Chemical Weapons

Mark Bishop

http://institutebishop.org/chemical_weapons_S&T_short_lecture.pdf

http://institutebishop.org/chemical_weapons_S&T.pdf

War of Nerves – Chemical Warfare from World War I to Al-Qaeda by Jonathan B. Tucker ISBN 978-1-4000-3233-4

https://smile.amazon.com/War-Nerves-Chemical-Warfare-Al-Qaeda-ebook/dp/B000XU4UWG/ref=sr_1_1?ie=UTF8&qid=1532920080&sr=8-1&keywords=war+of+nerves+chemical+warfare+from+world+war+i+to+al-qaeda

Chemical Weapons (CW)

- Chemical weapons are, “Any chemical which through its chemical action on life processes can **cause death, temporary incapacitation or permanent harm to humans or animals**. This includes all such chemicals, regardless of their origin or of their method of production, and regardless of whether they are produced in facilities, in munitions or elsewhere.” (OPCW)

Special gas mask for dogs-1917

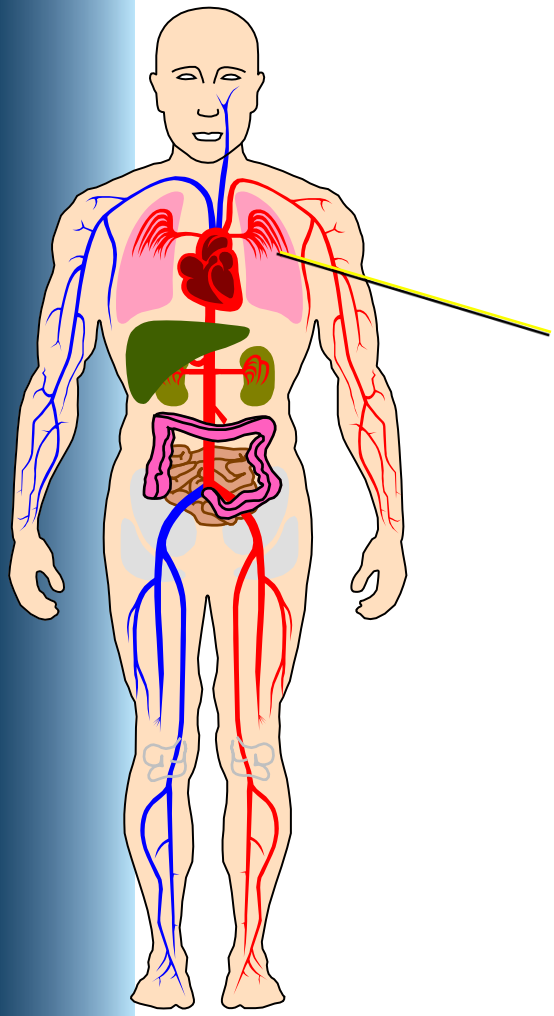
Types of Chemical Weapons

- Nerve agents (e.g. **sarin**, **VX**, **novichok**)
- Blood agents (e.g. hydrogen cyanide)
- Choking agents (e.g. **chlorine**, phosgene)
- Blistering agents (e.g. **sulfur mustard**)
- Tearing agents (e.g. CS)
- Opiate-like agents (e.g. fentanyl)
- Psychochemical Incapacitants (e.g. BZ)
- Toxins (e.g. ricin)

For terrorists or governments?

- **Terrorist criteria**
  - Either relatively simple to make or obtain in some other way.
  - Relatively simple to disperse
  - Can be lethal or incapacitating
  - Relatively low cost
- **Government with well-developed chemical industry (e.g. North Korea or Syria)**
  - Can be more difficult to make.
  - Can have more sophisticated dispersal techniques.
  - More likely to want lethal
  - Higher cost may be OK

Choking Agents



- Diphosgene, phosgene, **chlorine**, chloropicrin
- Mode of action: inhalation
- Physiological effects
  - Victim can die of oxygen deficiency via different mechanisms
- Form when disseminated: gas
- Required defensive gear: protective mask

1899 International Peace Conference

- At The Hague, Netherlands
- 26 countries, including Germany, signed the treaty
- One section outlawed the use of “projectiles the object of which is the diffusion of asphyxiating or deleterious gases.”

Chlorine and WWI

During peace time a scientist belongs to the world, but during war time he belongs to his country.

Fritz Haber

- In 1914-15, WWI, which was expected to end quickly, was bogged down in trench warfare, so each side was looking for ways to break through the lines.
- Fritz Haber, who won the Nobel Prize for chemistry for helping to develop a way of making ammonia from nitrogen and hydrogen in 1918, suggested loading projectiles with chlorine and shrapnel.
- Germans thought that they could avoid violating the Hague Convention by putting poison gas ***and shrapnel*** in projectiles, based on the interpretation that the convention banned "projectiles, the ***sole*** object of which is the diffusion of asphyxiating or deleterious gases.")

Chlorine as a Chemical Weapon

- Shortage of artillery shells led to use of chlorine from pressurized gas cylinders.
- Used against French troops near Ypres, Belgium, April 22, 1915.
- Wind conditions had to be in the correct direction, strong enough to move the gas to the enemy lines, but not too strong to disperse the gas too quickly.

Chlorine as a Chemical Weapon

- 168 metric tons (megagrams) released from 5730 cylinders
- Cl_2 is more dense than air
- 5-ft cloud moved at 4 mph
- Warmed, expanded to 30-ft yellow-green cloud, causing blindness, coughing, nausea, headache, and chest pain
- Created 4-mile gap in Allied line

Chlorine as a Chemical Weapon

- Reacts with water to form hydrochloric acid and hypochlorous acid, which damage tissues in the lungs and draw water into the lungs.

$$Cl_2 + H_2O \rightarrow HCl + HClO$$

Chlorine Lethality

- Death can come from asphyxia due to at least three possible mechanisms
  - Water in lungs displaces air ("*dry land drowning*").
  - Chlorine is more than twice as dense as air, so it displaces the air in the lungs.
  - Oxidative injury to the airways and lungs.
- Cardiac toxicity can lead to cardiac dysfunction.

Reluctance Overcome by Perceived Necessity

I must confess that the commission for poisoning the enemy, just as one poisons rats, struck me as it must any other straightforward soldier; it was repulsive to me. If, however, the poison gas were to result in the fall of Ypres, we would win a victory that might decide the entire campaign. In the view of this worthy goal, all personal reservations had to be silent. So onward, do what must be done. War is necessity and knows no exception.

Berthold von Deimling

Commander of the German XV Army Corps at Ypres

Personal Protection (Military)

