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ANALYSIS OF EVIDENCE WITH SPECIAL EMPHASIS ON THE DETECTION OF POISONS

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An understanding by police investigators of the workings of a laboratory engaged in analyzing evidence is essential for the effective use of the evidence in combating crime. The investigation of crimes with the aid of laboratory methods involves so many specialized tests that it is not possible in this discussion to do more than highlight a few procedures by describing the methods which are used to detect poisons. A variety of chemical methods as well as instrumental methods which measure some chemical or physical property are available for this type of examination, and the application of these procedures to the analysis of evidence in general will become obvious as we develop the discussion.

If the analyst were called upon to investigate homicides by poisoning only, he would not be kept very busy. It is a matter of interest that of the approximately 1,500,000 deaths which occur each year in the U. S. about 9,000 or 0.6 per cent are homicidal in nature, and only 45 of these are due directly to the use of poison. Many tests for poisons have been made for a variety of reasons locally, but in the last twenty years only three cases have resulted in indictments for homicide. Nevertheless, a laboratory investigating crime is kept busy performing tests for the detection of poisons. The reason for this is apparent from the data in Table I wherein are listed the causes of death that generally result in an investigation to rule out the possibility of a homicide masquerading as an accident or as a suicide.

Whether any material reaches the laboratory for examination depends on the circumstances surrounding a death and the skill of the examiner in unearthing evidence that arouses a suspicion of foul play. Once material, particularly that collected at autopsy, reaches a laboratory that is properly equipped and staffed, there is little chance that a homicide by poisoning will escape detection. This is in marked contrast to conditions which existed until the middle of the 19th century when poisoners were generally apprehended only as a result of a confession—often extracted by torture.

The advances in chemical technology in general, and the development of certain instrumental methods of analysis have placed in the hands of the analyst powerful and effective tools for detecting poisons. Modern chemical technology results in the introduction each year of many new materials. Some of them have toxic properties when used in excess, and one of the functions of the analyst, therefore, is to keep

TABLE I

ESTIMATED DEATHS BY A NUMBER OF CAUSES IN THE UNITED STATES AND IN OHIO IN 1954

	U. S.	Ohio
Total (all causes)	1,500,000	82,000
Motor vehicle accidents (2.2%)	33,000	1,800
Other accidents (4%)	60,000	3,200
Suicides (1.2%)	18,000	980
Homicides (0.6%)	9,000	400

abreast of these developments and to learn how to detect the newer materials when the need arises. Fortunately, the powerful poisons are hard to come by without attracting attention, and some can be obtained only on a doctor's prescription. A person planning a homicide by poison is limited, therefore, to the use of the few materials that he can obtain without arousing suspicion. Among them are those that he can easily come by because of his occupation (cyanide, arsenic, etc.) or by purchase in practically every grocery or hardware store because of their use in the household as bactericides, insecticides, or rodenticides.

The mere presence of a poison in an organ is not sufficient to prove that death by poisoning has occurred. Many materials which are powerful poisons when used in excess may be detected in certain organs because of their therapeutic use, exposure in industry, or their presence in trace amounts in the normal organism. Lead, arsenic, and mercury, among the metallic poisons, and the barbiturates and alkaloids of the organic or vegetable poisons are examples of these types of materials. The causal relationship to death, therefore, is a matter of the total quantity of the poison in the body, rather than its mere presence, and the evidence presented in court must establish the fact that the amount was sufficient to cause the death. The data of Table II illustrate the type of evidence used to aid in the conviction of the perpetrators of two homicides by arsenical poisoning. Approximately two grains (128 mgs.) of arsenic trioxide is considered a fatal dose for an adult; 6 grains were recovered from the organs of J. S. and 7 grains of arsenic trioxide were found to be present in the body of H. D.

TABLE II

THE DISTRIBUTION OF ARSENIC TRIOXIDE (IN MILLIGRAMS) IN THE ORGANS AND THE TOTAL QUANTITIES IN THE BODIES OF TWO VICTIMS OF POISONING

Organ	J. W.	H. D.
Liver	49.50	173.38
Brain	9.85	2.08
Muscle	135.00	166.23
Kidneys	9.84	8.93
Lungs	20.10	3.13
Heart	4.70	1.90
Bones		33.22
Blood		1.89
Total Quantity*	377.45	449.44

* Includes analysis of miscellaneous material omitted from the listing.

