Homework #7-2: The Hydrogen Atom, EM Spectroscopy, Fluorescence
Problems pg. 298 #7.23, 7.26, 7.28, 7.30; Additional Spectroscopy Questions

23 Briefly describe Bohr’s theory of the hydrogen atom and how it explains the appearance of an emission spectrum. How does Bohr’s theory differ from concepts of classical physics?
-- Bohr’s Theory of hydrogen atom states that the single electron in hydrogen atom can exist with a limited number of energies. This means that the energies of the electron are quantized.

--The emission spectrum consists of distinct lines. The lines are formed when the electron is first excited into a higher energy level (absorbs electricity, heat, etc.) and then when the electron falls back down to a lower energy level, light of a particular energy is emitted.

--This is different from classical physics because energies are quantized instead of continuous.

26 Some copper compounds emit green light when they are heated in a flame. How would you determine whether the light is of one wavelength or a mixture of two or more wavelengths?
The emitted light could be analyzed by passing it through a prism or diffraction grating.

28 Explain how astronomers are able to tell which elements are present in distant starts by analyzing the electromagnetic radiation emitted by the stars.
Excited atoms of the chemical elements emit the same characteristic frequencies or lines in a terrestrial laboratory, in the sun, or in a star many light-years distant from earth.

30 The first line of the Balmer series occurs at a wavelength of 656.3 nm. What is the energy difference between the two energy levels involved in the emission that results in this spectral line?

\[ E = \frac{hc}{\lambda} = \frac{(6.6256 \times 10^{-34} \, J \cdot s)(2.998 \times 10^8 \, m/s)}{656.3 \times 10^{-9} \, m} = 3.027 \times 10^{-19} \, J \]

A. How would the wavelength and energy of light absorbed as an electron is excited from the n = 2 to the n = 3 energy level compare to the wavelength and energy emitted in problem 30 above?
Since the energy difference is the same, the values of wavelength and energy absorbed would be equal to those for the wavelength and energy emitter; note, however, that the energy absorbed would be a positive value, and that emitted would be negative.

B. What kind of information (Molecular Rotation, Bond Vibration, or Electronic Transitions) is obtained by spectroscopy involving absorption of light in the UV/visible, region of the EM spectrum.

C. How does the color of light transmitted by a clear colored solution or reflected by a colored substance relate to the color of light absorbed by the substance?
The color transmitted or reflected is the complimentary color to that being absorbed; colors not absorbed are transmitted or reflected.
D. (i) What is Beer’s (Beer-Lambert) Law, and how is it used in chemical analyses?

Beer’s law states that the absorbance of a solution is directly proportional to the concentration of the absorbing species: \( A = abc = mc \), where \( A \) is absorbance and \( c \) is concentration in mol L\(^{-1}\). It is used to determine the concentration of an unknown solution.

(ii) Below is the absorption spectrum for CoCl\(_2\) (left) and the Beer’s Law plot for CoCl\(_2\) at 560 nm. Explain why 560 nm is an appropriate wavelength for the Beer’s Law analysis, then determine the concentration of a solution with absorbance = 0.32.

![Absorption Spectrum of CoCl\(_2\)(aq)](image1)

![Beer's Law Plot of CoCl\(_2\) at \( \lambda_{\text{max}} = 560 \text{ nm} \)](image2)

560 nm is an appropriate wavelength since it has the maximum absorbance (between 0.1 and 1).

\[
0.32 = (4.8571 \text{ M}^{-1})c + 0.0038 \Rightarrow c = \frac{0.32 - 0.0038}{4.8571 \text{ M}^{-1}} = 0.065 \text{ M}
\]

E. What is the basic process by which fluorescence and phosphorescence work? Why is higher-energy UV light necessary? How are the two processes different?

In both processes, higher energy UV light excites an electron into an upper energy level. After partially relaxing (losing a little energy), the electron relaxes back to the ground state, emitting a photon in the visible region of the spectrum.

Phosphorescence is a longer process, with the electron remaining excited for longer than in fluorescence.

F. At right is the IR transmission spectrum of diethylamine. What kind of information (Molecular Rotation, Bond Vibration, or Electronic Transitions) can be obtained from this region of the EM spectrum?

![IR Transmission Spectrum of Diethylamine](image3)

G. Microwave radiation spectroscopy (\( \lambda \) is actually in the mm range) can be used to investigate rotational motion of small molecules such as water. Rank the relative energies of UV-Vis, Infrared, and Microwave spectroscopies, from lowest to highest.

Microwave < Infrared < UV-Vis