CONSIDERATIONS REGARDING THE X-RAY FLUORESCENT SPECTROMETRY

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ABSTRACT: X-ray spectrometry is a technique that detects and measures photons or light particles that have visible wavelengths in the X-ray portion of the electromagnetic spectrum. It is used to help us understand the chemical and atomic properties of an object.
There are several types of X-ray spectrometry methods that are used in many disciplines of science and technology, including archeology, astronomy, and engineering. These methods can be used independently or together to create a more complete picture of the material or object being analyzed.
KEY WORDS: spectrometry, parameters, X-rays

1. INTRODUCTION

X-rays are a type of electromagnetic radiation. They are artificially produced in a cathode ray tube, where a hot cathode emits electrons that are accelerated by a high electrical voltage to hit a metal target at high speed and produce "invisible rays".

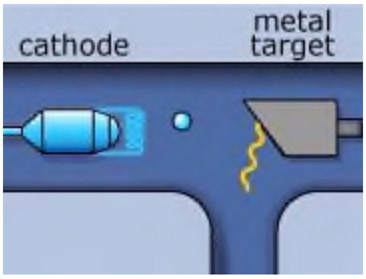

Fig. 1

These rays are partly the result of excited fluorescence in the metal, and partly what is called the Bremsstrahlung radiation effect. The latter occurs as a result of the rapid change of direction of the electrons in the vicinity of the atomic nuclei of the metal Another way X-rays can be produced is when the high initial energy of one electron removes another electron from the inner layers. Then an electron in the upper layers will pass into the vacant place and the excess energy will be emitted in the form of an X-ray.

In an X-ray tube, electrons are accelerated to an energy of 30 to 150 keV to hit a Tungsten target that produces X-rays from 1 eV to 150 keV with a maximum intensity between these values and two peaks at 59 and 67 keV (electronic transitions in tungsten atoms). X-rays with lower energies are used for medical applications for safety reasons. For soft tissues, for example mammograms, a typical energy is 20 keV, while for hard tissues (bones) higher energies are used (around 150 keV).
Although known for medical diagnostic applications, X-rays are the basis of several methods of analytical measurement, including X-ray fluorescence spectrometry (XRF).

Using X-ray sopectrometry, the chemical composition of a material can be determined. This method is based on identifying the chemical elements in a substance and quantifying the amount of chemical elements present. An element is defined by the characteristic wavelength of the emitted X-rays (λ) f or by the energy of the radiation (E). The quantity of each element present in the substance is measured by measuring the intensity of the spectrum of its characteristic line.

It is well known that all atoms have a fixed number of electrons, which orbit around the nucleus. The number of electrons in the atom is equal to the number of protons (particles tested with positive charges in the nucleus). In the periodic table of elements (Mendeleev) the atomic number is represented by the number of protons, each atomic number being associated with a certain chemical element.

XRF spectrometry typically uses the activity of electrons located in the first 3 orbitals, meaning the K, L and M lines, where K is the closest nucleus line. Each electronic orbital corresponds to a specific level of different energies for a given level.

In XRF spectrometry, high-energy primary photons are emitted by a source (X-ray tube or radioisotope) and strike the sample.

The primary photons emitted by the X-ray source have enough energy to remove electrons from their nearest orbital lines (K or L). If this happens, the atoms become energetically unstable ions. Electrons seek stability, so an electron in an upper orbital L or M occupies the vacant space in the orbital closest to the nucleus, emitting energy in the form of a secondary X-ray photon.

This phenomenon is called fluorescent, as can be seen in figure 2.

The secondary X-ray photon emitted is characteristic of a certain specific element. The energy (E) of the secondary emission is determined as the difference of energies between the initial and the final orbital for the individual transitions. This is described using formula (1):

$$E=hc/\lambda, \quad (1)$$

where λ is the Planck's constant, c is the speed of light and λ is the characteristic wavelength of that photon.

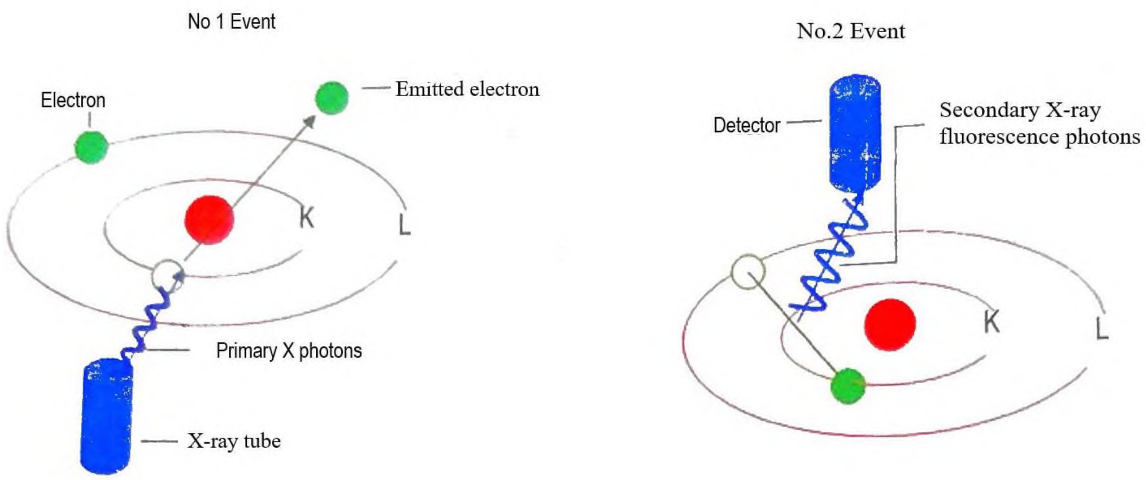

Fig. 2 The principle of fluorescence

2. CREATION OF A SECONDARY X-RADIATION. FLUORESCENT PHOTON

It is well known that the wavelengths of photons are inversely proportional to the energies and are characteristic of each chemical element.

