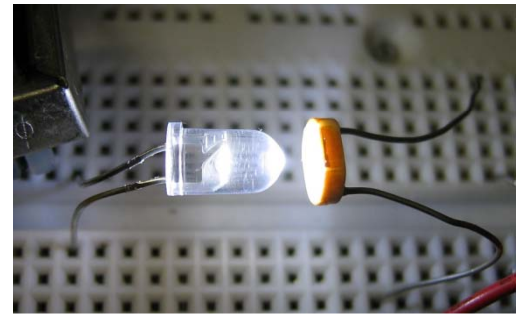
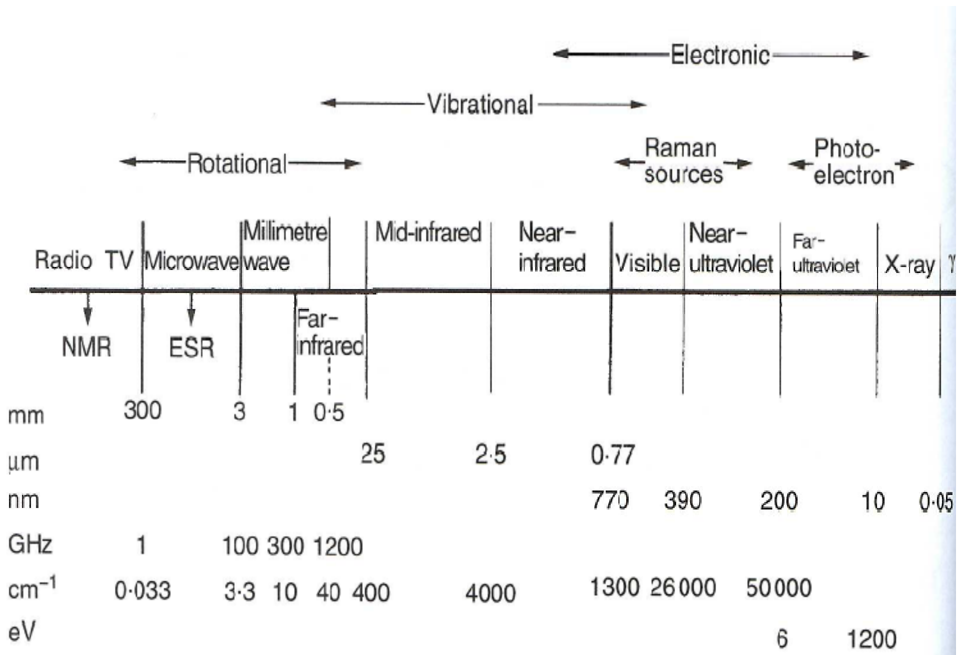
Light sources









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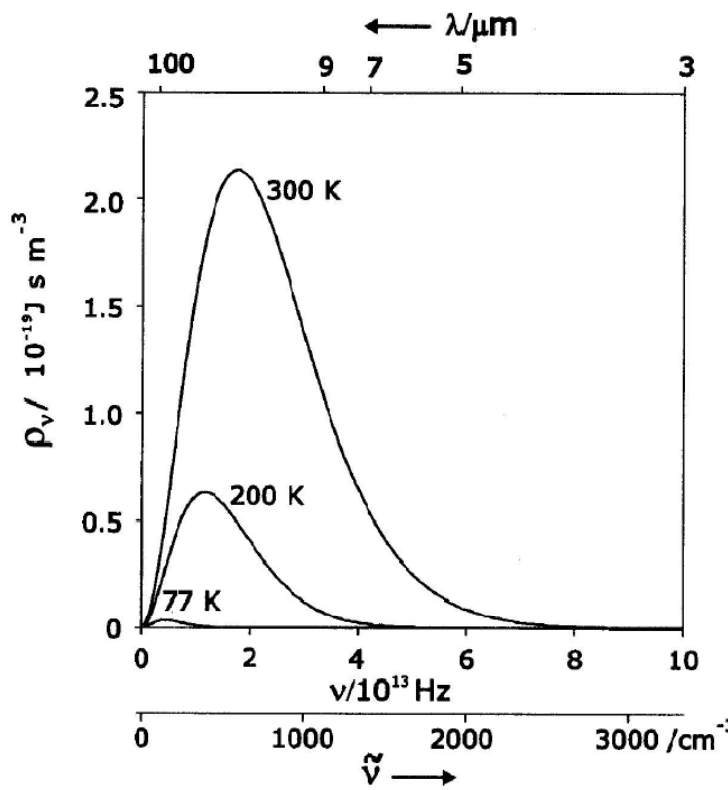
CHEM 5161

Thermal light sources

- Planck law
  - $\rho_\nu(T) = \frac{8\pi h\nu^3}{c^3} \frac{1}{e^{h\nu/kT} - 1}$ [J s/m^3]
  - $I_\nu = \rho_\nu \, c/4$ [J/m^2]
- Stefan Boltzmann law
  - $I = 5.6705 \times 10^{-8}\ T^4$ [W/m^2]
- Wien displacement law
  - $\lambda_{max}\, T = 2.898\ 10^{-3}$ [m K]