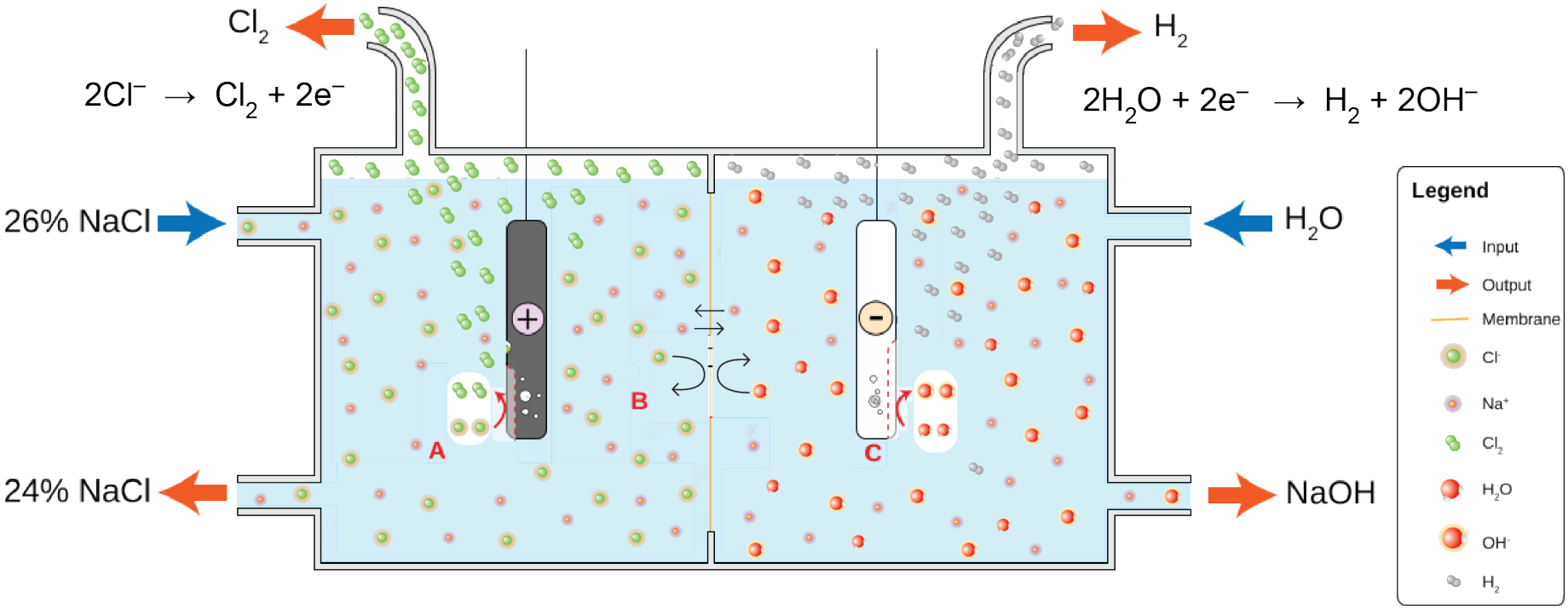
Ways to Obtain Chlorine, Cl_2

- Produce it
- Capture it from a production plant
- Divert it during transportation
- From water treatment plant

Production of Chlorine

- Compared to other chemical weapons, chlorine is relatively easy to make by electrolysis of sodium chloride in water.

$$2NaCl(aq) + 2H_2O(l) \rightarrow Cl_2(g) + H_2(g) + 2NaOH(aq)$$



Chlorine from Captured Production Plant

- December 2012 – a chemical plant east of Aleppo, Syria was taken by rebel fighters from the Al-Nusra Front (now part of Hay'at Tahrir al-Sham, Organization for the Liberation of the Levant). The factory produced chlorine among other chemicals.

http://www.france24.com/en/20121208-syria-warns-rebels-may-resort-chemical-weapons-assad-united-nations-islamists/

Transportation of Chlorine

- By rail in tank cars

- By highway in cargo tanks and cylinders
- By barge

Chlorine in Water Treatment Plant

- Commonly in one-ton containers

Ways to Disperse Chlorine, Cl_2, as a CW

- Stationary device, e.g. pressurized gas tanks
- Car or truck bombs
- Drop containers from planes or helicopters that will burst on impact (barrel bombs)
- Roadside bombs
- Projectiles

A 120-millimeter mortar shell struck fortifications at a Kurdish military position near the Mosul Dam in June, arms experts said, sickening several Kurdish fighters who were nearby.

Credit
Conflict Armament Research and Sahan Research

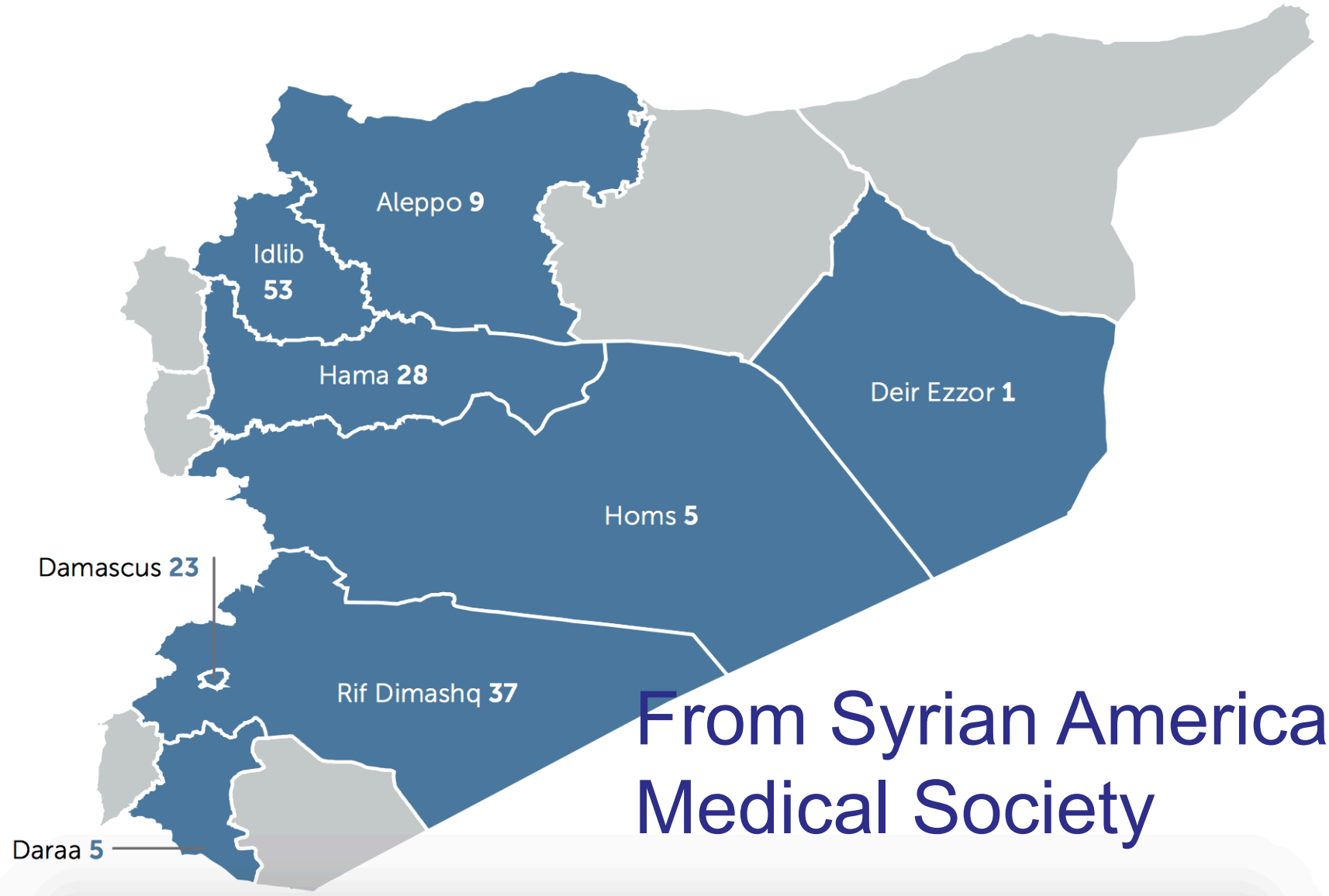
http://www.nytimes.com/2015/07/18/world/middleeast/islamic-state-isis-chemical-weapons-iraq-syria.html

Syrian American Medical Society

- Syrian American Medical Society, a charity that runs 95 medical facilities inside the country, reported the following.
  - Nearly 200 chemical attacks since 2012
  - Used reports and first-hand accounts from physicians and health workers in Syria.
  - By 2015, documented chemical attacks led to at least 1,491 deaths and 14,581 injuries from chemical exposure.

http://www.sams-usa.net/reports/a-new-normal-ongoing-chemical-weapons-attacks-in-syria/
https://www.sams-usa.net/press_release/sams-syria-civil-defense-condemn-chemical-attack-douma/

