Cluster for Natural and
Technical Science
Arms Control Research

Fact Sheet March 2025

Chemical Weapons

Identifying Chemical Warfare Agents Through Analytical Chemistry

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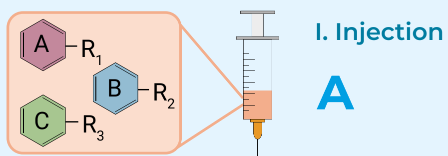
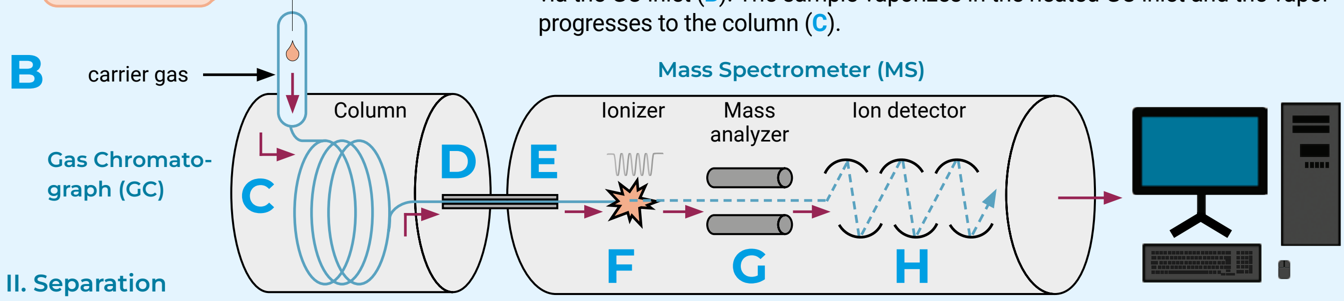
In August 2013, the residents of Ghouta, Syria, experienced the deadliest chemical weapons attack in the country's history. However, Syria and Russia denied that toxic chemicals had been used. To clarify the issue, the United Nations (UN), supported by the Organization for the Prohibition of Chemical Weapons (OPCW), conducted an investigation and concluded that a nerve agent known as sarin had indeed been used. By providing scientific evidence through forensic verification, the UN and the OPCW have laid the groundwork for legitimate action to enforce the ban on chemical weapons and maintain international peace and security.

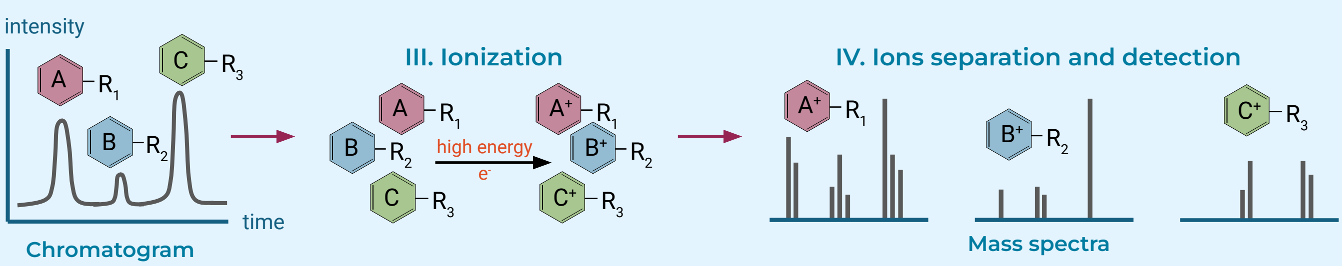
OPCW designated laboratories primarily use the analytical techniques of **GC-MS** (gas chromatography-mass spectrometry) **and LC-MS** (liquid chromatography-mass spectrometry) to analyze environmental and biological samples that could indicate the presence of chemical warfare agents. GC-MS is an analytical technique broadly used to study the chemical components of complex samples. The GC-MS equipment comprises two different modules: a gas chromatograph (GC), which separates every component of the mixture, and a mass spectrometer (MS), which determines the mass of each component. LC-MS is a variant of GC-MS and it is often used for similar purposes.

How Does GC-MS Work?



I. Injection. The sample is introduced into the GC (**A**) and enters the carrier gas via the GC inlet (**B**). The sample vaporizes in the heated GC inlet and the vapor progresses to the column (**C**).





II. Separation. The sample components are separated inside the GC column (**C**), which is coated with a chemical substance known as "stationary phase". The sample flows through the column via the carrier gas, known as "mobile phase". The sample components (e.g., molecules A, B, and C) are separated in the column by their differences in partitioning between the stationary and mobile phases depending on their chemical structures. Then, the molecules elute through a heated transfer line (**D**) into the mass spectrometer (**E**).

