29. Light Emitting Fluids

Wednesday, December 4, 2024 11:45 AM

Today: Light emitting fluids (last of dye/molecular techniques)
Friday:

Art, Science and Engineering Discussion

Flow Visualization

Fall 2020

Think about these questions. In class you'll be put in breakout rooms of 4-5 people for 30 minutes. Skip to the question you find most interesting first.

Choose a scribe to keep track of your discussion, and post notes on Slack. Note what you agree on and where you disagree.

The last 20 minutes of class we will harvest these ideas.

1. What is art? How do you know if an image is artistic?
2. What is science? How do you know if an image is scientific?
3. How are art and science similar?
4. How are they different?
5. What is engineering? How does it fit in compared to art and science?
6. What is filmmaking or photography? How does it fit in compared to art, science and engineering)?

Recap, Dye Techniques

Want dye to have strong interaction with light, to create contrast to unseeded fluid.
How does dye, or any matter interact with light?

1. Reflection
2. Refraction
3. Diffraction
4. Absorption

Light Emitting fluids: Photons are emitted for a range of reasons.

Black Body Radiation = yellow flame color, from BBR of soot particles. Random λ (wavelength) photons from thermal energy. Has a peak, but is very broad band.

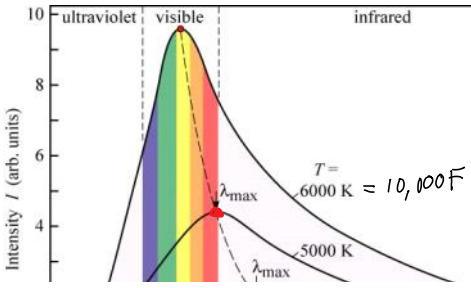
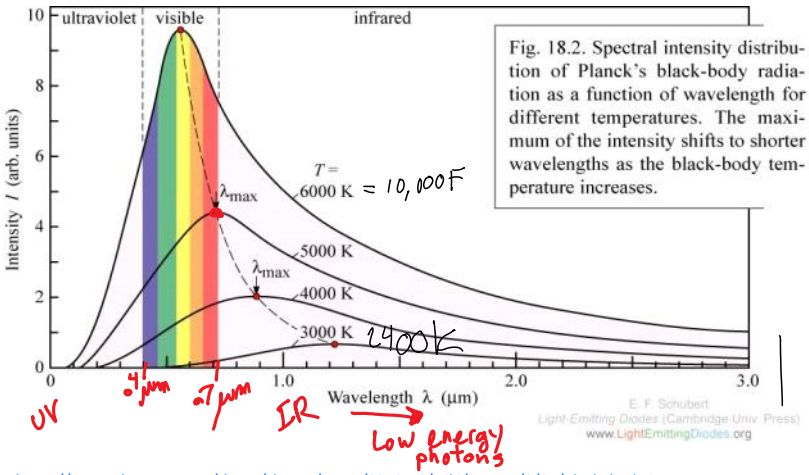


Fig. 18.2. Spectral intensity distribution of Planck's black-body radiation as a function of wavelength for different temperatures. The maximum of the intensity shifts to shorter wavelengths as the black-body temperature increases.



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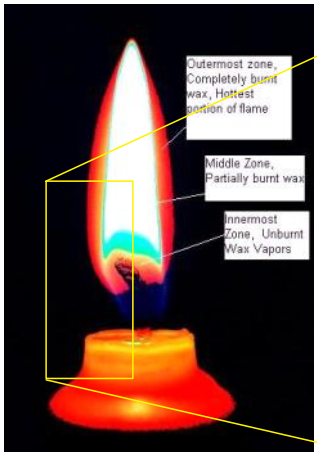
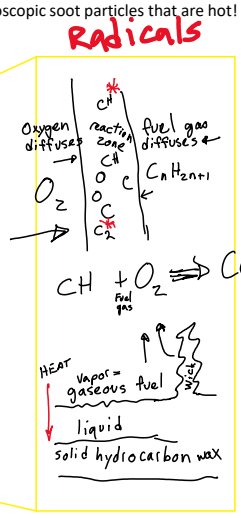
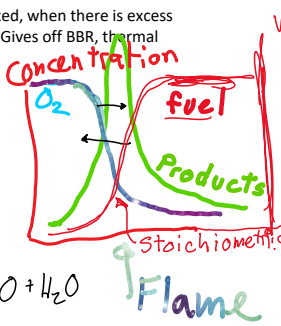
https://www.phy.questu.ca/rknop/classes/enma/2010-10/wiki/images/8/84/Black_body.jpg

Yellow flames: candles, wood fires. Happens when fuel and air are not premixed, when there is excess carbon. Carbon collects together into microscopic soot particles that are hot! Gives off BBR, thermal photons corresponding to temperature.

