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AEC RESEARCH AND DEVELOPMENT REPORT
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K-1719

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EFFECTS OF MATRIX GASES ON
THE ALPHA IONIZATION GAS ANALYZER
FOR URANIUM HEXAFLUORIDE

AUTHOR:

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**UNION
CARBIDE**

UNION CARBIDE CORPORATION
NUCLEAR DIVISION

Operating the

OAK RIDGE GASEOUS DIFFUSION PLANT • OAK RIDGE NATIONAL LABORATORY
OAK RIDGE Y-12 PLANT • PADUCAH GASEOUS DIFFUSION PLANT

*For the Atomic Energy Commission
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Date of Issue: January 15, 1968

Report Number: K-1719

Subject Category: CHEMISTRY

EFFECTS OF MATRIX GASES ON THE ALPHA IONIZATION
GAS ANALYZER FOR URANIUM HEXAFLUORIDE

W. S. Pappas

Technical Division

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UNION CARBIDE CORPORATION
NUCLEAR DIVISION
Oak Ridge Gaseous Diffusion Plant
Oak Ridge, Tennessee

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A B S T R A C T

Effects of matrix gas composition on the alpha ionization gas analyzer for trace uranium hexafluoride determination were examined. Theoretical and experimental studies led to a simple technique for calibrating the analyzer in any gas system, when its sensitivity in a single gas is known. The instrument was applied to measure trace uranium hexafluoride in C_8F_{16} (perfluorodimethylcyclohexane) at pressures much lower than is permissible in nitrogen or air systems.

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Efficient operation of a C_8F_{16} (perfluorodimethylcyclohexane) coolant recovery system at the Oak Ridge Gaseous Diffusion Plant required a continuous monitor for trace uranium hexafluoride in the purified C_8F_{16} vapor stream. Nier, et al. (2) have described a trace uranium hexafluoride analyzer based on alpha radioactivity measurement. They were concerned with the determination of trace uranium hexafluoride in nitrogen and air systems where a sample pressure above 8 to 10 psia was necessary to minimize interference from background radiation. Although the analyzer was later applied to the measurement of uranium hexafluoride in Coolant-114 (dichlorotetrafluoroethane) at 10 psia (1), a satisfactory treatment for the effects of matrix gases on its response has not been given.

This report presents theoretical and experimental studies which explain the effects of matrix gas composition on residual and analytical ion signal current. As a result, application of the instrument to the C_8F_{16} system was easily accomplished at 2.7 psia and 150°F. A new simple technique for calibrating the instrument for measurement of uranium hexafluoride in different gases is recommended.

SUMMARY

Effects of matrix gas composition on the alpha ionization gas analyzer for trace uranium hexafluoride determination were examined. Theoretical and experimental studies led to a simple technique for calibrating the analyzer in any gas system, when its sensitivity in a single gas is known. The instrument was applied to measure trace uranium hexafluoride in C_8F_{16} (perfluorodimethylcyclohexane) at pressures much lower than is permissible in nitrogen or air systems.

ANALYZER OPERATING PRINCIPLE (2)

The alpha ionization gas analyzer measures the specific radioactivity of a sample stream passing through an ionization chamber, to provide a sensitive measurement of trace uranium hexafluoride. The ionization chamber (figure 1) includes two electrodes located in the center. The negative electrode is an axially-centered fine nickel wire. The positive electrode is a grid network (cage) of fine nickel wire surrounding the negative electrode (ion collector). With the negative electrode and the shell of the chamber operating at ground potential, positively charged ions originating from ionizing radiation within the grid cage are drawn toward the central negative electrode. The ions formed outside the grid are accelerated outward and to the chamber walls. Therefore, the only ionization measured is that occurring inside the grid cage.