- Kirchhoff law
  - At thermal equilibrium, the emissivity of a body (or surface) equals its absorptivity.
  - "Black body" (emissivity = 1) vs. "Grey body" (emissivity < 1)
  - A "grey body" radiates with some emissivity multiplied by the black-body formula (Planck)

Examples of thermal emitters

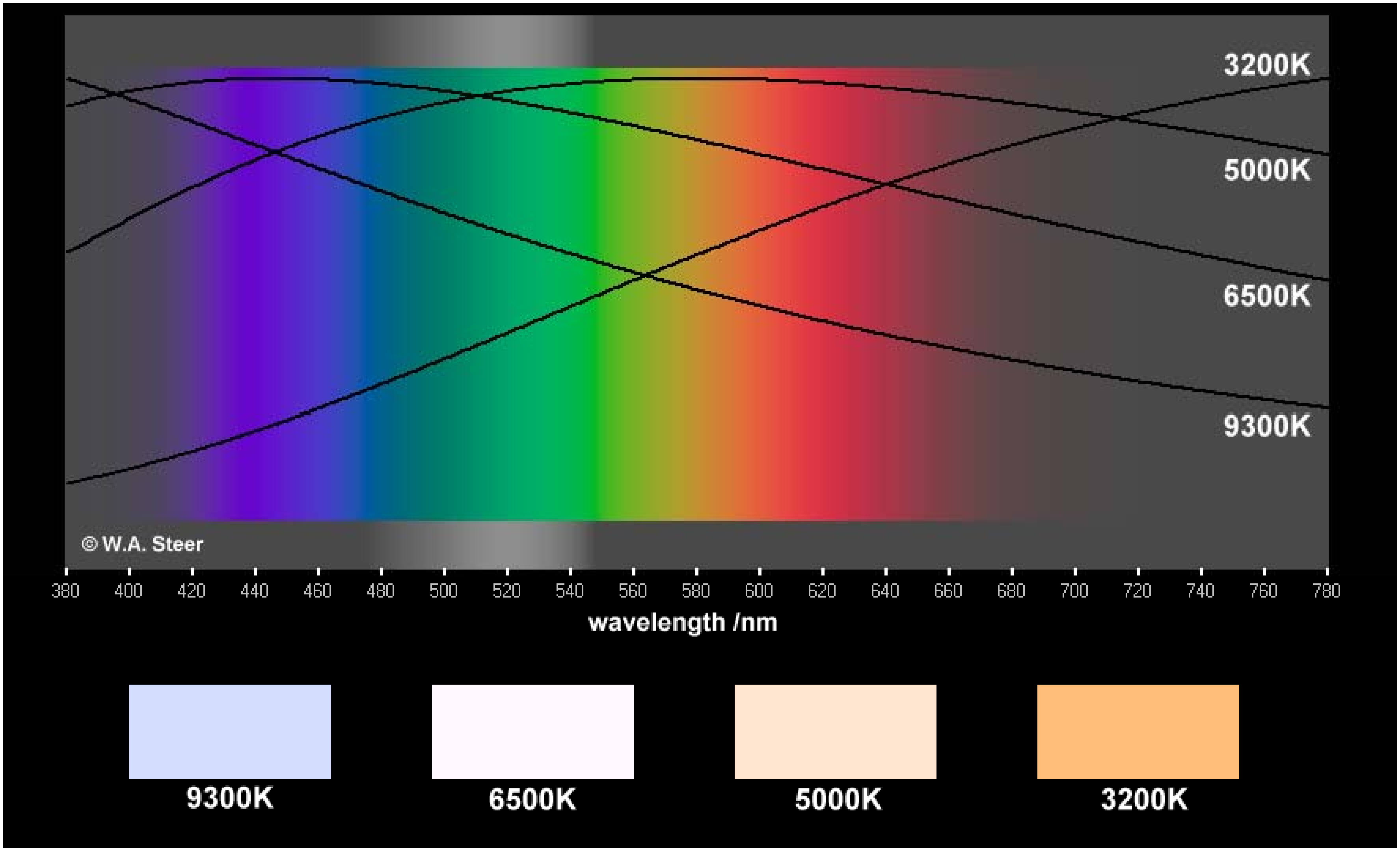
- Nernst Glower (rare earth oxide rod)
  - Temperature: 1200 – 2200 K
  - negative temperature coefficient of resistance
  - external heating (effective resistance heating; current controlled)
  - $\varepsilon \approx 1$
- Glowbar (silicon carbide rod)
  - Temperature: 1300 -1500 K
  - Positive temperature coefficient of resistance
  - Resistance heating (need for water cooling of electrical contacts)
  - $\varepsilon \approx 1$
- Incandescent Wire Source (nichrome)
  - Temperature: 1100 K
  - Resistance heating (no cooling needed, and near maintenance free)
  - $\varepsilon \approx 1$

Question ?