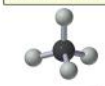
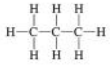
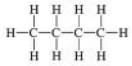
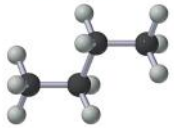




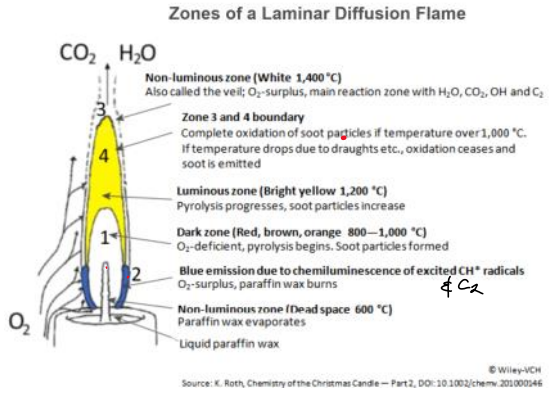


Diffusion flame vs. Premixed

Paraffin wax = Alkane = pure hydrocarbon, hydrogen+carbon = C_nH_{2n+2} .
Wax ~ 20-40 C atoms

name	Kekulé structure	condensed structure	ball-and-stick model
methane		CH_4	
ethane		CH_3CH_3	
propane		$CH_3CH_2CH_3$	
butane		$CH_3CH_2CH_2CH_3$	

https://commons.wikimedia.org/wiki/File:Alkane_4_structure.jpg



Carbon Black = Soot = pure carbon

PAH = Polycyclic Aromatic Hydrocarbon

Observed Blue at bottom?
A yes
B no

Pyrolysis is the process of thermal decomposition of materials at elevated temperatures, often in an inert atmosphere[1] without access to oxygen. From <https://en.wikipedia.org/wiki/Pyrolysis>
Blue Flames = reaction region. C_2 and CH radicals give off blue, high energy photons. More on this below, in chemiluminescence.

Luminescence

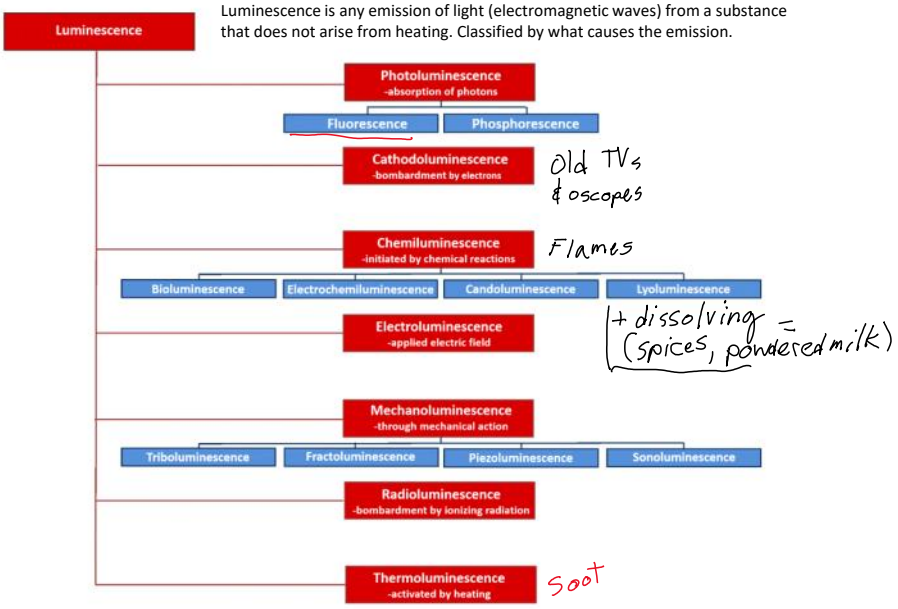


Figure 2: Types of luminescence and their energy sources.

Luminescence is any emission of light (electromagnetic waves) from a substance that does not arise from heating. Classified by what causes the emission.

