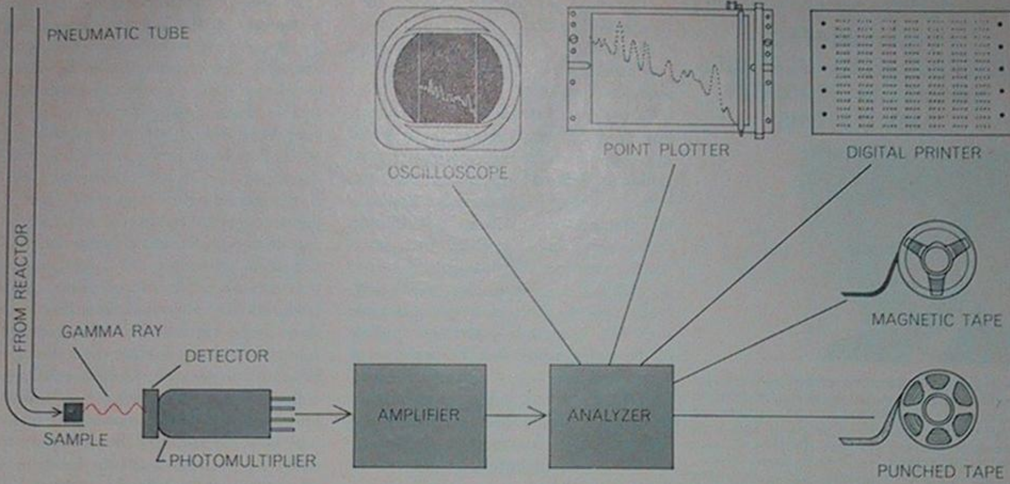

GAMMA RAYS from an activated sample are measured by allowing them to fall on a scintillation detector, which emits photons of visible light whose intensity is directly proportional to the energy of the absorbed gamma ray. The detector is coupled to a photomultiplier tube, which detects the light emissions and converts them into electronic pulses. The pulses are amplified before being fed into a multichannel pulse-height analyzer, which sorts them into a record of the energy distribution of the original gamma rays. The gamma ray data can be "read out" of the analyzer in a number of ways, some of which are represented schematically in illustration.

concentration at levels down to as little as 10 times the lower limit of detection. Analyses with an accuracy of better than 1 percent of the actual value are possible but extremely difficult to attain by this technique. As a result the neutron-activation technique is most widely used for trace-element analysis where an accuracy of from 2 to 5 percent is permissible.

One of the most fascinating applications of neutron-activation analysis in recent years was undertaken in 1961 by two Swedish physicians, Sten Forshufvud and Anders Wassén, in collaboration with Hamilton Smith of the Department of Forensic Medicine at the University of Glasgow. For a long time medical writers have doubted the official diagnosis of cancer as the cause of Napoleon's death in exile on the island of St. Helena in 1821. On the basis of the recorded symptoms a number of alternative diagnoses have been proposed, including peptic ulcer, malaria, dysentery, syphilis and gonorrhea. In order to test the hypothesis that Napoleon had in reality been poisoned, Forshufvud and his co-workers obtained well-documented samples of Napoleon's hair, which was shaved from his head the night after he died, apparently to provide as much hair as possible for distribution as souvenirs and to facilitate the making of a death mask. Several of the samples were irradiated with neutrons in a nuclear reactor. Consecutive half-millimeter lengths of rather long hairs were then analyzed for the presence of arsenic. The concentration of arsenic in the segments was found to be much higher than that in normal human hair, indicating that Napoleon may have suffered from chronic arsenic intoxication. Moreover, the arsenic content of the consecutive lengths of hair was not uniform, indicating that he was probably exposed to arsenic intermittently. Considering that the average growth of hair on the scalp is about .35 millimeter per day, it was possible to infer that periods of higher arsenic concentration in the hair coincide with days on which Napoleon was reported to be sicker during his captivity. Hence, judging by the arsenic concentration in hair found in healthy people today, it seems likely that Napoleon died from arsenic poisoning, the arsenic being administered at intervals during his illness.

Neutron-activation analysis has also been used in an attempt to date and authenticate old paintings. One method is to measure the concentrations of various trace elements in white lead paint, which has been used as a primer and white pigment since the Middle Ages. The purity of white lead is directly related to the purity of the lead used to make the paint. Since the metallurgical techniques for purifying lead have been modified several times during the past five centuries, the trace-element content of the white lead in a particular painting can be used to estimate the age of the painting. Using the neutron-activation technique, Jan Houtman and J. Turkstra of the Reactor Instituut at Delft in the Netherlands have analyzed tiny samples of white lead removed from a number of authentic "old masters" at museums in Belgium and the Netherlands [*see illustration on page 82*].

They have found that the concentrations of copper, silver, mercury and manganese were fairly high and constant in white lead made between 1500 and about 1850; after 1850 these concentrations dropped to about a tenth of their earlier values and have remained low and constant ever since. Similarly, the concentration of chromium was found to be high before 1650 and much lower since 1650. On the other hand, the concentrations of zinc and antimony, which were quite low before 1940, have increased considerably in recent years. The great sensitivity of the neutron-activation technique makes possible a complete analysis using less than a milligram sample of the white lead, which can be obtained from the edge of the painting without causing any noticeable damage. Data obtained by the neutron-activation technique can be used not only to date a painting but also in some cases to determine the identity of the artist by com-