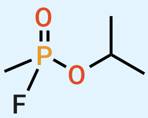
III. Ionization. The neutral molecules are ionized and fragmented (**F**). This process can be performed by various methods.

IV. Ions separation and detection. The mass analyzer separates the ions of different masses (**G**). The ions reach the ion detector (**H**) where the signal is amplified and recorded by an acquisition software on a computer to translate the information into graphical data: chromatograms and mass spectra. Finally, the mass spectra of each compound are compared against a vast database of known chemicals to identify potential matches.

Targets for Chemical and Biomedical Identification by Means of GC-MS and LC-MS

Chemical warfare agents (CWA) are usually highly reactive small molecules that in most cases undergo changes rapidly after being administrated. This characteristic makes detection and analysis of CWAs difficult. However, there exist some other traceable chemicals that can be studied in forensic investigations. Using **sarin** as an example, the following alternative targets can be analyzed:

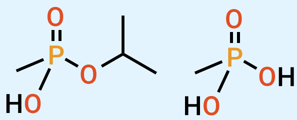
I. Residual chemical agent



Sarin (GB)

Original structure of sarin, one of the most toxic CWAs which belongs to the G-type family of phosphorous nerve agents

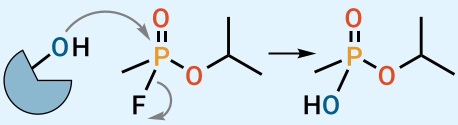
II. Hydrolysis products



Hydrolyzed sarin

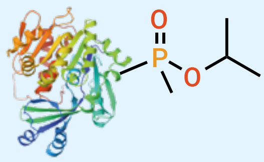
Moisture typically triggers the hydrolysis of sarin, resulting in various **–OH** functionalized derivatives.

III. Enzymatic biotransformation products



Enzymes can drive metabolic processes that transform sarin into other traceable products.

IV. Adducts with proteins



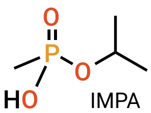
Sarin/protein adducts are usually traceable up to several weeks after poisoning.

Sarin Poisoning in Syria – A Real Forensic Case of Identification of Nerve Agents

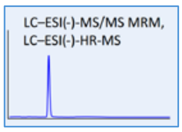
One of the most horrific chemical attacks was perpetrated in Syria in August 2013. Following this attack, two of the OPCW designated laboratories carried out forensic analysis of tissues from a deceased female victim. Both laboratories found irrefutable evidence confirming that the victim was poisoned with sarin. In 2018, Harald John and co-workers from the designated laboratory of the Bundeswehr Institute of Pharmacology and Toxicology reported their analyses by means of GC-MS and LC-MS (*Forensic Toxicol* 36, 61–71, 2018). They demonstrated the presence of sarin in the biological samples through five methods:

Method I:

Detection of IMPA, a hydrolysis product derived from sarin, by means of LC-MS

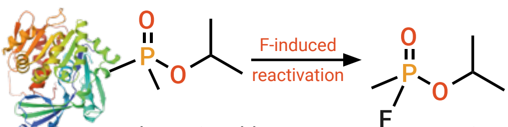


IMPA



Method II:

Direct detection of sarin by fluoride-induced reactivation of protein-bound sarin

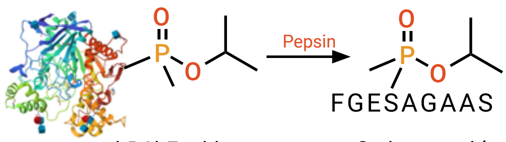


General protein adduct

Sarin

Method III:

Analysis of sarin-butyrylcholinesterase (hBChE) adducts

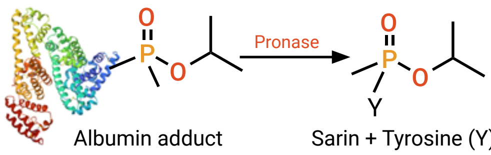


hBChE adduct

Sarin + peptide

Method IV:

Analysis of sarin-albumin adducts

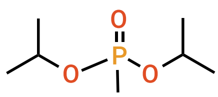


Albumin adduct

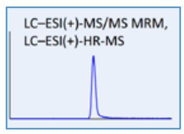
Sarin + Tyrosine (Y)

Method V:

Analysis of DIMP, a sarin synthesis by-product, by means of LC-MS



DIMP



Appendix

Imprint

CNTR is a research alliance between the Peace Research Institute Frankfurt (PRIF), Justus Liebig University Giessen and the Technical University of Darmstadt. www.cntrarmscontrol.org · V.i.S.d.P.: Elisabeth Waczek (PRIF), Baseler Straße 27–31, Frankfurt a.M., Germany, Phone (069) 959104-0, info@prif.org, www.prif.org · Design: media | machine GmbH · Layout: CNTR

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