exhibit decay constants of 29.4, 8.2, and 6.9 mμsec, respectively. It is important to note, however, that the degree of purity of the samples used is unknown, and therefore, it may not be said with certainty that the observed decay times and long components are those of the pure materials. It is certain, however, that the decay times observed are correct to within 2 percent for the materials tested. The accuracy may be further increased by improved methods of time base calibration.

ACKNOWLEDGMENT

The authors are indebted to Dr. Tomkins and Dr. Fred of the Chemistry Division of the Argonne National Laboratory for the use of their photoelectric comparator, without which we could not have obtained precision readings of the photographs; to Mr. J. S. Moenich, for his assistance in carrying out the experiments; to Mr. D. R. Hume and Mr. E. C. Berrill for assistance in the construction of the electronic power supplies; and to Dr. F. R. Shonka for his constant encouragement and support of the work. We are also grateful to Dr. G. A. Morton of R. C. A. Laboratories Division and to Mr. R. L. Butenhoff of the Atomic Energy Commission Radiation Instruments Branch for arranging for us to use an experimental type H-4646 photomultiplier.

THE REVIEW OF SCIENTIFIC INSTRUMENTS VOLUME 24, NUMBER 8 AUGUST, 1953

A Pulsed Mass Spectrometer with Time Dispersion

M. M. WOLFF AND W. E. STEPHENS
University of Pennsylvania, Philadelphia, Pennsylvania
(Received April 8, 1953)

An improved design of a pulsed mass spectrometer using linear time of flight analysis has been completed. A peak width of two mass units at mass 40 has been achieved as well as a linear mass scale.

A SHORT pulse of ions accelerated through a fixed potential can be analyzed as to mass by time of flight techniques.[1–4]

Such an instrument was constructed at the Esso Laboratories of the Standard Oil Development Company by William Priestley, Jr. and E. C. Rearick in consultation with W. E. Stephens; it achieved resolution of the cyclic hydrocarbon groups. (See Fig. 1.) In this instrument a pulsed electron beam produces one-half microsecond pulses of ions by impact with a gas stream. The ions are accelerated through a fixed potential of 300 volts. The time of flight t is given by

$$t = L(m/2VQ)^{\frac{1}{2}} = 5.75M^{\frac{1}{2}} \text{ microseconds},$$

where L is the length of the drift tube (100 cm), V the accelerating voltage, Q the ion charge, m the mass of the ion, and M the atomic weight of the ion in amu. The operation of the instrument has been improved at the University of Pennsylvania, and a typical spectrum of atmosphere gases and helium photographed from a scope face is shown in Fig. 2.

The ion peaks, from left to right, are ascribed to H^+, H_2^+, He^+, C^+, N^+, H_2O^+, N_2^+, and A^+. The peak width is one mass unit up to a mass of five and about two mass units at mass 20; which is about double that expected theorectically for half-microsecond pulses. The theoretical resolution is given by $M/\Delta M = t/2\Delta t$ and

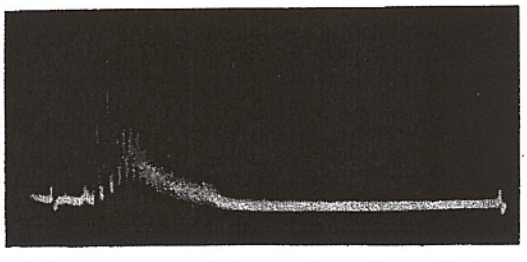

FIG. 1. Mass spectrum of a hydrocarbon mixture showing peaks due to H_2, H_2O, C_2, C_3, C_4, C_5, C_6, C_7, etc. (Courtesy of William Priestley, Jr., Esso Laboratories of the Standard Oil Devlopment Company).

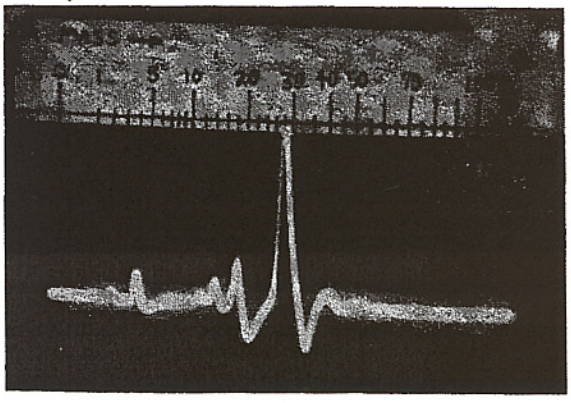

FIG. 2. Mass spectrum of atmospheric gases and helium showing ion peaks ascribed to H^+, H_2^+, He^+, C^+, N^+, H_2O^+, N_2^+, and A^+.

