Multi-step Pyrolysis of Powdered Meteorite Using a Pyroprobe with GC/MS

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Application Note
Aerospace

Abstract
This application note demonstrates multi-step pyrolysis GC-MS of a powdered meteorite sample.

Introduction
In the search for extraterrestrial life, finding organic molecules, which contain carbon and hydrogen, and also may include oxygen, in deep space has been a topic of special interest. NASA's Curiosity rover equipped with the Sample Analysis at Mars (SAM) Suite Investigation in the MSL Analytical Laboratory is designed to address this interest. The main analytical chemistry hurdle that SAM resolved is using pyrolysis as a powerful tool to (1) thermally extract organic matter with low molecular weight from a piece of inorganic matter sample, which is usually insoluble into common solvents, (2) thermally break carbon bond in organic matter with high molecular weight, and send to GC/MS for identification. As the inventor of the first commercial pyrolyzer for GC/MS system, CDS Analytical contributed to the development of SAM in the Curiosity rover[1], which was launched on November 26, 2011 and landed on Mars on August 5, 2012.

This application note focused on demonstrating the operation of SAM by thermally extracting 15 mg of powdered meteorite in a multi-step sequence of 120°C, 200°C, 280°C, followed by a flash pyrolysis at 610°C to evaluate its organic matter content.

Experimental Setup
A small piece from Murchison meteorite, which fell in Australia in 1969, was powdered, and 15 mg of the powder was added to a Drop-In-Sample Chamber (DISC) tube, to run on a Pyroprobe 6200.

Experimental Parameters

Pyroprobe		GC/MS	
DISC Chamber:	120°C 15min	Column:	5% phenyl (30m x 0.25mm)
	200°C 15min	Carrier:	Helium 1.25mL/min
	280°C 15min		25:1 split
	610°C 30sec	Injector:	300°C
		Oven:	40°C for 2 minutes
Trap Rest:	40°C		10°C/min to 320°C
Trap Final:	300°C 4min	Ion Source:	230°C
		Mass Range:	35-600amu
Interface:	300°C		
Transfer Line:	300°C		
Valve Oven:	300°C		

Results
All four temperature runs were summarized in Figure 1. The run at 120°C did not yield organic compounds at enough concentration to be identified. Aromatics started to emerge at 200°C, along with cyclic sulfur. At 280°C, aromatics at higher boiling point, like naphthalene and some hydrocarbons become more abundant. Sulfur compounds such as thiophenes also were extracted.

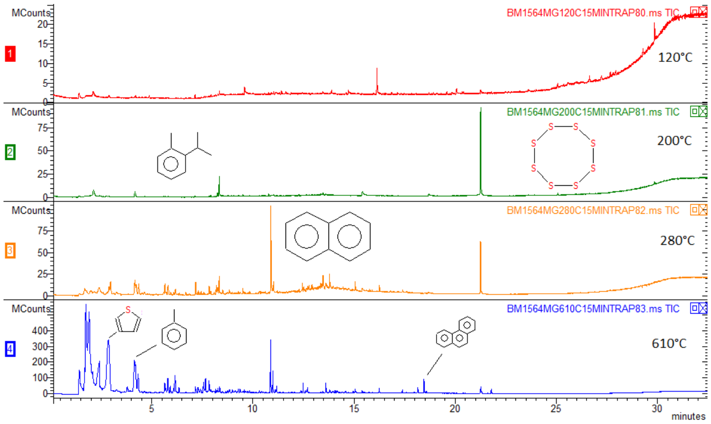

Figure 1. Meteorite, 15mg multi-step at 120°C, 200°C, 280°C and 610°C

The last flash pyrolysis run at 610°C in Figure 1 was zoomed in Figure 2 to show more details. Pyrolysis at 610°C revealed sulfur dioxide, more thiophenes, hydrocarbons, and polycyclic aromatic hydrocarbons, including phenanthrene.

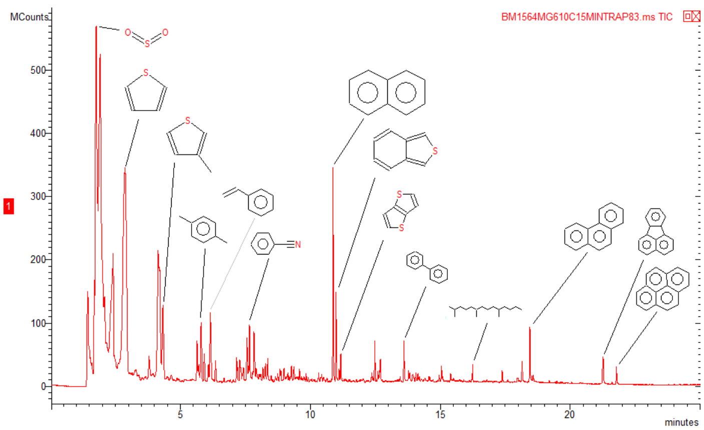

Figure 2. Powdered Meteorite, 610°C, after multi-step extraction at 120°C, 200°C, and 280°C.

The composite mass spectra contains ion 64 from the sulfur, and ions representative of both aliphatic hydrocarbons (55), and aromatics (78, 128). The Pyrogram in Figure 2 was matched to CDS Analytical's polymer pyrolysis database as shown in Figure 3. The top matches include baking yeast, which is which is a single-celled fungi, and fly ash, both very different materials, which produce aromatics when pyrolyzed.

These findings are consistent with other studies on the Murchison metreorite, where organic molecules and amino acid were reported [2,3].

Conclusion

This application note demonstrated thermal extraction and pyrolysis analysis of powdered meteorite using a 6200 Pyroprobe with GC/MS.

The data proves again that the Murchison meteorite is carbon enriched and contains a variety of extraterrestrial organic molecules. The message conveyed by the meteorite could inspire more study on the chemical evolution in the early solar system.

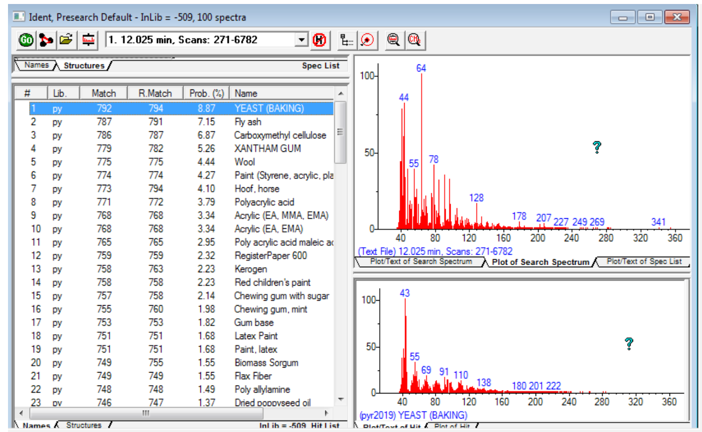

Figure 3. Powdered meteorite pyrolysis database match

References:

1. Navarro-González, Rafael, et al. "The limitations on organic detection in Mars-like soils by thermal volatilization–gas chromatography–MS and their implications for the Viking results." Proceedings of the National Academy of Sciences 103.44 (2006): 16089-16094.
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3. Llorca, Jordi. "Organic matter in meteorites." Int Microbiol 7.4 (2004): 239-248.