GAS CHROMATOGRAPHY
POSSIBLE APPLICATION OF ADVANCED INSTRUMENTATION
DEVELOPED FOR SOLAR SYSTEM EXPLORATION
TO
SPACE STATION CABIN ATMOSPHERES

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Gas chromatography (GC) technology has been under development for flight experiments in solar system exploration for some years. GC is a powerful analytical technique where relatively simple devices can separate individual components from complex mixtures and then make very sensitive quantitative and qualitative measurements. It is particularly suited to monitoring samples containing mixtures of fixed gases and volatile organic molecules. GC has been used on the Viking mission in support of life detection experiments and on the Pioneer Venus Large Probe to determine the composition of the venusian atmosphere. A flight GC is currently being developed to study the progress and extent of STS astronaut denitrogenation prior to extravehicular activity. Advanced flight GC concepts and systems for future solar system exploration are also currently under study. Studies include miniature ionization detectors and associated control systems capable of detecting from ppt up to 100 percent concentration levels. Further miniaturization is being investigated using such techniques as photolithography and controlled chemical etching in silicon wafers. Novel concepts such as ion mobility drift spectroscopy and multiplex gas chromatography are also being developed for future flight experiments. These powerful analytical concepts and associated hardware are ideal for the monitoring of cabin atmospheres containing potentially dangerous volatile compounds and could be applied with minimal development.
### TABLE 1

**PIONEER VENUS LGC RESULTS**

<table>
<thead>
<tr>
<th>SAMPLE NUMBER</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<tbody>
<tr>
<td>ALTITUDE, KM</td>
<td>51.6</td>
<td>41.7</td>
<td>21.6</td>
</tr>
<tr>
<td>PRESSURE, BARS</td>
<td>0.7</td>
<td>2.9</td>
<td>17.8</td>
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<table>
<thead>
<tr>
<th>GAS</th>
<th>% CONCENTRATION</th>
<th>ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>95</td>
<td>95</td>
</tr>
<tr>
<td>N₂</td>
<td>4.6</td>
<td>4.6</td>
</tr>
<tr>
<td>H₂O</td>
<td>&lt;0.06</td>
<td>0.52</td>
</tr>
<tr>
<td>O₂</td>
<td>44</td>
<td>16</td>
</tr>
<tr>
<td>Ar</td>
<td>60</td>
<td>64</td>
</tr>
<tr>
<td>CO</td>
<td>32</td>
<td>30</td>
</tr>
<tr>
<td>Ne</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>SO₂</td>
<td>&lt;600</td>
<td>180</td>
</tr>
</tbody>
</table>

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Figure 1. Pioneer Venus short column chromatogram of 24 km sample, showing raw data points. Solid line shows detector signal at a range of 0.7 to 1.6 mV. Dashed line shows detector signal at a range of 0.7 to 900 mV. Inset at right is expanded view of SO$_2$ peak.
Figure 2  Pioneer Venus long column chromatogram of 24 km sample, showing raw data points. Solid line shows detector signal at a range of 0.6 to 15 mV. Dashed line shows detector signal at a range of 0.6 to 90.6 mV. Inset at left is expanded view of Neon peak.
Figure 4. Gas Chromatograph separates components of sample mixture. IMDS reactant ions ionize each sample component as it elutes from the GC column forming product ions. These product ions are separated in the drift tube according to their size and structure forming Ion Mobility Spectra of the sample components.
Figure 5. Top: Typical positive reactant ion spectrum (background) of three heptylhalides. Although similar in structure, the heptylhalides produce distinctly different spectra.

Bottom: m/s spectra of three heptylhalides.
Figure 6. Block Diagram of Two-Dimensional Multiplex Gas Chromatographic System. Computer controls sample introduction using two concentration modulators and analyzes detector output to produce 2-dimensional chromatogram.
VIKING GEX CHROMATOGRAPHIC SEPARATIONS

Figure 8.
VL-1 GAS CHANGES IN GEX HEADSPACE
DATE: 020482
DETECTOR: ARC-2
COLUMN: PORAPAK-N
20°C, 1 bar
200-325
8.0 m/20°C
0.5 cm
SAMPLE: 12.2 cm³/min
DETECTOR SETTING: 300 V/1.74 x 10⁻⁹ A

\[ N_2 = 3 \times 10^{-1} \]
\[ K_1 = 10^{-7} \]
\[ C_2H_4 = 2 \times 10^{-7} \]
\[ C_2H_6 = 10^{-7} \]
\[ C_2H_2 = 3 \times 10^{-7} \]

CHROMATOGRAM, DEMONSTRATING CAPABILITY OF CURRENT TECHNOLOGY TO MEASURE SPECIES IN THE PARTS-PER-\[ \text{Billion Range (e.g., CO}_2 \text{ at 20 ppb)} \]

TIME, min: 0 10 20 30 40 50
MODULATED VOLTAGE METASTABLE IONIZATION DETECTOR

GAS CHROMATOGRAPH

METASTABLE IONIZATION DETECTOR (MID)

VENT

MID ELECTROMETER

MID VOLTAGE MODULATOR

RECORDER

MID POWER SUPPLY

APPLIED VOLTAGE

DETECTOR CURRENT

Figure 12
LABORATORY PROTOTYPE MICRO GAS CHROMATOGRAPH

SAMPLE INPUT PORT (VALVE IS ON OTHER SIDE OF SILICON WAFER)

CARRIER GAS INPUT

OUTPUT PORT

THERMISTOR BEAD DETECTOR CAVITY

0.5 meter COLUMN

PYREX GLASS PLATE

SILICON WAFER

Figure 13

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