X-rays – The Friendly Photons!

An Energy-Dispersive X-ray Microanalysis Enrichment

Field Experience for High School Physics Classes

CCMR Research Experience for Teachers I
Summer 2004

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Support for Cornell Center for Materials Research is provided through NSF Grant DMR-0079992

Acknowledgements

Development of this field experience would not have been possible without the financial, technical and logistical support of the Cornell Center for Materials research, particularly Nev Singhota, the Educational Programs Director for the Center.

I would like to especially thank Mr. John Hunt, Facility Manager of the Cornell University Electron and Optical Microscopy Facility, and Dr. Maura Weathers, X-ray Diffraction Facility Manager, for their assistance in providing materials for this lesson.

Connection to NYS Regents Physics Core Curriculum Guide

Performance Indicator 5.3 Students can compare energy relationships within an atom's nucleus to those outside the nucleus.

Major Understandings:

- 5.3a States of matter and energy are restricted to discrete values (quantized).
- 5.3c On the atomic level, energy is emitted or absorbed in discrete packets called photons.
- 5.3d The energy of a photon is proportional to its frequency.
- 5.3e On the atomic level, energy and matter exhibit the characteristics of both waves and particles.

Process Skills:

- 5.3i Interpret energy-level diagrams.
- 5.3ii Correlate spectral lines with an energy-level diagram.

Context

You can't teach in a vacuum. All too often, students are the recipients of content in science classrooms without any real meaning attached. It is imperative that we (science educators) make efforts to tie our content to real world applications whenever possible. We must stress why what we teach is important. This field experience is an enrichment activity designed to contextualize modern physics content from the New York State Regents Physics Core Curriculum Guide (listed above). More specifically, students are expected to be familiar with energy level diagrams for hydrogen and mercury, and must be able to determine photon energies due to electron energy level transitions. Ideally, this experience would take place after students had been exposed to this content, so that they could then witness a common, yet important, application of it in modern material science and research.

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Premise of Lesson

During my RET I experience, I noticed that characteristic X-rays were commonly used to determine sample compositions in many of the electron microscopes and the microprobe analyzer. NYS Regents physics students are required to learn about photons and calculate photon energies given certain electron energy level transitions. Since characteristic X-rays are emitted due to similar electron transitions in the atoms of samples, I developed this enrichment activity to place this curriculum into a realistic and worthwhile context and expose my students to Materials Science.

Field Experience Overview

1. Students complete lessons covering requisite NYS Physics Core Curriculum concerning Performance Indicator 5.3 (at the discretion of the individual physics instructor).

2. Students view PowerPoint presentation "EM and EDXA presentation.ppt."

3. Students travel to Cornell University and split up into small groups among various microscopy facilities; specifically, the UHV-STEM facility, the Optical and Electron Microscopy facility, and the X-ray Diffraction Facility. During the day, students rotate between facilities (recommend 1 hour minimum at each facility).

4. At each facility (except the X-ray Diffraction Facility), students are briefed on the basic operation and capabilities of each microscope, with careful attention paid to how characteristic X-rays are used to determine sample compositions.

5. Students will observe some X-ray graphs of prepared specimens at the various facilities (except the X-ray Diffraction Facility) and use periodic tables of X-ray emission energies to verify results.

6. In the X-ray Diffraction Facility, students will complete the "X-ray Diffraction Activity."

   - In this activity, students will be introduced to the X-ray powder Diffractometer and the general operation of the X-ray Source tube will be discussed.

   - Students will not be told which metal is the source of the X-rays in the tube.

   - Students will be given only the wavelength, in Angstroms, of the characteristic X-rays ($K\alpha$) given off from the tube.

   - Students will then determine the energy and frequency of the photons, and the name of the metal in the tube.

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7. Upon completion of the experience, students will complete the EDX Field Experience Post Assessment.

Instructor Information

Useful Information for X-Ray Diffraction

Radiation	$K_{\alpha 1}$	$K_{\alpha 2}$	$K_{\beta 1}$	Filter
Silver	0.55936	0.56377	0.49701	Rhodium
Molybdenum	0.70926	0.71354	0.63225	Zirconium
Zinc	1.43511	1.43894	1.29522	Copper
Copper	1.54051	1.54433	1.39217	Nickel
Nickel	1.65784	1.66169	1.50010	Cobalt
Cobalt	1.78892	1.79278	1.62075	Iron
Iron	1.93597	1.93991	1.75653	Manganese
Chromium	2.28962	2.29351	2.08480	Vanadium

$n\lambda = 2d \sin \Theta$ $d = \frac{\lambda}{2 \sin \Theta}$

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These are the metals in the different X-ray source tubes that could be used for the X-ray Diffraction Activity, along with their corresponding Kα wavelengths. Copper is very commonly used, so this would more than likely be the source installed on the machine.

References

The following internet resources were used in the development of this lab. All websites were active as of August 2004.

http://www2.rgu.ac.uk/life_semweb/xray.html
http://www.thermo.com
http://www.edax.com
http://xdb.lbl.gov
http://www.semiconfareast.com/edxwdx.htm
http://www.mos.org/sln/sem/seminfo.html

The following reference was also used in the development of this lab.

Energy-Dispersive X-ray Microanalysis: An Introduction, 1989, Kevex Instruments, Inc., San Carlos, California

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