means of the Haldane[38] or Orsat[39] gas burettes; for the determination of radon by means of especially constructed electrometers (page 266); for the determination of nitrogen oxides by the phenoldisulfonic acid method; and for many other determinations. Usually this type of sample is not larger than 1 liter. The sample is readily taken upon opening the bottle to the atmosphere, either by opening a glass stopcock or a pinchcock on a short length of heavy-walled tubing, or by breaking off the tip of a sealed inlet orifice, being careful not to warm the bottle by contact with the hands, and then closing or sealing the orifice.

2. *Samples in Partially Evacuated Bottles*

Samples may be conveniently taken in partially evacuated bottles of any size up to 20 liters. A measured volume of a suitable absorbent liquid is added to a calibrated bottle and the bottle is partially evacuated by a hand pump or other means, the residual partial pressure being recorded. The bottle is opened in the atmosphere to be sampled. It should then be taken to the laboratory, or to an uncontaminated zone, shaken well, and the contents washed into a suitable container with 2 or 3 successive portions of wash solution. After this, analysis may be made by appropriate methods.

The volume of the sample is computed as follows:

$$Vs = (V - A)\frac{P_2 - P_1}{P_2}$$

where Vs = sample volume, V = volume of bottle, A = volume of absorbent added to the bottle, P_1 = residual partial pressure in the bottle, and P_2 = atmospheric pressure at the time and place of sampling.

F. SPECTROMETRY

1. *Infrared*

The infrared spectrometer[40] is a relatively new tool with great possibilities for use in industrial hygiene as a means of recognizing and evaluating organic materials in the air. The basis of application is that practically all organic substances possess selective absorption at certain frequencies in the infrared portion of the spectrum. The essential parts of the apparatus are a heat source emitting a continuous range of the wave lengths desired; a means of dispersing the radiation and providing narrow wave length bands at accurately known wave length positions (for this purpose prisms of sodium chloride, potassium bromide, etc. are supplied); cells for placing a suitable thickness of material for analysis in the path of the radiation; and a detector, such as a sensitive thermocouple and amplifier, for accurately measuring the radiation. Absorption cells of various thicknesses are available, from 0.05 mm for liquids and solids to several centimeters for gases. The size, weight, and complexity of the apparatus do not make it attractive as a portable instrument, and

[38] L. B. Berger and H. H. Schrenk, *U. S. Bur. Mines Circ.* No. 7017 (1938).
[39] W. P. Yant and L. B. Berger, *U. S. Bur. Mines, Miners' Circ.*, No. 34 (1936).
[40] R. B. Barnes, U. Liddel, and V. Z. Williams, *Ind. Eng. Chem., Anal. Ed.*, 15, 659 (1943).

the length of absorption cells would have to be considerably increased to make it suitable for measuring a few p.p.m. of most vapors in air. However, when the material to be analyzed is absorbed or dissolved in a liquid, analysis is readily accomplished, providing a liquid vehicle has been chosen that has no interfering absorption bands in the significant range for the material to be analyzed. The absorption pattern furnishes positive identification of single compounds having a known pattern; furnishes helpful clues to the composition of complex mixtures (superimposed patterns); and identifies linkages, bonds, and groups in obscure compounds. It is a quantitative tool as well, since Beer's law has been found true for this region of the spectrum (the absorption is proportional to the concentration of absorbent in the solution). Many ranges of wave lengths in the spectrum, between visible and ultra short radio waves, have yet to be explored, largely because of the difficulty of generating, controlling, dispersing, and measuring the intensity of these waves.

2. *Ultraviolet*

Several organic solvents, especially in the aromatic series, have characteristic absorption patterns in the ultraviolet region of the spectrum.[41] The patterns can be used to identify very small amounts of solvents, while the opacity of the solvent at specific wave lengths can be used to measure the amounts. As in the case of infrared analysis, a sample must be collected from the air by condensation, by collection on silica gel (page 208), or by scrubbing air through a tenacious nonvolatile solvent that has no interfering absorption pattern. It is frequently necessary to refrigerate the scrubber in order to obtain high collection efficiency.

3. *Light Absorption*

Visible light spectrometry[42] is similar to infrared and ultraviolet spectrometry except that there are fewer compounds having distinctive absorption patterns. In spectrometry accurate results require a source of radiant energy confined to a narrow band of known (calibrated and checked) wave length, recognition and consideration of interfering absorption, and reliable measurement of transmitted energy.

DUSTS, FUMES, AND SMOKES

I. Sampling

The instrument to be employed for sampling and evaluating particulate matter in the atmosphere will depend upon the availability of instruments, place to be sampled, nature of the contaminant, and purpose of the investigation.

A. IMPINGEMENT

There are several dust-sampling instruments that employ the principle of impingement. Dust carried by air at high velocity is impinged against a plate, where it is arrested by an agent such as a film of water or other liquid, gelatin, or grease.

[41] M. E. Maclean, P. J. Jencks, and S. F. Acree, *J. Research Natl. Bur. Standards*, 34, 271 (1945).
[42] M. G. Mellon, *Ind. Eng. Chem., Anal. Ed.*, 17, 81 (1945).