Fast slow

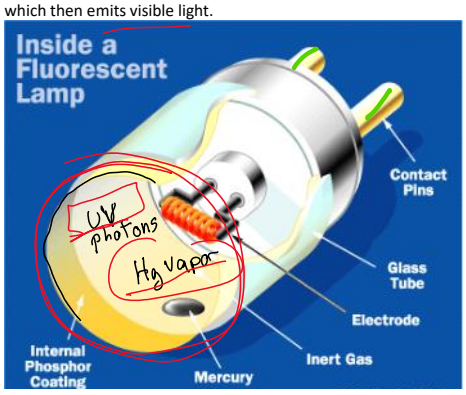
https://www.edinst.com/us/blog/photoluminescence-differences/

Photoluminescence = Fluorescence and Phosphorescence

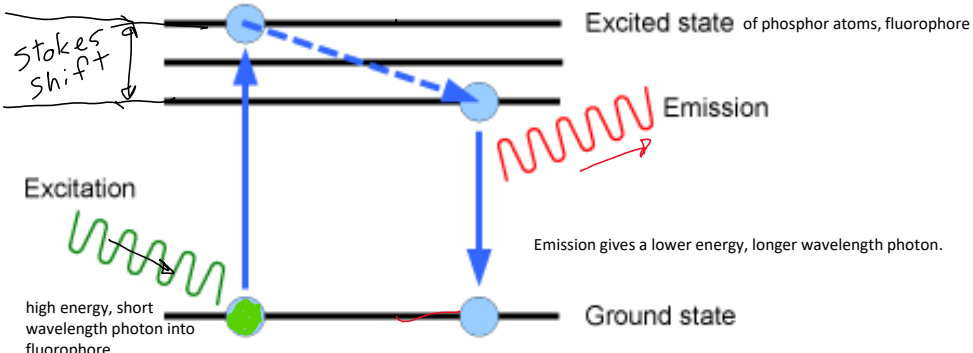
Fluorescence = absorption of photons at a specific short λ, emits at a longer λ.

E.g. some laundry detergents and fabric softeners absorb in the UV, and emit blue or orange

Fluorescent bulbs: Current is conducted through mercury vapor, energizes it to emit UV photons which hit a phosphor coating on the inside of the tube, which then emits visible light.



http://home.howstuffworks.com/fluorescent-lamp.htm/

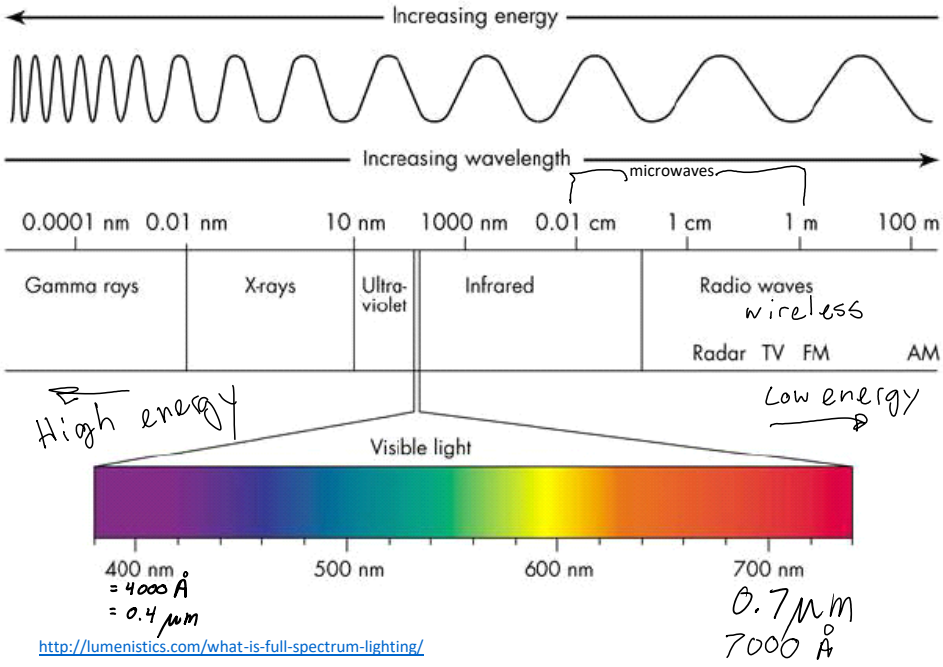


http://www.art.ca/en/preclinical/optical-molecular-imaging/fluorescence.php

Wavelength change between absorption and emission = Stokes shift:

- some heat lost from excited state,
- and/or returns to ground state + highest vibrational mode, not all the way down.

EM spectrum review



http://lumenistics.com/what-is-full-spectrum-lighting/

We talk about how wavelength = color, but it's really frequency and energy = color

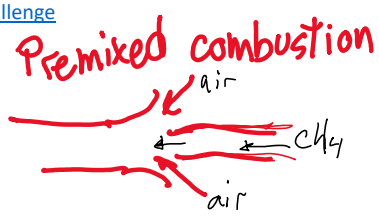
$$c = \lambda f$$
$$\left[\frac{m}{s}\right] \quad [m]\left[\frac{1}{s}\right]$$

Speed of light = wavelength x frequency
In dense media c decreases, wavelength decreases
Frequency and photon energy stays constant, color is constant.