For example the energy Ka for iron (Fe) is about 6.4 keV. This is the basic principle of XRF spectrometry: it measures the intensity of X-rays specific to an element in a sample, ie the number of emissions in a time interval.

Thus, the quantity of a certain element present in the study sample is determined.
In the typical spectra for EDXRF spectrometry, the intensity (I) is represented graphically as a function of energy (E), as in figure 3.

XRF technology is a surface analysis technology in which X-rays penetrate most alloy samples over very short distances. The analyzer detects what is on the surface of the alloy, not what the material itself is composed of. If the material is painted, coated or galvanized, or has been subjected to a surface treatment, such as hardening, the identification of the elements of which the material is composed may not take place.

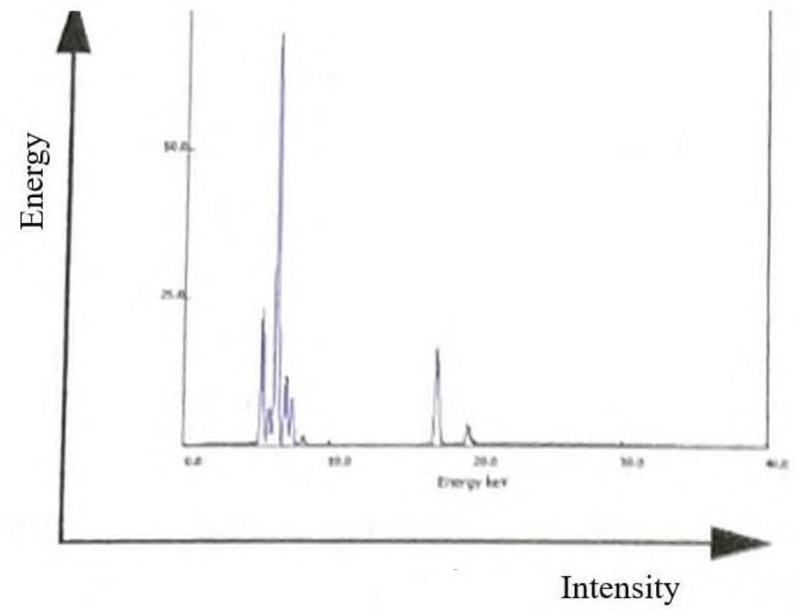

Fig. 3. Characteristic spectrum: Energy vs Intensity

3. EDXRF SPECTROMETERS

EDXRF analyzers are very simple devices from a mechanical point of view, there is no moving component in excitation substances and detectives. However, a laboratory analyzer may have a moving component.
An EDRXF instrument fypically has three major subsystems, as in figure 4:

Compared to WDXRF systems, EDXRF systems have the following attributes:
- ease of use
- short analysis time
- lower initial purchase price
- low long-term maintenance costs

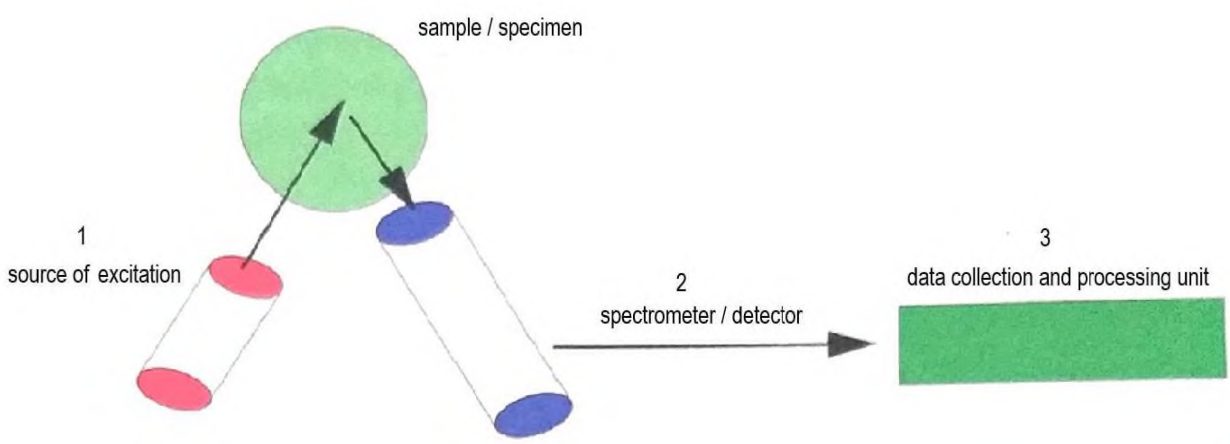

Fig. 4. EDXRF analyzer subsystem

CONCLUSIONS

XRF spectrophotometry has the following advantages:

- quickly, easily identifies and quantifies elements in a wide range of concentrations from PPM levels up to 100 percent of the sample mass.
- it is a non-destructive examination
- the final result is fast: the preparation time of the sample if any is short, and the results are available in a few seconds or minutes for a better detail.
- reduced cost per test

XRF spectrophotometers are useful for several applications: environmental analysis, sorting of waste alloys, forensics, archaeometry.

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