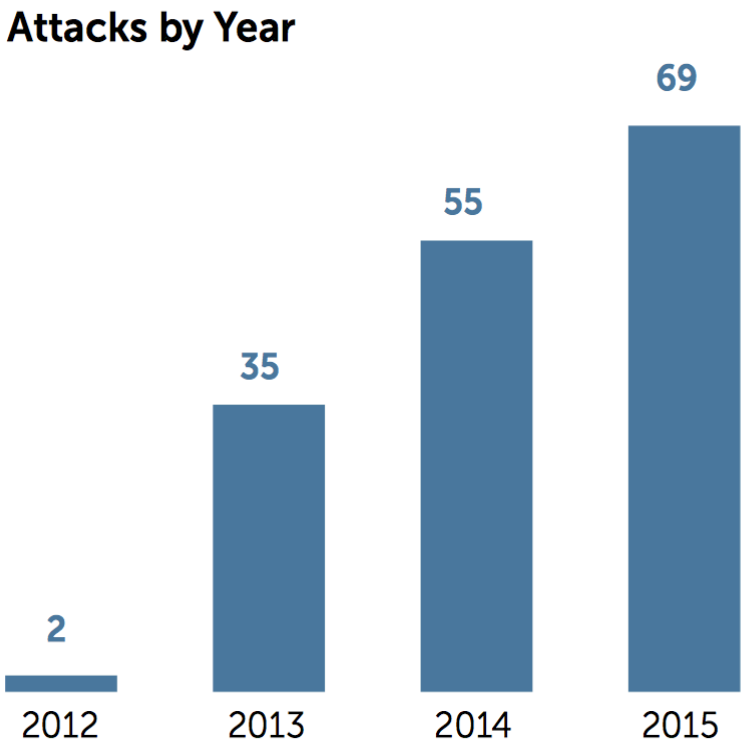
Attacks by Governorate

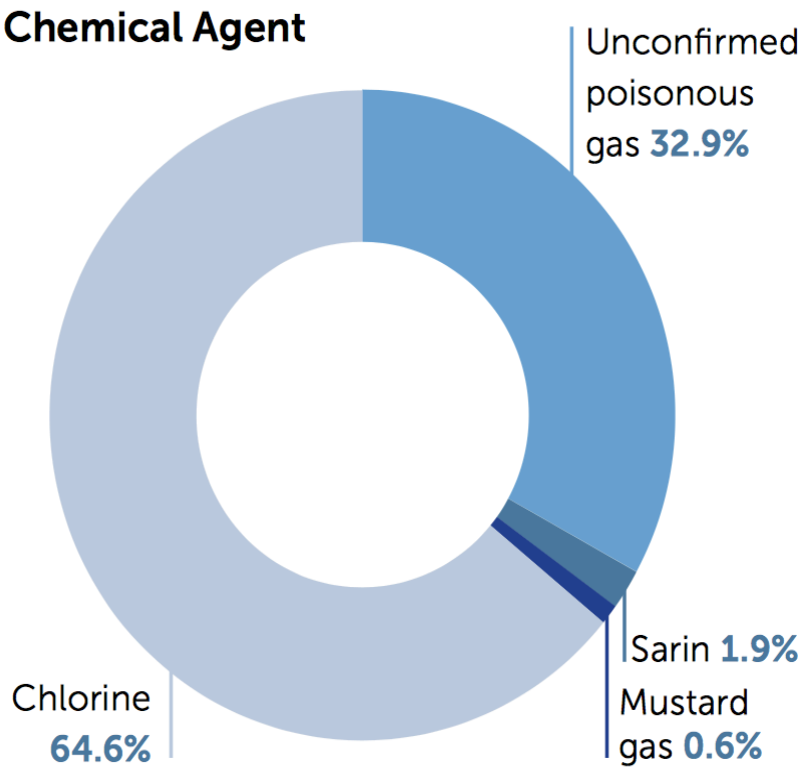


From Syrian American Medical Society

http://www.sams-usa.net/wp-content/uploads/2016/09/A-New-Normal_Ongoing-Chemical-Weapons-Attacks-in-Syria.compressed.pdf

From Syrian American Medical Society





http://www.sams-usa.net/wp-content/uploads/2016/09/A-New-Normal_Ongoing-Chemical-Weapons-Attacks-in-Syria.compressed.pdf

OPCW-UN Fact-Finding Missions and Joint Investigative Mechanisms (JIM)

- Described the investigations and results of **eight cases of possible use of chlorine or a chlorine derivative and one related to the use of sulfur mustard in Syria**.
- Reported that there were three incidents where there was either a substance “matching the characteristics of chlorine”, “a canister with traces of chlorine or a chlorine-like substance”, “a significant number of people — up to 150 — may have been exposed to chlorine” and a “canister with traces of chlorine”.
- Two cases with a “toxic substance” used.
- They reported one incident where “there was sufficient information to conclude that Islamic State in Iraq and the Levant (ISIL) was the only entity with the ability, capability, motive and means to use sulfur mustard in Marea on 21 August 2015”.
- For the other incidents, they were unable to confirm the use of chemical weapons.

https://www.un.org/ga/search/view_doc.asp?symbol=S/2016/738

OPCW-UN Fact-Finding Missions and JIM

https://unoda-web.s3.amazonaws.com/wp-content/uploads/2013/12/report.pdf

http://www.the-trench.org/wp-content/uploads/2016/01/OPCW-FFM-20140616-1st-Chlorine-investigation-report.pdf

http://www.the-trench.org/wp-content/uploads/2016/01/OPCW-FFM-20140910-2nd-Chlorine-investigation-report.pdf

http://www.the-trench.org/wp-content/uploads/2016/01/OPCW-FFM-20141218-3rd-Chlorine-investigation-report.pdf

http://www.the-trench.org/wp-content/uploads/2016/01/OPCW-FFM-20151217-Syria-request-Rev1.pdf

http://www.the-trench.org/wp-content/uploads/2016/01/OPCW-FFM-20151029-Idlib-Governorate.pdf

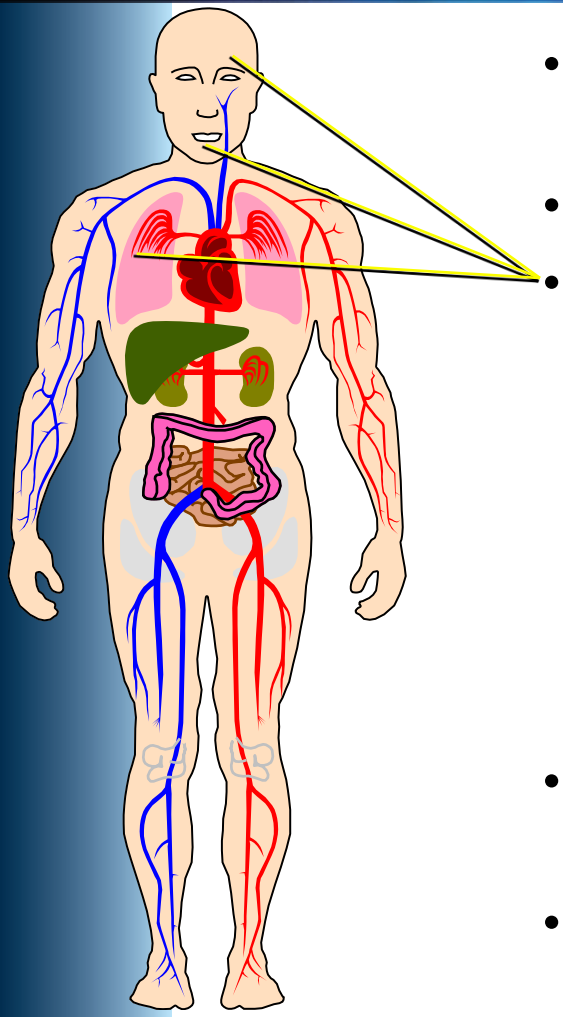
http://www.the-trench.org/wp-content/uploads/2016/01/OPCW-FFM-20151029-Marea.pdf

http://www.securitycouncilreport.org/atf/cf/%7B65BFCF9B-6D27-4E9C-8CD3-CF6E4FF96FF9%7D/s_2016_142.pdf

http://www.un.org/en/ga/search/view_doc.asp?symbol=S/2016/530

https://www.un.org/ga/search/view_doc.asp?symbol=S/2016/738

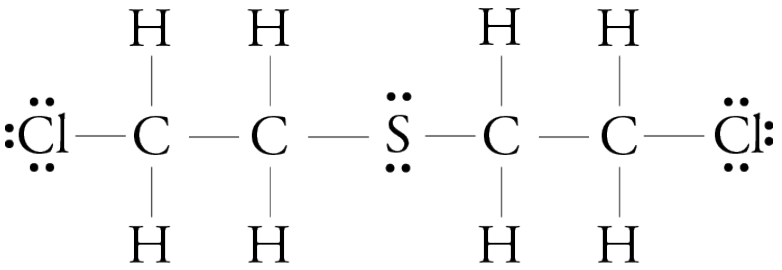
Blister Agents (Vesicants)