- What are the differences in spectral output between a Nernst source, Glowbar and Incandescent wire source ?
- Which source would you prefer to use if you are to do spectrochemical analysis at wavelengths > 5μm ?
  - A: Nernst @ 2200 K
  - B: Glowbar @ 1400 K
  - C: Incandescent Wire @ 1100 K
  - D: either of the above

Examples of thermal emitters (cont)

- Mercury Arc (plasma)
  - Temperature: 1870 K
  - Quartz jacketed tube containing mercury vapor (pressure > 1atm)
  - $\varepsilon \approx 1$
- Tungsten filament
  - Temperature: 2800 K
  - Melting temperature of tungsten T = 3410 K
  - This is limiting the attainable UV output from this lamp
  - $\varepsilon \approx 0.27$
- Xe arc lamp (plasma)
  - Temperature: 5000 – 10000 K
  - Wolfram vaporization temperature () is limiting the UV output attainable from this lamp)
  - $\varepsilon \approx 0.05$



http://www.techmind.org/colour/coltemp.html

Color temperatures

- Some common examples.
- 1700 K: Match flame
- 1850 K: Candle
- 2800 K: Tungsten lamp (incandescent lightbulb)
- 3350 K: Studio "CP" light
- 3400 K: Studio lamps, photofloods, etc...
- 4100 K: Moonlight
- 5000 K: Typical warm daylight
- 5500–6000 K: Typical cool daylight, electronic flash (can vary between manufacturers)
- 6420 K: Xenon arc lamp
- 6500 K: Daylight°
- 9300 K: TV screen (analog)

UV light sources

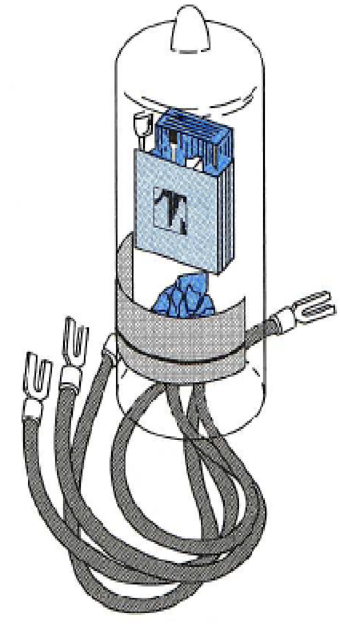
- Deuterium and Hydrogen Lamp
- LED
- Tungsten filament (see above)
- Xe-arc lamps (see above)

Deuterium lamp

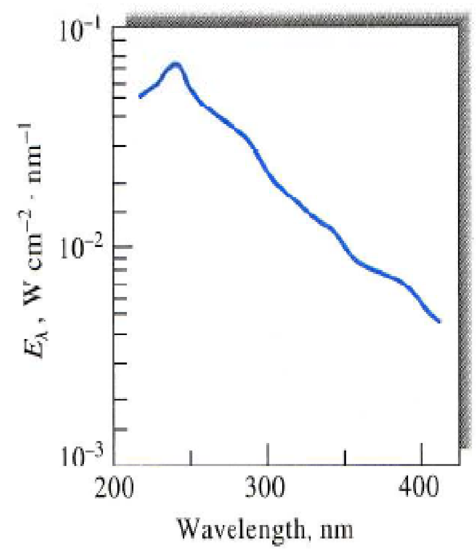
- Maximum intensity occurs at 225 nm
- What temperature is this equivalent to ?

- How can this be acchieved ?
  - formation of an excited molecular species
  - followed by dissociation to give two atomar species and a UV photon
  - UV photon of variable wavelength, due to kinetic energy distribution of the atoms

- Output region: 160 – 800 nm
- Continuum output: 160 – 400 nm

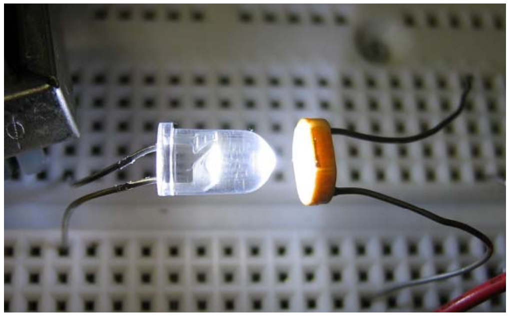


(a)



(b)

Light Emitting Diodes (LED)



- Semiconductor: pn-junction device (forward biased)
- Gallium Aluminum Arsenide (900nm)
- Gallium Aresenic Phosphide (650nm)
- Gallium Nitride (465 nm)
- Indium Gallium Nitride (450nm)
- Spectral region: 375 – 1000nm (mixtures)
- FWHM: 20 – 50 nm
- White LED: blue LED strikes phosphor (400-800nm)

- Long lifetimes
- Small environmental impact

Next time: Laser light sources

- Much smaller spectral width
  - Typically on the order of fractions of cm^{-1}
- Pulsed lasers are subject to broadening of their emission line width
- What is the bandwidth of a femtosecond laser? 1fs = 10^{-15} s

$$\Delta E \Delta t \geq \hbar \quad \text{or} \quad \Delta\nu\Delta t \geq \frac{1}{2\pi}$$