Now let us see how a modern toxicological laboratory analyzes material for the presence of poisons. For analytical purposes, poisons are generally divided into classes according to the methods which are used to isolate them. The general classification is as follows:

1. *Heavy metals:* Arsenic, mercury, lead, thallium, cadmium, etc.
2. *Volatile poisons:* Alcohols, cyanide, chloral hydrate, elemental phosphorus, phenols, aniline, etc.—carbon monoxide by aeration.
3. *Non-volatile organic poisons:* Alkaloids, barbiturates, glucosides, oxalate, etc.
4. *Inorganic poisons:* Fluorides, etc.

Methods based on the chemical or physical properties of the toxic material are employed most frequently to identify a poison following its isolation from an organ or other material. Many of the methods are examples of classic chemical tests of value for identifying a class of compound (alkaloid, barbiturate, alcohol, etc.) and are in universal use for this purpose. Sometimes, however, the requirements imposed by the need for greater speed of analysis, greater specificity and sensitivity of detection, or the inability to handle small samples, limit the usefulness of the chemical methods and call for the application of instrumental methods which have been developed to measure rapidly and accurately certain chemical and physical properties of matter.

The Microscope

The ordinary visual microscope is one of the most useful instruments that is applied to the examination of material. Many poisons can be identified by their structure and physical condition when they are observed either in pure form or when reacted to form a characteristic compound. Microscopes of varying types are also used to identify and compare fibers, hair, dusts, paints, floor sweepings, bullet markings and for the examination of various types of micro evidence. No laboratory engaged in the investigation of crimes can operate without adequate microscopic equipment.

The Spectrograph

The spectrograph is an instrument found in many research laboratories. Although it is not essential for the operation of the ordinary toxicological laboratory, its use, when it is available, facilitates the examination of certain material. It is in common use for making rapid analyses, particularly when many tests are to be made daily.

The instrument analyzes light, and therefore, material that can be vaporized in an electric arc (or a flame) can be identified from the characteristic colors imparted to the flame. A prism (or grating) separates the colors so that their positions can be observed with an eyepiece or they can be photographed as lines on a plate (Figure 2). When a quartz prism is employed, bands not visible to the eye can also be recorded, and it is this type of instrument (and the grating type) which is most useful for analytical work. A view of the entrance slit and photographic end of a large quartz Littrow spectrograph is given in Figure 1.

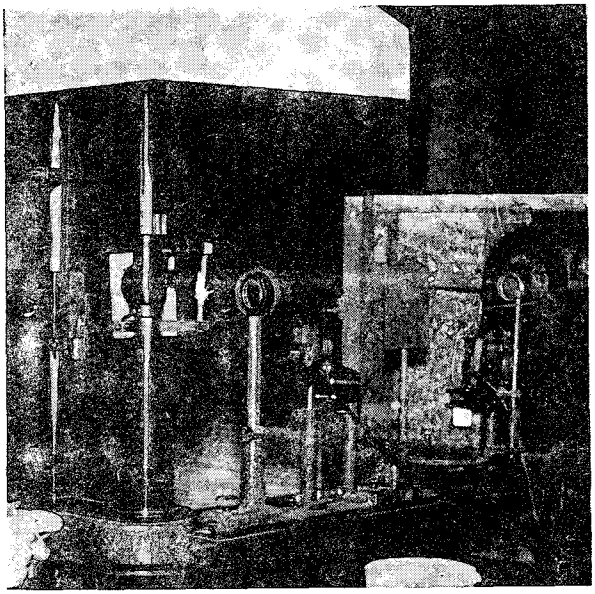

Figure 1

A view of the entrance-slit end of a large quartz Littrow spectrograph, showing the arcing stand used to vaporize the test material.

