A TESLA DISCHARGE DETECTOR FOR GAS CHROMATOGRAPHY*

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During the course of a spectroscopic study of glow discharges in gases excited by a high frequency Tesla coil source (an ordinary laboratory leak-tester), it became apparent that the properties of the electrodeless Tesla discharge were a very sensitive function of the composition of the gas. A discharge in a carrier gas is visibly altered by small amounts of added vapor. Two new detectors for gas chromatography based upon the properties of such discharges have been developed and offer certain unique advantages over the other means of detection; their greatest advantage is probably in the simplicity and economy of construction of a high sensitivity detector and its associated electrical measuring circuit.

The new detectors utilize measurement of:

(a) the emitted light intensity, and

(b) a direct current signal produced by inserting a pair of probe electrodes asymmetrically in the discharge.

Both detectors can be constructed without elaborate fabrication and with a minimal expenditure for components. Both means of detection can, if desired, be incorporated into a single detector unit without complication; a detector designed for the current measurement can also be used conveniently for measurements of light intensity.

APPARATUS

The discharge tube portion of the detector is simply a glass capillary tube (0.5–2 mm diameter) attached directly to the column exit. A laboratory Tesla coil leak-tester provides the source of excitation of the discharge, which is transmitted through a piece of aluminum foil connected to the high voltage probe terminal (the probe itself is removed and the aluminum foil inserted in the end of the leak-tester in place of the probe) and wrapped around the capillary tubing. A small diameter wire lodged in the capillary and extending downstream from the region encircled by the aluminum foil serves as a low work function source of electrons and stabilizes the discharge, which otherwise would have to depend for initiation upon more difficult removal of electrons from the glass walls.

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The discharge occurs downstream from the end of the inserted wire to a region nearer ground potential. A similar "electrodeless electrode" can serve as the ground, by inserting another free piece of wire in the capillary and surrounding the region of the capillary containing the wire by a grounded piece of aluminum foil. A better ground can be prepared by attaching the capillary to a grounded metal tubing connector, using "O"-ring seals. For the direct current measurement, a brass "T"-tube connector can conveniently be used. The discharge capillary tube is connected to one arm of the "T"-tube; an inner electrode is mounted in glass and connected to the opposite arm of the "T"-tube, with the inner electrode extending within the "T"-tube very nearly to the end of the discharge capillary tube; the third arm of the "T"-tube contains the exit tube, which may be vented to the atmosphere or may lead to a manometer, flow control valve, ballast flask, and vacuum pump or water aspirator. The inner electrode is connected to ground, and the body of the "T"-tube serves as the other electrode for the direct current measurement.

PROPERTIES OF THE DISCHARGE

The Tesla coil sets up a high voltage (about 50 kV), high frequency (about 3 megacycles) electrical field, which initiates and maintains the discharge. A visible glow discharge occurs in air, nitrogen, helium, or argon carriers at reduced pressures, and extends to more than one atmosphere pressure in helium or argon and to about 350 mm in nitrogen and in air. The discharge is visibly altered by even very small quantities of sample gases (organic compounds are particularly characterized by a bright blue-green color, predominantly due to bands of C_2). The visible indication itself provides an excellent qualitative identification of sample bands for lecture demonstrations of gas chromatography or for monitoring preparative column separations in the organic laboratory.

A photoconducting cell (cadmium sulfide or cadmium selenide) mounted on the side of the capillary discharge tube gives convenient and sensitive quantitative light intensity measurement; the circuitry required is a battery-supplied direct current circuit in which the current can be measured directly or the voltage drop across a selected resistor can be observed, using either a dial instrument or a recording potentiometer. The use of filters or a monochromator with the photocell makes possible preferential observation of emission due to the carrier gas or emission due to sample gas fragments (such as C_2, which is generally observed for organic molecules); with observation of carrier gas emission, the quenching by samples is detected, while in observation of sample emission an enhancement of emission indicates presence of a sample in the carrier. Particularly high sensitivity has been observed with argon carrier in a detector at atmospheric pressure. The use of a spectrophotometer equipped with photomultiplier, or of photographic observation of spectra, offers a possible qualitative identification of certain sample components.

The electrical properties of the discharge afford another means of detection. The brass "T"-tube with its inner electrode actually serves as a rectifier of the radio-

frequency Tesla discharge, so that a direct current signal is obtained without an applied voltage; KARMEN AND BOWMAN[1] have reported a similar effect in their radiofrequency discharge detector, which appears to involve very similar operating principles despite their very different experimental arrangement. There are other reports in the literature of rectification from radiofrequency[2] and Tesla-spark discharges[3]. The signal depends upon the asymmetrical location of the electrodes, and must be attributed to preferential capture of electrons at the more accessible center electrode, with the positive ions becoming discharged at the outer jacket. The inner electrode is thus negative and the jacket is positive with respect to the external circuit. The circuit used includes a bias battery for adjusting the zero level, a resistance-capacitance network for signal and noise attenuation, and an indicating or recording microammeter or millivoltmeter.

RESULTS

With the direct-current measurement, the detector seems to be most applicable at reduced pressures. It is then possible to use essentially any desired carrier gas and to obtain a signal for any sample gas in that carrier—there are no limitations due to ionization potentials or other properties of the gases. Responses to sample gases in a given carrier may be to produce enhancement of current or to produce a quenching of current; both types of response are illustrated in Fig. 1, for methane and helium, respectively, in air carrier at 3.6 mm. Both response for the pure carrier and sensitivity to samples show a pressure dependence and pass through a maximum at some particular pressure; these properties are illustrated in Fig. 2, again for air carrier.