[1] W. E. Stephens, Bull. Am. Phys. Soc. 21, No. 2, p. 22 (1946).
[2] A. E. Cameron and D. F. Eggers, Jr., Rev. Sci. Instr. 19, 605 (1948).
[3] R. Keller, Helv. Phys. Acta 22, 336 (1949).
[4] W. E. Stephens, U. S. Patent 2,612,607.

for $t=0.5\cdot10^{-6}$ sec, $V=300$ volts, and $L=100$ cm, $M/\Delta M=5.75\ M^{\frac{1}{2}}$.

A further improvement in resolution for the heavier masses has been achieved by using a voltage pulse for accelerating the ions.[5] If the ions have not passed through the accelerating field before it is turned off, the ions all acquire the same momentum (instead of equal energy as in the previous model) and the time of flight is, for typical values of the constants,

$$t=Lm/ET_PQ=0.3M \text{ to } 3M \text{ microseconds},$$

where T_P is the time of the accelerating pulse and E is the ion accelerating field. This produces a linear mass

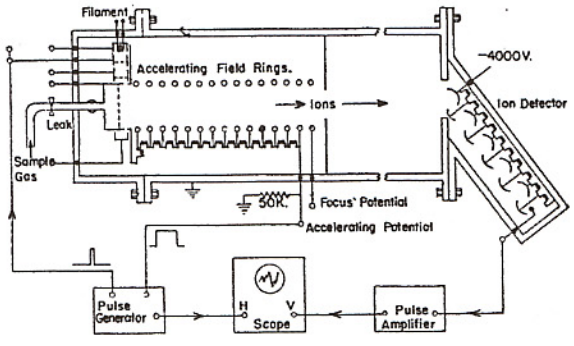

FIG. 3. Schematic diagram of the arrangement for linear mass dispersion.

scale and a theoretical resolution of

$$M/\Delta M=mL/ET_PQ\Delta t=0.6M \text{ to } 6M.$$

However, calculations suggest that the thermal velocity of the sample gas molecules limits the resolution also.

Figure 3 shows a schematic diagram of the arrangement used. Electrons from a tungsten filament are accelerated by 300 volts through three collimating slits to define a beam which passes through the ion chamber in front of a stream of sample gas. The electron beam is pulsed by 100-volt, one-half-microsecond pulses on the first collimating slit. At the same instant, a 200-volt pulse is applied to the accelerating rings which produce an accelerating field relatively uniform in space and lasting for 5 to 50 microseconds (T_P), according to the

[5] Hays, Richards, and Goudsmit, Phys. Rev. 84, 824 (1951).

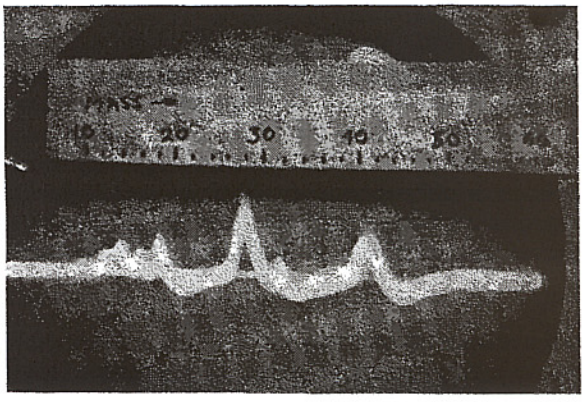

FIG. 4. Linear mass spectrum of atmospheric gases showing ion peaks from C^+, N^+, O^+, H_2O, N_2^+, O_2^+, and A^+.

mass range which it is desired to observe linearly. Ions which do not pass through the accelerating field before the accelerating pulse is over receive fixed equal momenta and travel down the drift tube with velocities inversely proportional to their mass. Consequently the time of arrival is proportional to the mass. The detector is a ten-stage electron multiplier using beryllium-copper dynodes patterned after Allen.[6] The ion pulses are amplified by an Elmore and Sands model 100 amplifier and put on the vertical plates of a Tektronix scope, triggered by the pulse generator. A photograph of a typical linear mass spectrum of atmospheric gases is shown in Fig. 4.

The ion peaks are presumed to be C^+, N^+, O^+, H_2O^+, N_2^+, O_2^+, and A^+. The peak width is about two mass units at mass forty and some of this spread may be due to insufficient filtering in the multiplier power supply.

These results indicate the present stage of development of this technique. Its present limitations are primarily in sensitivity and outgassing of the ion source.

We gratefully acknowledge a grant from the Committee for the Advancement of Research of the University of Pennsylvania and the invaluable aid of the Esso Laboratories of the Standard Oil Development Company.

[6] J. S. Allen, Rev. Sci. Instr. 18, 739 (1947).