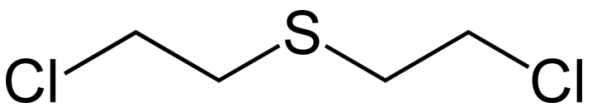


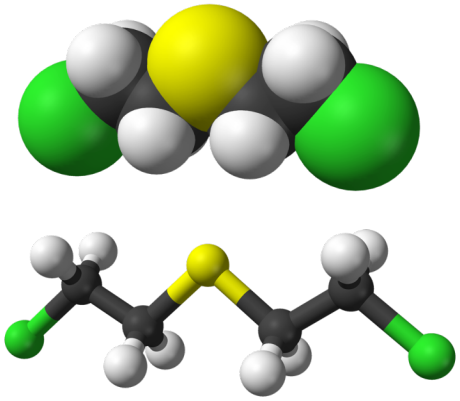
- **Sulfur mustard**, nitrogen mustard, phosgene oxime, Lewisite
- Mode of action: inhalation, skin contact
- Physiological effects
  - Burns skin, mucous membranes, and eyes, causing large water blisters on exposed skin
  - Causes damage to upper airways
  - Primarily used to cause medical casualties, but can be lethal when large amounts are inhaled
- Form when disseminated: liquid, aerosol, vapor, dust
- Required defensive gear: protective mask & clothing

Sulfur Mustard, H or HD

- Called “mustard” because of its horseradish- or garlic-like smell.
- It is fat-soluble, so it dissolves in the oils in the skin, causing severe chemical burns and blisters.







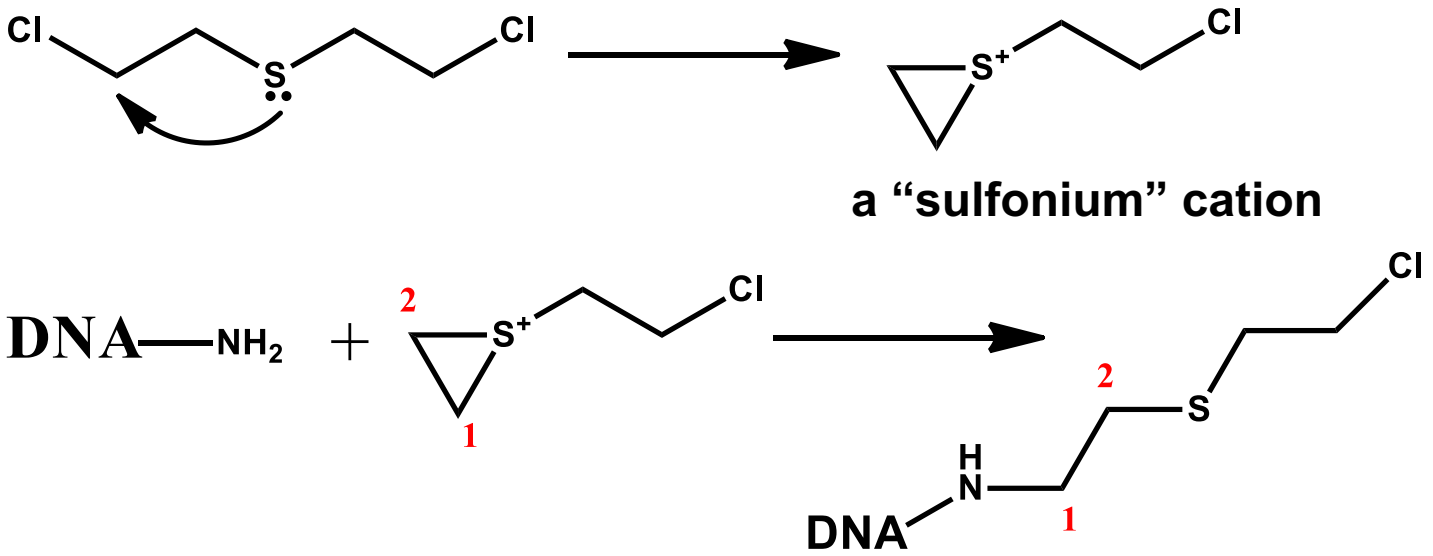
Sulfur Mustard (cont.)

- “H” usually refers to an impure form of sulfur mustard with 20-30% impurities…has short shelf-life. It is relatively easy to make.
- “HD” refers to a more pure form (96% pure) that can be stored longer.
- It can remain on the ground for weeks, making the area dangerous long after its dispersal.

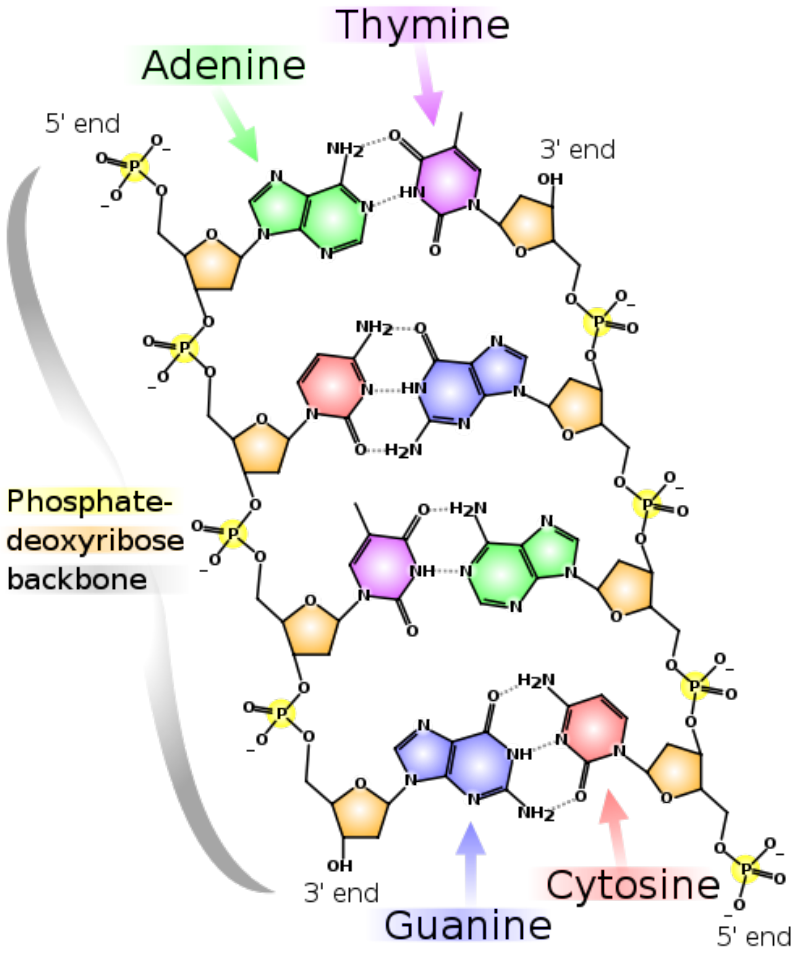
155 mm artillery shells that contained "HD" (distilled sulfur mustard agent) at Pueblo chemical weapons storage facility

Effect of Sulfur Mustard on DNA

Sulfur mustard forms a sulfonium ion, which attaches to a number of different biomolecules, including proteins and the nucleotides of DNA, disrupting cell division and function. This can lead to cellular death or cancer.

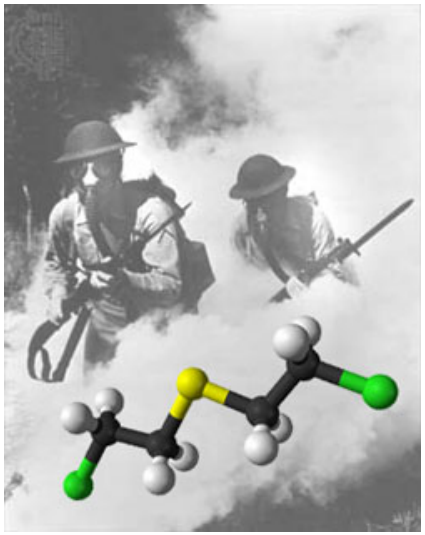


DNA Segment


Thymine
Adenine
5' end
3' end
Phosphate-
deoxyribose
backbone
3' end
Guanine
Cytosine
5' end

Sulfur Mustard Military History

- Used first by Germans in WWI in 1917.
- Captured mustard agent shells used by Allies in 1917.
- Later dispersed as an aerosol, in aerial bombs, land mines, mortar rounds, artillery shells, and rockets.
- Adolf Hitler claimed he was exposed to mustard agent in 1918 and temporarily blinded. He may have been trying to cover up hysterical blindness.