As in other ionization detectors[4-6], sensitivity is characteristic of each particular sample gas, in addition to its dependence on carrier gas, pressure, and detector geometry. An approximate comparison of sensitivities for different sample gases has been obtained by comparing responses to large injections of different sample gases in

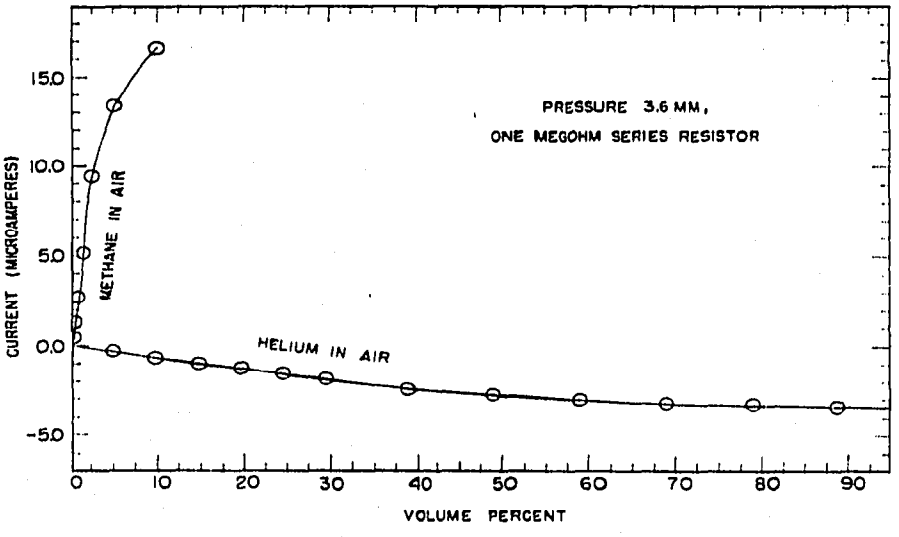

Fig. 1. Methane solutions in air and helium solutions in air; air carrier. Response relative to air *vs.* concentration.

solution in the carrier gas at a concentration of 1 % by volume, which is nearly in the linear response range (see Fig. 1); the response (sample current minus pure carrier current) is given in Table I for 1 % solutions of several different sample gases in air carrier at 3.5 mm. It is seen that response increases with number of carbon

TABLE I

RELATIVE RESPONSE IN AIR CARRIER TO 1 VOL. % SOLUTIONS IN AIR FOR VARIOUS SAMPLE GASES
Pressure = 3.7 mm, 1 MΩ series resistor

	Response (μA)
Hydrogen	2.8
Acetylene	3.6
Methane	4.7
Ethylene	5.5
Ethane	7.3
Cyclopropane	9.2
Propylene	11.4
Propane	11.6
1-Butene	13.0

atoms within homologous series of compounds. The best sensitivity seems to be possible with argon as the carrier gas, at reduced pressure, since argon gives a discharge with exceptional stability and low noise level. Under these conditions, the Tesla discharge detector appears to be as sensitive as other types of ionization detectors, and to be unrestricted in the types of vapors detectable. However, with argon

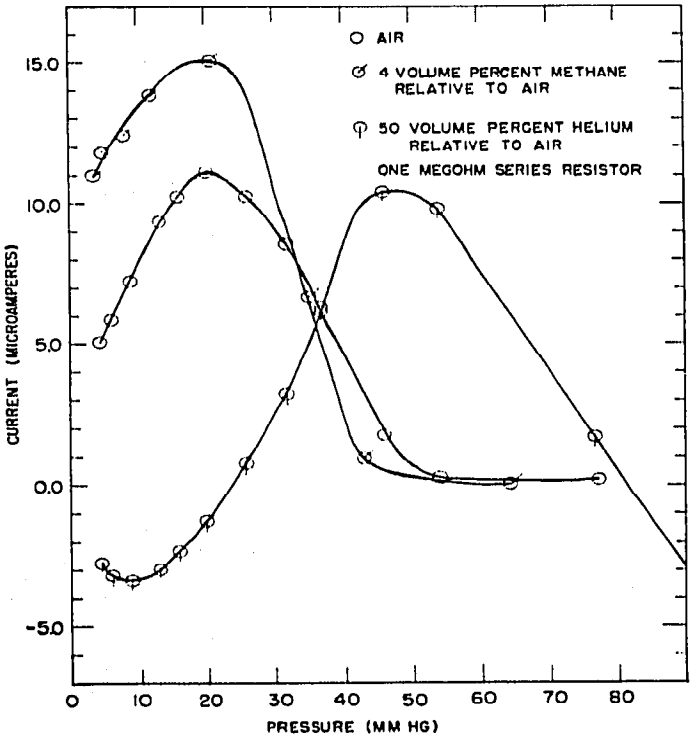

Fig. 2. Sensitivity *vs.* pressure for air, methane in air and helium in air.

carrier it has been found desirable to introduce a controlled slow flow of oxygen gas through a "T"-tube into the carrier-sample stream just before the point of excitation of the discharge. The oxygen removes free radical fragments and prevents tailing and faulty band shapes resulting from contamination of the discharge tube and electrodes with carbonaceous breakdown products.

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SUMMARY

Two new detectors for gas chromatography, based on properties of the Tesla discharge, have been developed. Their simplicity and economy of construction suggests their use in lecture demonstrations, undergraduate laboratory instruction, and in monitoring preparative column work at the laboratory bench. The possibility of use of air as the carrier gas opens up interesting applications of the detector, with or without a column, in measurement of humidity, vapor pressures above solvents or solutions, molecular weight determinations, and observation of various atmospheric contaminants. The visible discharge can be monitored spectroscopically to obtain some information on the nature of the components.

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