Phosphorescence
In fluorescence, the outgoing photon is emitted very quickly, while in phosphorescence there can be a lengthy time delay resulting in 'glow-in-the-dark' materials. The difference has to do with electron spin multiplicity in the materials

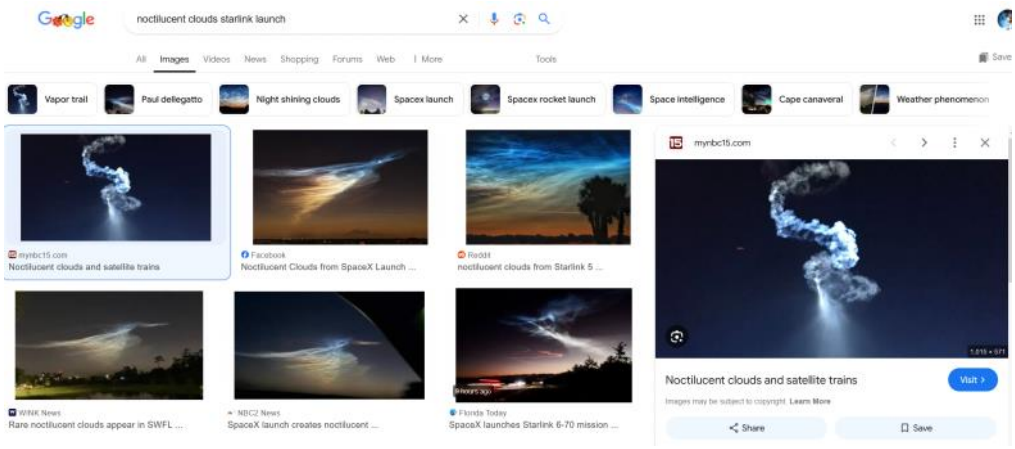
Luminescence = cold body emission, usually at specific λ.
A general term. More specific: chemiluminescence, bioluminescence, electroluminescence

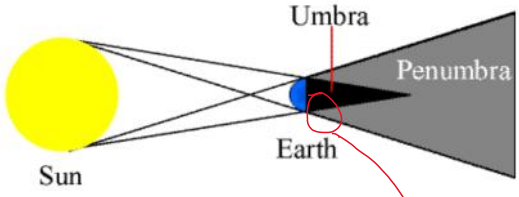
Chemoluminescence - Cyalume, party bracelets: chemical reaction releases photon, which then drives fluorescence. Needs mix of chemicals for reaction, and choice of color.
Flames: C_2, CH^* , radicals = highly reactive intermediate molecules (between reactant and product species) that only exist in the thin reaction zone. Excited by reactions, emit blue photons to get to lower energy state.
Also, hot soot gives off black body radiation; yellow glow.
https://www.aldacenter.org/outreach/flame-challenge



Have you ever seen noctilucent clouds?
A) Yes 20%
B) No 10%
C) Not a clue. What is noctilucent? 70%

80% after discussion





https://www.businessinsider.com/what-is-airglow-2014-9

High atmosphere gets some sunlight even after sunset

Airglow:
Molecules of OH, sodium and oxygen in the high (80 km) atmosphere give off characteristic photons when excited by UV light from the sun.

From <https://www.flowvis.org/Flow%20Vis%20Guide/dye-techniques-3-light-emitting-fluids/>

Bioluminescence - Fireflies, deep sea fish, worms. Good for flow vis?
Photoluminescence = Fluorescence and Phosphorescence https://www.youtube.com/watch?v=Fvob6L8q3I8 Red tide, blue waves off San Diego

https://www.nationalgeographic.com/animals/fish/group/anglerfish/

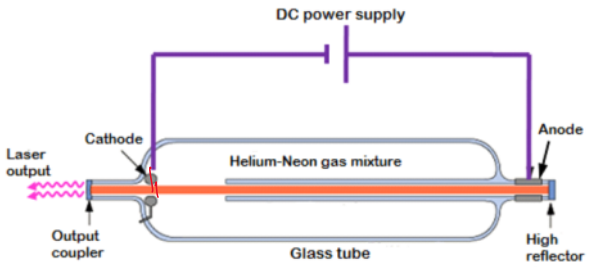
Electroluminescence - LEDs, sodium vapor, mercury vapor lamps etc. Specific λ.

E.g. electric pickle http://www.youtube.com/watch?v=tMhXCG6k6oA

Laser : population inversion, specific λ, resonant cavity with mirrors. Gas dynamic laser: after supersonic expansion, lower vibrational states relax before higher ones = inversion. A type of 'chemical laser'

Light Amplification by Stimulated Emission of Radiation

Ar^+
He Ne
Nd-Yag



https://www.physics-and-radio-electronics.com/physics/laser/heliumneonlaser.html