Sulfur Mustard Military History

- 1919: United Kingdom against the Red Army
- 1921-27: Spain and France against insurgents in Morocco
- 1935-40: Italy against Abyssinia (now Ethiopia)
- 1937-45: Japanese against China
- 1963-67: Egypt against North Yemen
- 1983-88: Iraq against Iran and the Kurds
- 1995, 1997: Possibly Sudan against insurgents in their civil war

World War I Casualties from CW

Total Amount of Chemical Agents Used – 112,000 Tons			
Nations	**Non-fatal**	**Deaths**	**Total Casualties**
Commonwealth Forces (Britain, Canada, Australia, New Zealand, India,...)	180,597	8,109	188,706
France	182,000	8,000	190,000
United States	71,345	1,462	72,807
Italy	55,373	4,627	60,000
Russia	419,340	56,000	475,340
Germany	191,000	9,000	200,000
Austria - Hungary	97,000	3,000	100,000
Others	9,000	1,000	10,000
Total	1,205,655	91,198	1,296,853

Sulfur Mustard Treatment

- Early rinsing of the exposed area with Betadine (providone-iodine) dissolved in glycofural will reduce symptoms.
- Can limit the formation of blisters by applying household bleach or a solution called DS2 (2% sodium hydroxide, NaOH, 70% diethylamine, $CH_3CH_2NHCH_2CH_3$, and 28% ethylene glycol monomethyl ether, $CH_3OCH_2CH_2OH$)
- After initial treatment, the patient is treated in the same way that any burn victim would be treated.
- Because the symptoms do not appear for about 24 hours, it less likely that the treatments would be done in time to avoid problems.
- Fatal in about 2% of exposures, so mostly used as an incapacitating agent.

Factors Affecting the Ability to Make CW

- Scientific and industrial expertise
- Availability of precursors
- Availability of equipment
- Money available
- Desired quantity
- Desired purity
  - For a variety of reasons, products of chemical reactions are rarely pure, so after the initial reactions, steps are taken to purify the product.
- Concern for safety of workers
- Concern for the environment

Production of Sulfur Mustard

- Thiodiglycol and concentrated hydrochloric acid react to form sulfur mustard.

  $(HOCH_2CH_2)_2S + 2\ HCl \rightarrow (Cl\text{-}CH_2CH_2)_2S + 2\ H_2O$

- Thiodiglycol (CWC Schedule 2 Part B)
  - Used to make many things, including pen inks, plastics, pesticides, dyes, and photographic developing solutions
  - Produced in several countries, including Germany and the UK.
  - Many firms purchase it.

- Does not require sophisticated equipment.
- Distillation leads to improved purity, which allows longer storage.
- Plant cost of $5-10 million

1925 Geneva Protocol

- Protocol on the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare
- **Banned first use of chemical and biological weapons but not their production and stockpiling**
- Adopted by the League of Nations
- Within ten years, it was ratified by forty countries, including most of the majors powers except the U.S. and Japan.
- U.S. signed with reservations 50 years later
- A number of countries reserved the right to retaliate and therefore stockpiled chemical weapons.

U.S. Chemical Warfare Service (CWS)

- Formed in 1918
- Headquartered at Edgewood Arsenal
- Headed by General Amos Fries
- Later became the U.S. Army Chemical Corps

When properly safe-guarded with masks and other safety devices, [chemical weapons give] the most scientific and most ingenious people an advantage over the less scientific and less ingenious…It is just as sportsman-like to fight with chemical warfare material as it is to fight with machine guns.

General Fries

Chemical Weapons Convention (CWC)

- **A disarmament agreement that bans the production, stockpiling, transferring, and use of chemical weapons.**
- Approved by the U.N. General Assembly in November, 1992.
- Open for signature in 1993
- The U.S. ratified CWC in 1997.

http://www.cwc.gov/

http://www.opcw.org/chemical-weapons-convention//

http://www.opcw.org/news-publications/publications/history-of-the-chemical-weapons-convention/

CWC General Obligations

1. Each State Party to this Convention undertakes never under any circumstances:

(a) To develop, produce, otherwise acquire, stockpile or retain chemical weapons, or transfer, directly or indirectly, chemical weapons to anyone;

(b) To use chemical weapons;

(c) To engage in any military preparations to use chemical weapons;

(d) To assist, encourage or induce, in any way, anyone to engage in any activity prohibited to a State Party under this Convention.

CWC General Obligations (cont.)

2. Each State Party undertakes to **destroy chemical weapons it owns or possesses**, or that are located in any place under its jurisdiction or control, in accordance with the provisions of this Convention.

3. Each State Party undertakes to **destroy all chemical weapons it abandoned** on the territory of another State Party, in accordance with the provisions of this Convention.

4. Each State Party undertakes to **destroy any chemical weapons production facilities** it owns or possesses, or that are located in any place under its jurisdiction or control, in accordance with the provisions of this Convention.

5. Each State Party undertakes not to use riot control agents as a method of warfare.

Organisation for the Prohibition of Chemical Weapons (OPCW)

- Model of multilateralism - 193 member states that contain 98% of the world's population.
- 4 nonmember states
  - Signatory states that have not ratified the CWC
    - Israel
  - States that have neither signed nor ratified the CWC
    - Egypt
    - North Korea
    - South Sudan ("has all but concluded the process of joining the Organisation for the Prohibition of Chemical Weapons" 12/1/17)

States Outside CWC

- Israel
  - Analysts believe that Israel initiated a CW program between mid-1950s and mid-1980s.
  - Refuses to ratify CWC until there's more regional participation.
  - Israel's chemical industry is advanced and diverse.
  - Although Israel is capable of creating CW weapons, there is insufficient information available to reconstruct their CW program.

http://www.nti.org/country-profiles/israel/

States Outside CWC

- Egypt
  - Used CW in North Yemen
  - Thought to have inherited mustard agent and phosgene from British forces when they withdrew in 1954
  - May have nerve agents
  - Refuses to join CWC until Israel joins the Nuclear Nonproliferation Treaty (NPT)
  - Thought to have helped Iraq get CW production capabilities

http://www.nti.org/e_research/profiles/Egypt/Chemical/index.html

States Outside CWC

- North Korea
  - Thought to have 2500-5000 metric tons of phosgene, hydrogen cyanide, mustard agent, and sarin
  - Has capable but aging chemical industry

http://www.nti.org/country-profiles/north-korea/

CWC Definitions

- **Toxic Chemical** = Any chemical which through its chemical action on life processes can cause death, temporary incapacitation or permanent harm to humans or animals.
- **Precursor** = Any chemical reactant which takes part at any stage in the production by whatever method of a toxic chemical.
- **Key Component** of Binary or Multicomponent Chemical System = The precursor which plays the most important role in determining the toxic properties of the final product and reacts rapidly with other chemicals in the binary or multicomponent system.

CWC Schedule 1

http://www.opcw.org/chemical-weapons-convention/annex-on-chemicals/a-guidelines-for-schedules-of-chemicals/

- Schedule 1 chemicals have few or no uses other than as chemical weapons agents or to arm chemical weapons.
- Examples include the nerve agents, sulfur mustards, nitrogen mustards, and lewisite
- They are the most highly regulated of all chemicals.

http://www.cwc.gov/index_chemicals_sch1.html

CWC Schedule 2

- Schedule 2 chemicals are chemicals that could be used as weapons or to make weapons, but also have legitimate small-scale uses.
- Examples include Amiton (a V-series nerve agent) and BZ.

http://www.cwc.gov/index_chemicals_sch2.html

CWC Schedule 3

- Schedule 3 chemicals have large-scale uses other than chemical weapons.
  - Chemical plants producing more than 30 Mg per year must report to the Organisation for the Prohibition of Chemical Weapons (OPCW).
  - The plants can be inspected, and there are restrictions on export to countries that have not signed the CWC.
  - Phosgene and hydrogen cyanide are examples.

http://www.cwc.gov/index_chemicals_sch3.html

CWC Parts A and B

- Each schedule is divided into
  - Part A – toxic chemicals themselves
  - Part B – their precursors (chemicals used to produce the toxic chemicals)

