X-Ray Fluorescence

1 Introduction

When a vacancy is created in one of the electron energy shells in an atom, an electron from a higher energy shell will fill that vacancy. The excess energy is emitted as a photon. If the photon has an energy from 100 eV to 100 keV, it is usually classified as a x-ray although detection difficulties put the lower limit at 1.0 keV. Photons of this energy are the result of a vacancy in the innermost shell of Sodium.

The transitions between discrete energy states are in general different for all elements so the photons from all the elements have a unique energy. For example the x-ray which results from removing the innermost electron in Cu has an energy of 8.047 keV, while the adjacent element Ni produces an x-ray of energy 7.477 keV. This uniqueness permits the identification of chemical elements in a sample, subject to instrument resolution (the ability to separate nearby peaks) and sensitivity (the minimum detectable amount of an element).

Figure 1 shows the transitions in the atom which produce the x-rays. Note that any transition which ends on the K shell will be called a \( k \) x-ray. If the transition to the K shell came from the M shell, the x-ray is called \( k_{\alpha} \); if the transition came from the N shell, the x-ray is called \( k_{\beta} \).

![X-Ray Series Diagram]

Fig. 1 X-Ray Series

2 Theory:

In this experiment you will use the low energy gamma-rays from a shielded radioactive source to remove electrons from the sample under investigation. All that is required is for the gamma-rays to have an energy greater than the binding energy of the electron you want to remove. When the sample is bombarded by these gamma-rays of sufficient energy, vacancies will be created in general in all the shells. The vacancies in the K shell will produce x-rays each with an energy which is characteristic of the element from which it came.
3 Detector

The detector is a lithium-drifted silicon detector. Lithium is drifted into the p-type silicon to form a p-n junction diode. Under the conditions of reverse bias on the diode, a photon interacting within the intrinsic region frees electrons and holes (charge carriers) which are swept to the collecting electrodes by the electric field. The charge collected in one electronic charge ($1.6 \times 10^{-19} \text{ coul.}$) for every 3.5 eV of incident photon energy. The detector is operated at liquid nitrogen temperatures to reduce the noise due to the thermal release of electrons. The Si(Li) crystal is also kept in a vacuum. There is a thin (0.0125 mm) Beryllium entrance window for the x-rays. It is very fragile and should never be touched! Electronics then amplify and digitize the electrical signal. A computer plots the number of x-rays detected versus their energy. A correct calibration permits the immediate identification of the chemical element by comparing the measured energy of x-rays with known values from all the elements.

4 Experimental Procedure

Obtain a set of samples from the laboratory instructor and place them in a sample holder (if they are not already in holders). Start the data collection in the multi-channel analyzer. When the data collection phase is over, you will see a display on the computer screen. The plot is intensity versus energy. You can move a cursor along and position it over a peak. The digital display will indicate the energy. Using the energy and the K/L x-ray tables, identify the unknowns in the sample. Place your sample in the sample holder and obtain a spectrum. Determine the chemical elements in your sample.