THE GEIGER COUNTER X-RAY SPECTROMETER

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The Geiger Counter X-ray Spectrometer is a research physicist's tool which has recently been successfully adapted to commercial manufacture and use, and is found to be invaluable in many testing, quality control, and analysis jobs in modern industry. It is reliable, safe and easy to operate and extremely sensitive, being able to detect almost unbelievably small traces of chemicals in a matter of minutes. The X-ray spectrometer is analogaus, in many ways, to an ordinary optical spectrometer. The X-rays pass from the target of the X-ray tube through a collimating slit or set of slits and impinge upon a crystal face, held at an angle to the incident beam. The X-ray beam is then reflected (more properly diffracted) by the crystal, passes through more slits and finally strikes a Geiger counter which measures the beam intensity.

The X-ray beam produced by the X-ray tube is composed of many different wave lengths of X-rays, corresponding to various colors of light. The wave length of the X-rays is only of the order of one Angstrom unit, however, whereas that of light is from 4,000 to 8,000 Angstrom units (an Angstrom unit is 10^{-8} cm.). In the case of light, ruled gratings can be made with as many as 25,000 or more lines per inch to use to diffract the light. For X-rays, however, since the wave length is so very much shorter, there would have to be around a quarter of a billion lines per inch. Since no one yet has been able to make ruled gratings of this type, crystals of various kinds are used. These have rows of atoms, ions or molecules spaced at just about the right distance so that the crystal will act as a ruled grating for X-rays.

For any given angle between the X-ray beam and the crystal face there will be one particular wave length (or color) of X-rays refracted. By rotating the crystal the X-rays of many wave lengths will be diffracted each at it's own characteristic angle. Only the angle need be measured to identify the particular X-ray wavelength.

The X-ray intensities may be measured in several ways, but the Geiger counter is the most sensitive. With this instrument one may actually count each individual X-ray quantum, or wave-packet. It consists of a metal cylinder with a fine wire stretched down the axis. The whole thing is enclosed in a glass envelope and filled with various gases, depending on the particular use to which it is to be put. Then the metal cylinder is connected to a high voltage source. Now, if any ionizing radiation, such as X-rays, alpha, beta, or gamma rays, or cosmic rays should happen into the cylinder and ionize any of the gas, the ionized particles will rush toward the center wire or the cylinder, depending on their charge. If the voltage is sufficiently high they will collide with other gas molecules, ionizing them, and these new ions will ionize still more, and so on. Now, instead of a single X-ray quantum there is a tremendous avalanche of charged particles striking the center wire (and the cylinder) and thus actuating a meter or other recording instrument. These counters usually have a very thin window, of glass, aluminum or some special substance, at the end of the tube to permit the ionizing rays to enter the tube. Naturally, the more intense the beam of X-rays, the more quanta, and therefore the more ionizations and counts by the Geiger counter. Some tubes will count intensities as high as 3,000 quanta per second.

There are three methods of introducing the material to be analyzed.

1. It can be used as the target in the X-ray tube itself. This is an inconvenient method and is seldom used except in research. The meth- depends on the principle that different materials produce different kinds of X-ray spectra.
2. The material to be investigated can be used as the crystal to refract the X-rays. This is the usual method used. Various crystals, having various-sized molecules, spaced in different patterns and at different distances, will refract a known beam of X-rays into various spectra, which may be analyzed to determine many of the characteristics of the crystal used. If the substance does not occur in large single crystals, it may be powdered and the powder glued to a plate and used as a crystal. At least some of the myraid of tiny crystals thus produced will always be oriented correctly to give the right angle of incidence needed for the spectrum.
3. The material may be introduced into the path of the beam in a thin film or sheet. This will tbsorb some of the X-ray wave lengths, but not others, giving an absorption spectrum characteristic of the material.

The advantages of this method over photographic methods of analysis previously used are many. The Geiger counter affords a sensitivity far beyond any photographic plate. It is thought that at least 10,000 quanta are needed to make a barely discernible photographic spectrum line. The intensity of this same line could be measured with a Geiger counter to an accuracy of one per cent! This astounding sensitivity can be used either to improve accuracy, increase sensitivity, or cut down on time required for analysis. It does not require exensive accessory equipment, darkrooms, plumbing, microphotom ers, etc., and skilled operators for d velopment of film, nor the necessari long time to develop the film before r sults are known. No corrections a needed for film sensitivity, or for fi shrinkage. The instrument is a fo proof and as safe as modern enginee ing can make it—which is to say th it would take real effort to be injur by it. There are only a few contro easily operated.

There are limitations, however. Se eral factors introduce inaccuracies the results. The X-ray beam is partia ly absorbed in the X-ray tube windo in the atmosphere in the beam pat and in the window of the counter tub These things and the natural bac ground due to cosmic rays and eve present natural radioactivity, preve absolute measurements from bei made. Since these factors are ordinari constant, comparative results are n affected by them, and they are not in portant for practical purposes.

The Geiger counter will not functic accurately above 3,000 counts per se ond. This fact limits the intensi which can be measured, as the mechan cal and electronic circuits associate have a much better resolution than th counter. This too, is unimportant f practical purposes, as few spectral lin are more intense than this and if the are, absorbing filters and various size collimating slits may be used to de crease the amplitude.

A more serious limitation is the fa that only crystalline materials may b examined. However, a surprising num ber of substances are crystalline i character, including many chemical metals, soaps, paraffins, constituents c paints, minerals, etc. Absorption mea surements are not limited by the re quirement that the material be crystal line, and solids, liquids, or gases may b handled with almost equal facility. Th development of this spectrometer mark a considerable advance in the use o X-rays industrially.