Organisation for the Prohibition of Chemical Weapons (OPCW)

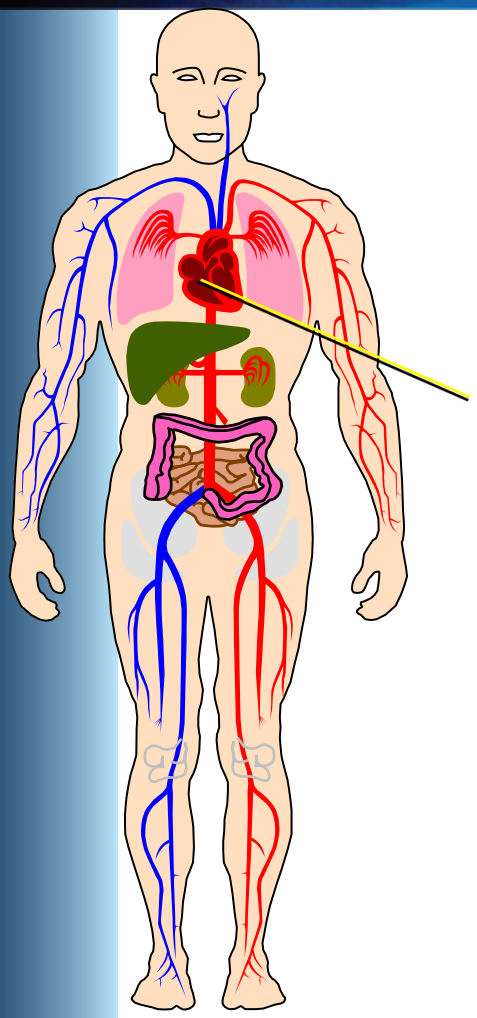
- Intergovernmental organization located in The Hague, Netherlands
- *"…implementing body of the [CWC]…given the mandate to achieve the object and purpose of the Convention, to ensure the implementation of its provisions, including those for international verification of compliance with it, and to provide a forum for consultation and cooperation among States Parties."*

http://www.opcw.org/about-opcw/
http://www.opcw.org/

OPCW Tasks

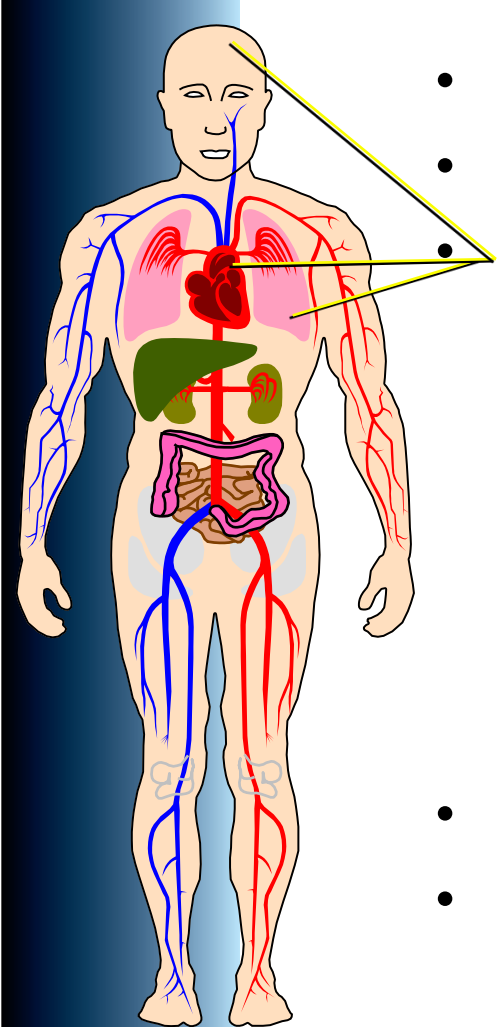
- Bring all States into the CWC
- Verifying the destruction of declared chemical weapons, including those in abandoned CW weapons
  - The CWC is unique among disarmament treaties in having a verification regime.
- Verifying the destruction or conversion of CW plants
- Monitoring future compliance with CWC

Blood Agents



- **Hydrogen cyanide**, cyanogen chloride, **sodium or potassium cyanide**, and arsine
- Mode of action: inhalation or ingestion
- Physiological effects of cyanide
  - Disrupts cellular respiration by diminishing the transfer of oxygen into the mitochondria of cells.
- Form when disseminated: gas or solution
- Required defensive gear: protective mask

Nerve Agents



- Tabun, **sarin**, soman, cyclosarin, **VX**, **Novichok**
- Modes of action: contact, inhalation
- Physiological effects
  - Disrupt the mechanism by which nerves transfer messages to organs
  - Causes seizures and loss of body control
  - Exhausts muscles, including heart and diaphragm
  - Lethal dose can cause death from respiratory failure in five minutes
- Form when disseminated: liquid, vapor, aerosol
- Required defensive gear: protective mask & clothing

Nerve Agents

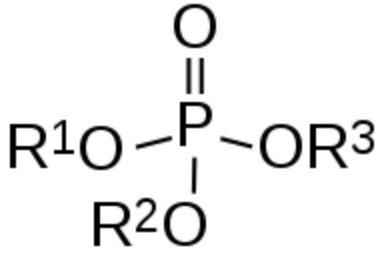
- Cause contraction of pupils, profuse salivation, convulsions, involuntary urination and defecation, and eventual death by asphyxiation as control is lost over respiratory muscles.
- U.S. and the Soviet Union developed and stockpiled large quantities of nerve agents in a chemical arms race that mirrored the nuclear arms race.

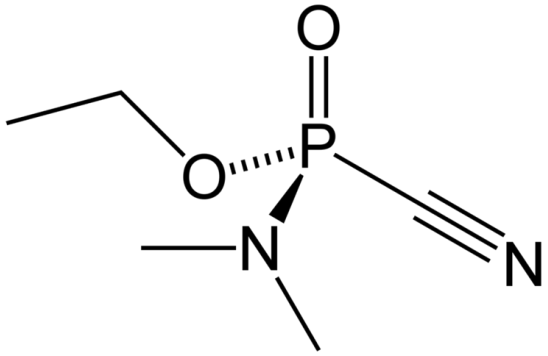
Nerve Agents – Three Series

- G-series
  - Produced by Germans
  - 1936 – GA (tabun)
  - 1939 – GB (sarin)
  - 1944 – GD (soman)
  - 1949 – GF (cyclosarin)
- V-series
  - More persistent after dispersal
  - VX most important…first produced by the British in the 1950s
- Novichoks (produced by Soviets/Russians)

Nerve Agents

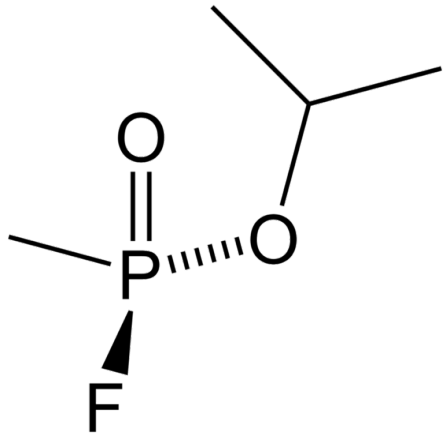
- Discovered accidentally by German chemists developing pesticides.
  - Germany had the world's most advanced chemical industry.
  - Searching for new organophosphate pesticides
- Made many variations of the structure and tested them for potency.
- One compound found to be very dangerous and therefore considered "taboo" (tabu in German)…called Tabun.

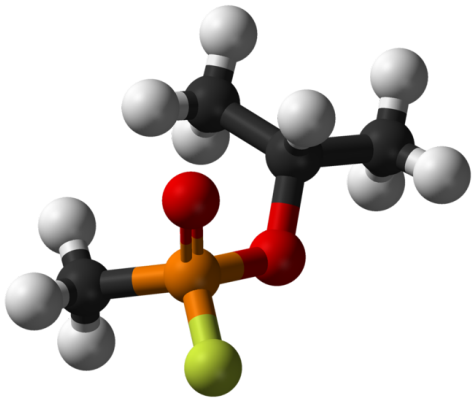




Sarin (GB)

- Developed by the Germans in 1939
- Odorless
- Hard to make
- Stable when stored
- Volatility similar to water
- Very potent
- Breaks down fairly rapidly in the environment
- Has antidotes
- Adopted as the standard nerve agent for the U.S. in 1948.



