

The chemistry of chemical weapons

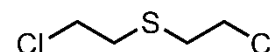
Education in Chemistry

November 2019

rsc.li/36092UV

The word Novichok means ‘newcomer’ in Russian. Novichoks are a family of nerve agents developed by the Soviet Union in the 1970s and 1980s to elude international restrictions on chemical weapons. However, Novichoks are not the only chemical weapons that present a threat to human life. In this activity you will look at the chemistry behind a number of chemical weapons that have been employed throughout history.

- Mustard gas has a long history as a blister agent in warfare. First used in the First World War it causes severe burning of the skin, eyes and respiratory tract of anyone exposed to it.



Mustard gas

Mustard gas can be made by two consecutive chemical reactions. In the first reaction sulfur dichloride is made from sulfur and chlorine. In the second, sulfur dichloride reacts with ethene to make mustard gas.

- Write an equation for the formation of sulfur dichloride.
- Draw and name the shape of a molecule of sulfur dichloride.
- The mass spectrum of mustard gas is shown in **Figure 1**.
 - Explain the three peaks at m/z 158/160/162. State the relative abundance of each peak.
 - Suggest a structure for the fragments responsible for the peaks at m/z 109/111 and m/z 63/65.

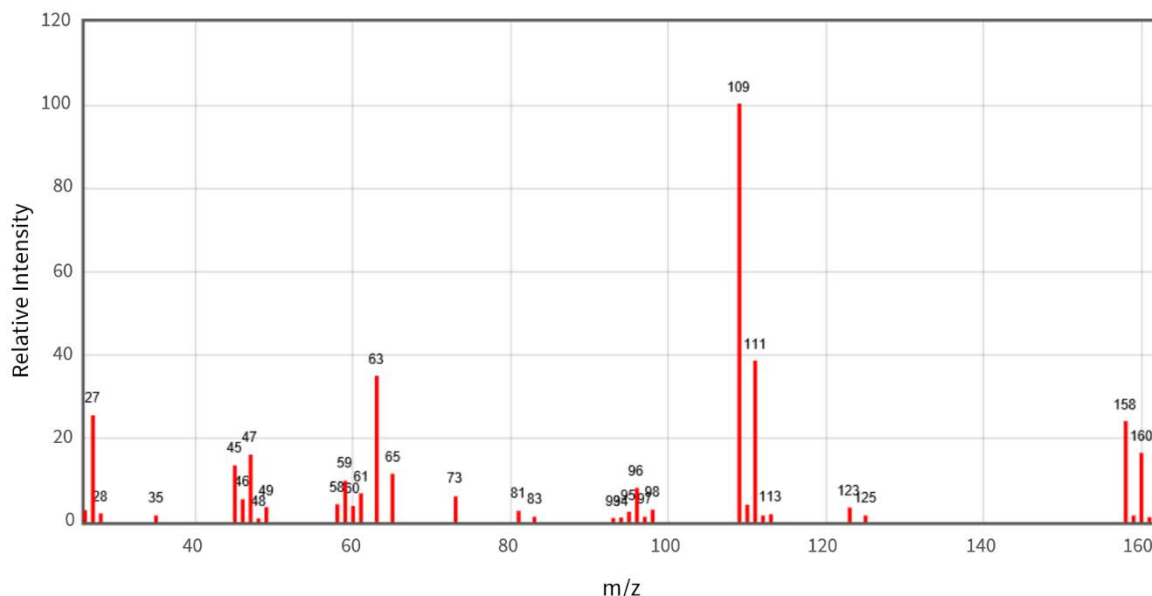
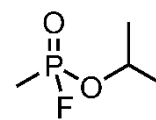


Figure 1– Mass spectrum of mustard gas; © NIST Mass Spectrometry Data Center

2. Sarin is a chemical warfare agent classed as a nerve agent. First synthesised by German scientists researching new pesticides it is thought to be approximately 500 times more deadly than cyanide.



Sarin

- a. Sarin is a chiral molecule. One enantiomer is known to be more active than the other due to its greater binding affinity to the enzyme acetylcholinesterase.

Draw the two enantiomers of sarin.

- b. The lethal dose of sarin is about 0.5 mg. If the average adult breathes in approximately 10,000 l of air a day, calculate the time to the nearest second it would be before an adult received a lethal dose when 100 mg of sarin was released per m³ of air.
- c. One known Novichok has the chemical formula C₁₂H₂₀PO₂N₃. Like sarin it is an organophosphorus compound.

Part of the structure of the Novichok is shown in **Figure 2**.

Analysis of the Novichok by mass spectrometry shows fragments at *m/z* 15 and *m/z* 93.

Complete the structure of the Novichok by attaching groups to the phosphorus atom.

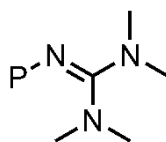


Figure 2 – partial structure of Novichok agent