Since seventy of the total number of ninety-six or so elements are amenable to spectrographic analysis, the usefulness of the method is readily apparent. The instrument identifies only the elemental composition of a material and not its molecular structure. For example, in the compound arsenic trioxide, only arsenic would be detected. The method is also quantitative since within certain limits, the blackness of a line is a measure of the concentration of the element in question. The method is one of the most specific of analytical procedures, and a trained operator will not confuse an identification.

The instrument is used extensively for making preliminary exploratory examinations of tissues, body liquids, dusts, and other matter. One or two exposures will cover the regions in which the characteristic lines of most of the metals occur, and as the instrument is quite sensitive one can tell rapidly whether a heavy metal (arsenic, mercury, antimony, lead, cadmium, etc.) is present in an amount that could have produced illness or even death. Subsequently, a quantitative determination of the toxic material can be made either chemically or spectrographically.

The spectrographic examination gives information which can be used to incriminate a suspect or to prove his innocence. Thus in a recent homicide of poisoning with arsenic, a white powder was found in the glove-compartment of a suspect's car. The spectrum of this powder is shown in Figure 2 where it may be seen that the powder did indeed contain some arsenic. However, the large quantity of lead and the weakness of the arsenic lines along with the finding of normal levels of lead in the tissues of the victim indicated that this powder was not the homicidal agent. The weak lines

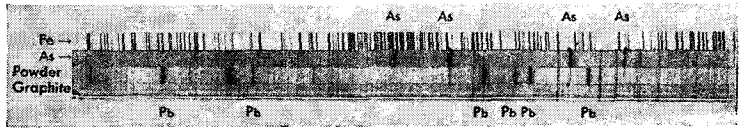

Figure 2

Part of the spectrogram of white powder taken from a suspect and compared with the spectrograms of arsenic trioxide (As_2O_3) and of a pure graphite electrode. Some lines due to lead and arsenic are indicated.

of arsenic suggested that this metal was an impurity in the lead compound that was investigated further to establish its identity (see section on X-Ray Analysis).

In the same case, a bottle carrying a label of a commercially prepared rat poison called "Zip" containing a small amount of dried material and a bottle of a colorless liquid, suspected to be a diluted solution of the "Zip" found on the premises were also examined spectrographically. The residue and the liquid both contained large amounts of arsenic, and traces of antimony, an impurity commonly found in preparations of arsenic trioxide. Therefore, if this material had been used in the homicide, traces of antimony should have been present in the tissues of the victim. When the liver was re-examined in light of this information, a significant trace of antimony, a metal not normally present in biologic material, was found. The result of this examination of a material known to have been in the suspect's possession and the related analyses, were very useful links in the chain of evidence which convicted the poisoner.

Spectrophotometers

Colored substances are those in which the colors or wave lengths of light, except that seen, have been absorbed. The wave lengths of light that are absorbed characterize the absorbing material, and the instruments which are used to determine these special spectral regions are called spectrophotometers. The instruments most commonly used are specialized photoelectric adaptations of the spectroscope designed to measure absorptions in the visible, ultraviolet, or infrared spectral regions. Instruments provided with quartz prisms measure the visible, ultraviolet, and the near infrared regions while those provided with reflecting gratings extend the measurement into the longer wave lengths of the infrared region. The infrared region is also measured in special instruments, with optics which are made from rock salt, sylvine, potassium bromide, or other transmitting material depending on the spectral region to be covered. The ultraviolet and infrared regions are particularly important for the identification of the many colorless compounds which absorb wave lengths of light in these regions.

Spectrophotometric equipment is most commonly applied to the quantitative analysis of constituents by colorimetric procedures or by their selective absorption in the ultraviolet or infrared regions. The instruments are particularly useful for the examination of colored substances such as dyes, inks, lacquers, etc. (Soluble dye pigments such as are present in many automobile lacquers may be identified from their absorption patterns.) The identification of a material is usually made by comparing the absorption pattern with the patterns of pure known materials.