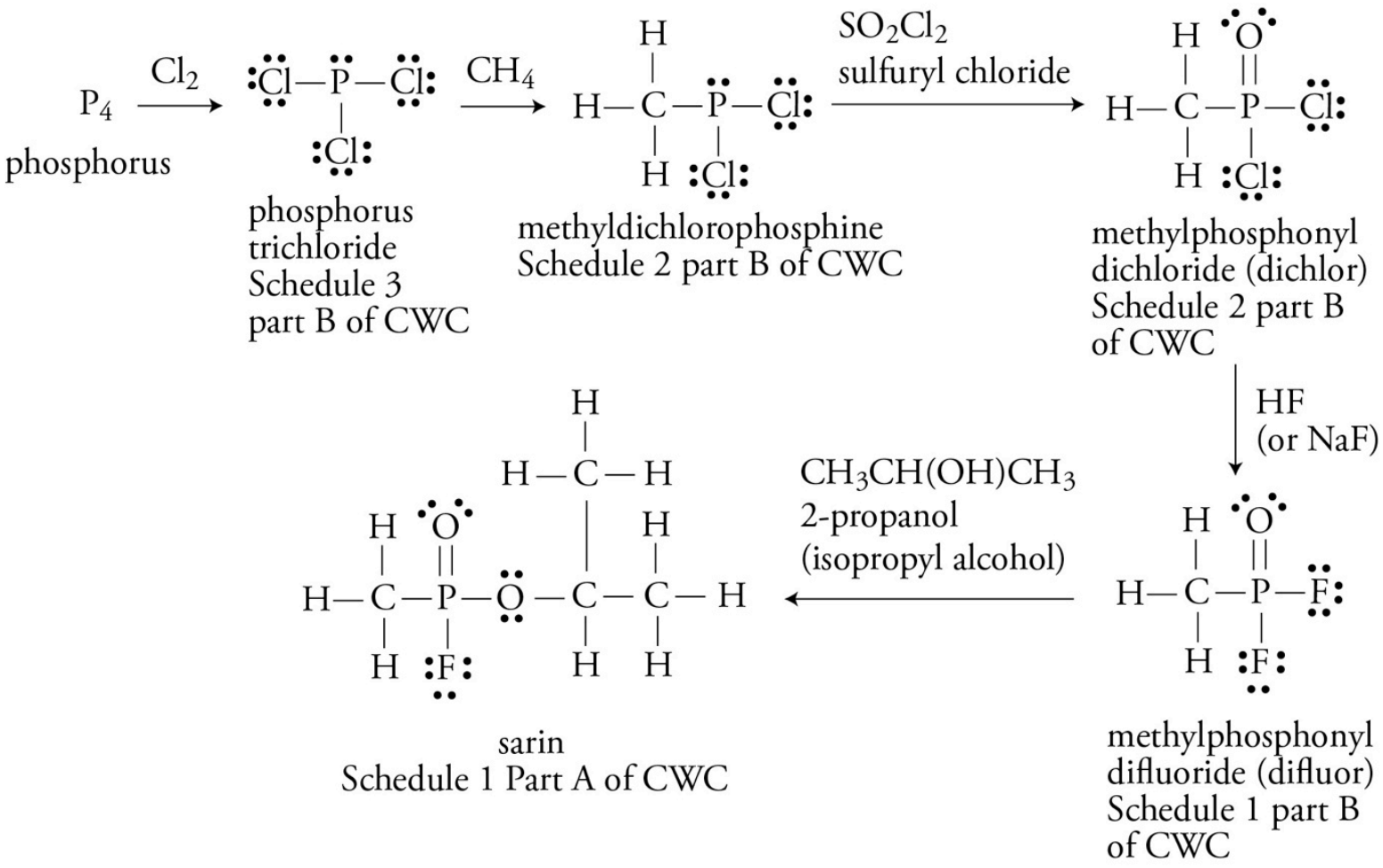


http://chemapps.stolaf.edu/jmol/jmol.php?model=FP%28%3DO%29%28OC%28C%29C%29C

Sarin (GB)

- A very large amount of sarin has been made, but very little of it has been used.
  - March 1988 - Iraq used against Kurdish city of Halabja
  - April 1988 – Iraq against Iran.
  - 1995 - Used in the Tokyo Subway attack by Aum Shinrikyo
  - 2013 - Used in Ghouta, Syria
  - 4/4/2017 – used in Khan Shaykhun, Syria
  - 3/24,25/2017 - Ltamenah, Syria

Rough Steps in Production of Sarin



Production of Sarin

- Most easily prepared from methylphosphonyl difluoride and isopropyl alcohol.

  $CH_3P(O)F_2 + (CH_3)_2CHOH \rightarrow [(CH_3)_2CHO]CH_3P(O)F + HF$

- Three technical hurdles when making from simpler substances.
  - Involves corrosive hot hydrochloric acid, HCl, and hydrogen fluoride, HF, so need corrosion resistant equipment, e.g. vessels and pipes of an alloy that is 40% nickel…Monel and Hastalloy.
  - To make $CH_3P(O)F_2$ (schedule 1, part b), alkylation reaction in which methyl, $-CH_3$, group is added to the phosphorus atom is technically difficult.
  - Distillation necessary to produce high-purity necessary for long storage.
- Plant cost $30-50 million

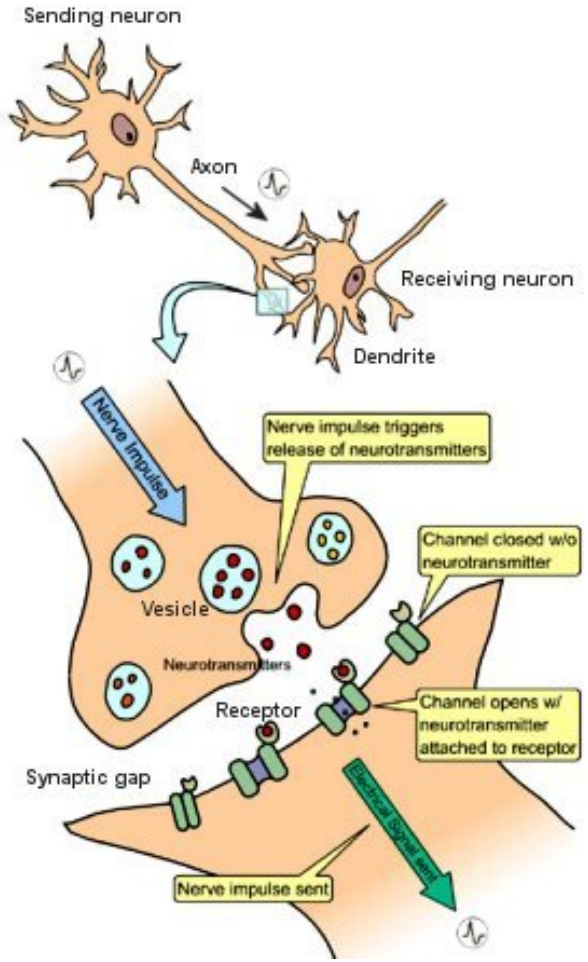
It's not that easy.
Example: Aum Shinrikyo

- $2 BILLION assets; 40,000 members, government deference
- $10 million plant; 100 scientists/engineers
- Goals: sarin - 2 tons/day; 70 ton arsenal; small targets
- Achieved: ~2 kg sarin/attack
  - Auditorium (Feb 1994)
  - Dormitory (June 1994)
  - Subway (March 1995)
- Casualties: 17 total killed

Neurotransmitters

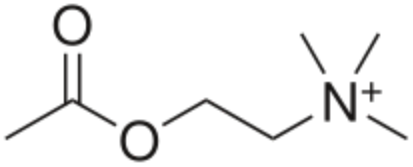
- Neurotransmitters cause nerve cells to fire.