The electrodes are designed to present a minimum surface on which uranium

IONIZATION CHAMBER DIAMETER = 12 INCHES
GRID CAGE DIAMETER = 8 INCHES
IONIZATION CHAMBER LENGTH = 24 INCHES
GRID CAGE LENGTH = 19 INCHES

IONIZATION CHAMBER CONSTRUCTION

Figure 1

deposits can collect. The effects of alpha radiation from uranium deposits on the chamber walls are minimized by operating the can at a pressure of at least 8 to 10 psia, for nitrogen and air samples. At this pressure practically all of the alpha background arises from the nonvolatile uranium products deposited on the wire grid. As the pressure is decreased, the range of the alpha particles emitted from the wall increases and the background interference rises rapidly.

THEORETICAL STUDIES

Matrix Effect on Analytical Sensitivity

The total number of ion pairs created by completely stopping an alpha particle in several halocarbon gases varies from 1.09 to 1.44 times the total number produced in nitrogen (3). Since the ion current generated in the ionization chamber is a measure of the total number of ion pairs formed, the analytical sensitivity to uranium hexafluoride in a C_8F_{16} matrix should be comparable to, or moderately higher than, that obtained in nitrogen at the same pressure.

Background Residual Current Suppression

The minimum pressure required for acceptable background suppression is inversely related to the range of an alpha particle in the gas being examined, and depends on the electron density of the gas. For a given initial velocity, the range of an alpha particle is inversely related to the sum of terms calculable from the structure of the gas molecule, as discussed by Steidlitz, et al. (3).

$$R = \frac{K}{\sum_i n_i Z_i^{2/3}}$$

where R = the range of an alpha particle,
 Z_i = the atomic number of an atom of type i ,
 n_i = the number of such atoms, and
 K = a proportionality constant.

The calculated range of an alpha particle in C_8F_{16} is 0.081 of its range in nitrogen, assuming equal pressures. This compares with the value, 0.080, obtained experimentally (4). Accordingly, to obtain equal background suppressions, the required C_8F_{16} pressure would be only 0.08 times the pressure of nitrogen; thus a C_8F_{16} pressure of 0.8 psia would be equivalent to a nitrogen pressure of 10 psia, in alpha-stopping power.

EXPERIMENTAL

Signals generated by the same alpha source (uranium deposits on surfaces) in nitrogen and C_8F_{16} at 150°F. and at variable pressures, were compared. A method for calibration based on the comparative measurement is presented.

Analytical Sensitivity

The almost identical peak backgrounds obtained with the same uranium deposits (figure 2) show that the ratio of analytical sensitivity in C_8F_{16} to sensitivity in nitrogen is approximately one:one. This is because in each case the peak value corresponds to the same range (pressure optimized) for all alpha radiation originating within the whole chamber. Calibration of the instrument for the C_8F_{16} system requires only multiplying the sensitivity for uranium hexafluoride in nitrogen at the same temperature and pressure (2) by the peak signal ratio, 1180/1160. This simple empirical ratio method of calibration can be equally well applied to other gas systems, even when the matrix constituents are unknown.

Background Suppression

The measured C_8F_{16} pressure required to provide the suppressed background furnished by nitrogen at 10 psia is 0.85 psia. This is, within experimental error, identical to that predicted from the theory above. The selected operating pressure of 2.7 psia gives an acceptably low background (figure 2) and is a reasonable maximum pressure at 150°F. to avoid C_8F_{16} condensation.

Calibration

Figure 3 presents a comparison of sensitivity for uranium hexafluoride in nitrogen at 10 psia and in C_8F_{16} at 2.7 psia, assuming the same uranium isotopic composition. The lower sensitivity in C_8F_{16} is principally a result of the lower sample pressure required to avoid condensation. The C_8F_{16} curve is derived by multiplying the nitrogen curve by 1180/1160 times 2.7 psia/10 psia.

ACKNOWLEDGMENTS

The Instrument Maintenance Department and K-29 Operations personnel assisted in the experimental work. L. F. Haese of the Instrument Maintenance Department performed sensitivity calculations for application.

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ION CURRENTS IN C_8F_{16} AND NITROGEN

Figure 2

DWG. NO. G-67-367

ANALYTICAL SENSITIVITY IN NITROGEN AND
 C_8F_{16} AT DIFFERENT PRESSURES

Figure 3