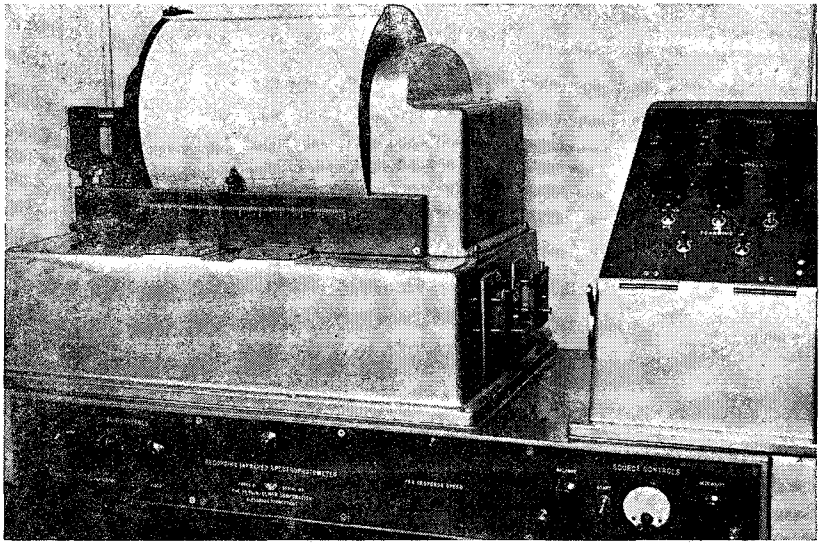

Figure 3

A Perkin-Elmer Model 21C, infrared spectrophotometer.

A Beckman quartz spectrophotometer can be used in the visible, ultraviolet, and near infrared regions. A Perkin-Elmer, Model 21 C, spectrophotometer for use in measuring absorptions in the infrared region is shown in Figure 3. Figure 4 records the results of the infrared examination of two liquids that were suspected of being

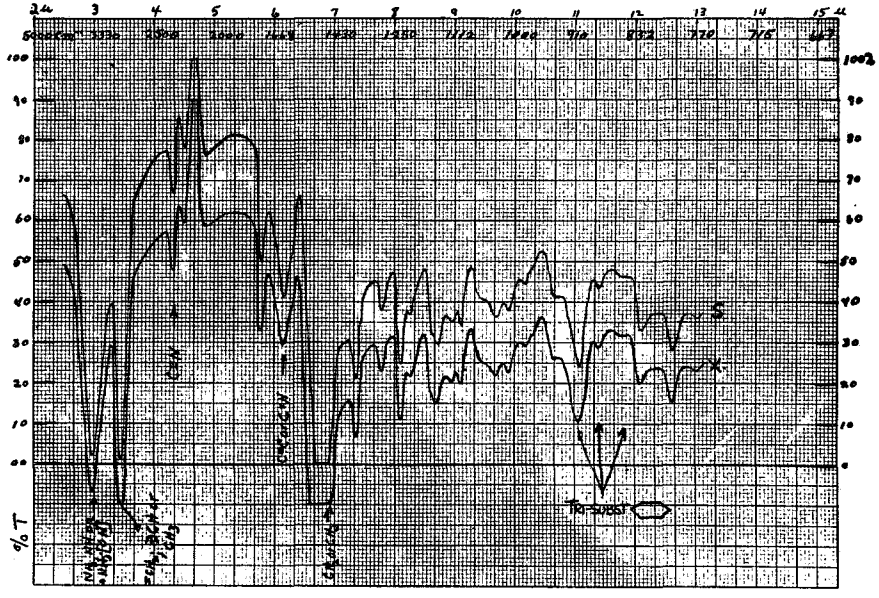

Figure 4

A comparison of the infrared absorption patterns of two liquids suspected of being similar in nature. Pattern for X has been displaced for convenience in comparing the patterns.

