

Spectroscopy in AP Chemistry

A general understanding of spectroscopy techniques is required for the 2014 AP Chemistry exam. The types mentioned in the AP Chemistry Course and Exam Description are Photoelectron (PES), Ultraviolet-Visible (UV-Vis) and Infrared (IR) spectroscopies.

Spectroscopy Basics:

Spectroscopy refers to a broad range of laboratory techniques that use radiation to interact with a sample; how this interaction occurs determines information about the structure of its atoms and/or molecules. Spectroscopy is classified based on the energy of the radiation source used - different energies of light probe for different kinds of information about a sample (binding energy, excitation energy, bond vibrations, etc.).

Technique	Energy of Source Radiation	Probes	Why you would choose it....*
<i>Photoelectron Spectroscopy</i>	X-ray to UV XPS: 1 - 20 keV UPS: 10 - 100 eV	electron binding energy	- want to know mostly about individual atoms - sample is a solid or in the gas phase - looking at the energy levels of individual orbitals (1s vs. 3p)
<i>UV-Vis Spectroscopy</i>	UV to visible: 200 - 800 nm	electron excitation energy	- want to know about molecules or metal ions - sample is in an aqueous solution - probing purity or concentration of sample that absorbs UV light (pi-bonds or metal cations) - determine concentrations using Beer's Law
<i>IR Spectroscopy</i>	infrared radiation: 200 - 4000 cm^{-1}	bond vibrational energy	- want to know about molecules, mostly those with covalent bonds - sample is in solution or a solid - interested in what functional groups are in a molecule

*based on most common usage of spectroscopic method

How it works:

In Photoelectron Spectroscopy (sometimes called XPS when using X-ray incident radiation, and UPS when using UV incident radiation), monochromatic radiation interacts with the sample. The energy is absorbed, and ejects electrons from the sample. The kinetic energy of the electrons is measured, and can be related back to the binding energy of electrons in the sample.

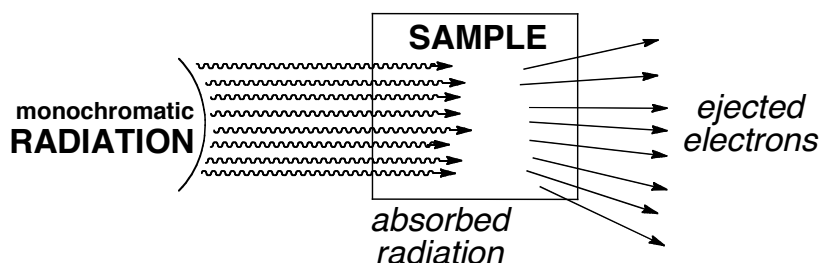


Figure 1: Photoelectron Spectroscopy Schematic Diagram

Monochromatic radiation is absorbed by sample and ejects electrons with a measurable kinetic energy.

In the case of IR and UV-vis Spectroscopy, multi-chromatic radiation interacts with the sample: some of it will be transmitted through the sample and some will be absorbed by the sample. The radiation that is absorbed corresponds with particular bond vibration of characteristic functional groups in IR spec, and with the electron excitation energy of conjugated systems or metal cations in UV-vis spectroscopy.

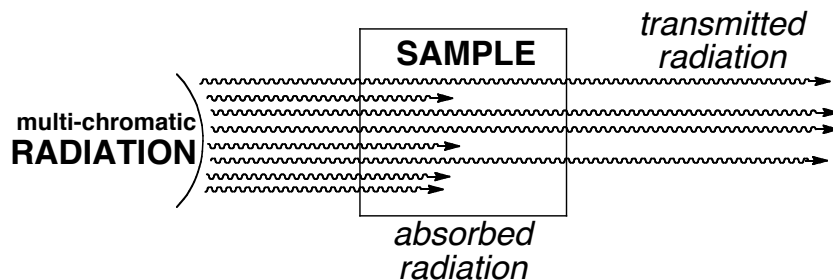


Figure 2: IR and UV-Vis Spectroscopy Schematic Diagram

Multi-chromatic radiation is probes the sample, and some is absorbed. The absorbed radiation corresponds to particular bond vibrational energies or electron excitation energies of the sample.

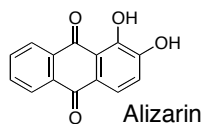
How is Spectroscopy incorporated into the AP Chemistry curriculum?

While the fundamentals of Photoelectron Spectroscopy are emphasized in the AP Chemistry curriculum (see *PES in AP Chemistry*), other spectroscopy techniques are encompassed by LO1.15.

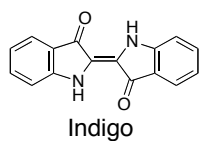
Learning Objective 1.15 The student can justify the selection of a particular type of spectroscopy to measure properties associated with vibrational or electronic motions of molecules.

Example UV-vis spectroscopy would be ideal to determine the concentration of aqueous solutions of which of the following?

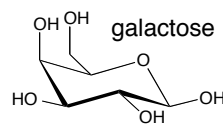
I.



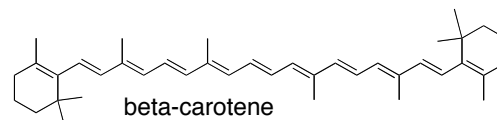
II.



III.



IV.



a. II only

b. I and III only

c. I, II and IV

d. I, II, III, and IV

Sample Question: AP Chemistry Practice Exam and Notes, Fall 2013 #41

Resources:

Li, Y., "Spectroscopy Techniques" PowerPoint Slides for CHEM268, University of California.

<http://research.pbsci.ucsc.edu/chemistry/li/teaching/chem268/Spectroscopic%20techniques.pdf>

This document contains a brief overview of 9 types of spectroscopy at the second-year undergraduate level. It is appropriate for background information for a teacher.