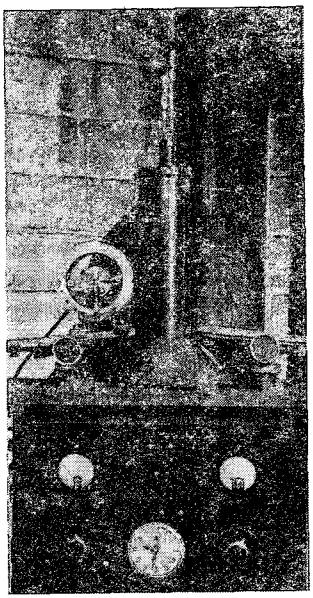

Figure 5
A General Electric, XRD-1, X-Ray Diffraction Unit and XRD Powder Camera.

similar in nature and of having been used in a criminal abortion. One of the liquids was found in the patient's home, the other in the office of the doctor. While a lack of a reference pattern did not permit an exact identification of the nature of the liquid, the similarity in the two patterns is so striking that there can be no doubt that the two liquids are identical in nature.

X-Ray Diffraction Apparatus

In the section describing the use of the spectrograph mention was made that a powder of a lead compound was examined to determine its nature. This could have been accomplished by laborious chemical tests, but in this case it was done quickly and accurately by x-ray diffraction analysis. X-ray diffraction methods are used most commonly to identify the nature of powders from the wave lengths of the light diffracted due to the internal structure of crystals. The x-ray diffraction technique, therefore, provides information which permits interpretation on how a particular crystal is built from atomic units. A photographic type of instrument that provides this type of information is illustrated in Figure 5. Rays from the x-ray tube or source are focused on the powder placed at the center of the circular device which is the camera of the instrument. The rays refracted from the crystal planes of the powdered material are then photographed on a film lining the inner periphery of the camera. The positions (wave lengths) of these lines on the film identify the crystals. Different crystalline forms of even the same molecular composition will have different x-ray diffraction patterns. By measuring the wave lengths of the lines in the spectrum of the unknown, and comparing the pattern with the x-ray diffraction patterns of the

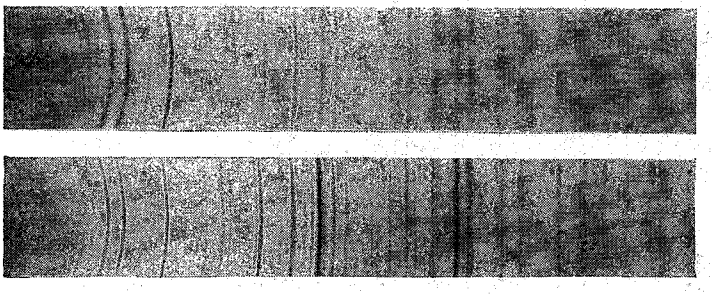

Figure 6

Comparison of x-ray diffraction patterns of a white powder identified as lead acetate (upper pattern) and of a sample of pure lead acetate (lower pattern).

many compounds that have been published as reference spectra, one can usually identify the material.

In the case of the lead compound referred to above, the x-ray diffraction pattern shown in Figure 6 revealed that the material was "sugar of lead" or lead acetate. The x-ray diffraction pattern of the "unknown" is shown above that of a sample of "sugar of lead" in order to indicate the perfect coincidence of all of the lines in the patterns of the two materials.

Other Instruments

A number of other instrumental methods are also useful for the analysis of evidence. The electron microscope, for instance, can be used to characterize a dust as to size and form and even to identify its crystalline nature if it is provided with accessory equipment that permits the collection of electron diffraction data. A single small crystal may often be identified in this manner.

Polarography, a form of electro-analysis is used in many laboratories as a substitute for spectrographic equipment for identifying the metals and other material.

In addition to the actual procedures and equipment necessary to perform the analyses which may be requested from the laboratory, the crime investigator is naturally interested in knowing how quickly the results of a toxicologic examination can be reported. If the cause of death is not obvious and a suspicion of poisoning arises, a painstaking search is involved. This thorough examination is extremely difficult and time-consuming and may require anywhere from 2 to 4 weeks of painstaking work if all of the possibilities are to be investigated. Where a test for a poison is indicated by the symptoms or by the findings of the autopsy surgeon, the examination is much simpler, and sometimes the report is available in a matter of a few hours or in some special cases even minutes. The best example of the latter case is furnished by the application of accelerated spectrographic techniques to detect the presence of the heavy metals in tissues or other evidence.