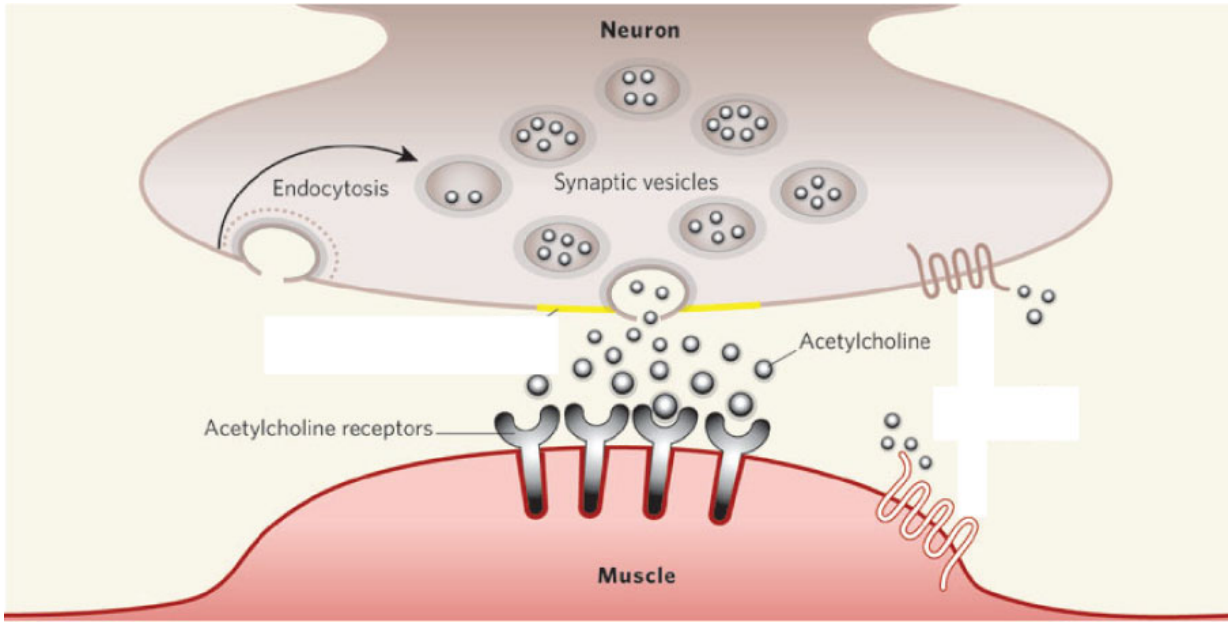
From http://universe-review.ca/R10-16-ANS.htm



Acetylcholine and Muscle Contraction

- Among other things, the neurotransmitter acetylcholine (ACh) stimulates nerve cells that cause muscle contraction.

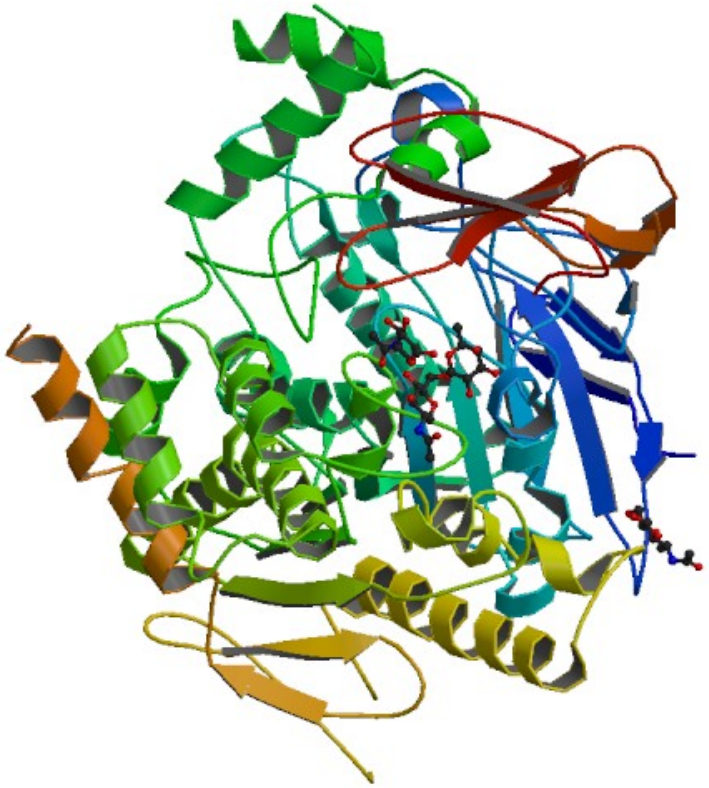




From Nature 436, 473-474 (28 July 2005)

Acetylcholine, Acetylcholinesterase, and Transfer of Nerve Information

- Normally, acetylcholine (ACh) is broken down in the active site of an enzyme, acetylcholinesterase (AChE).
- Each enzyme molecule converts about 25,000 molecules of ACh per second.
- Together, ACh and AChE are like an on-off switch for muscles



Sarin and Acetylcholine-Acetylcholinesterase

- Sarin forms a covalent bond to a serine side chain in the active site of acetylcholinesterase, deactivating it.
- If acetylcholinesterase is deactivated, the acetylcholine levels remain high, and the switch gets stuck in the “on” position.

http://preparatorychemistry.com/nerve_agent_sarin.html

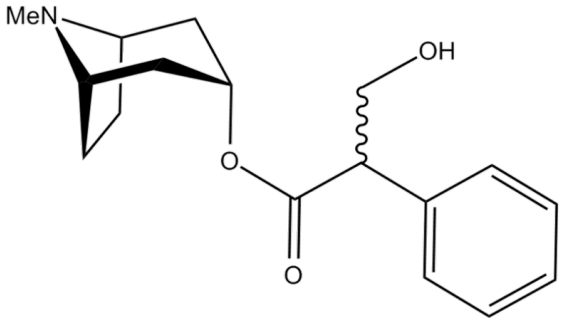
Effects of Nerve Agents

- For skeletal muscles: uncontrolled spasms, followed by paralysis
- For involuntary muscles: pupil contraction, excessive salivation, intestinal cramps, vomiting, and constriction of bronchial tubes
- For central nervous system: overstimulates the brain, causing seizures
- Causes glands to be overactive, secreting excess nasal mucus, saliva, and sweat
- Causes death by asphyxiation through constriction of bronchial tubes, suppression of the respiratory center of the brain, and paralysis of the breathing muscles

Low-level Exposure to Nerve Agents

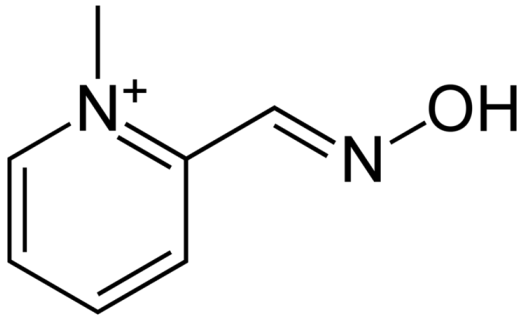
- Low doses lead to inability to think clearly, insomnia, trouble concentrating, and mood swings.
- Continuing exposure to low doses leads to a gradual increase in symptoms.
- It can take up to months for the acetylcholinesterase levels to return to normal.

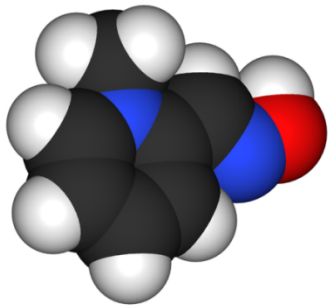
Nerve Agent Antidotes - Atropine



- Standard antidote for organophosphate poisoning
- Used in ancient Greece to dilate pupils (to make women's eyes prettier)
- Competes successfully with one type of acetylcholine receptors. This type of receptor is found in smooth muscles and glands.
- Helps relax muscles
- Stops the symptoms from nerve agent poisoning, *not* the cause

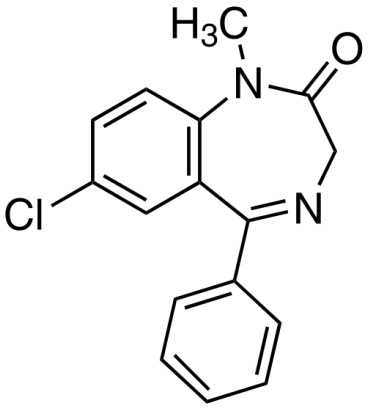
Nerve Agent Antidotes (2-PAM)

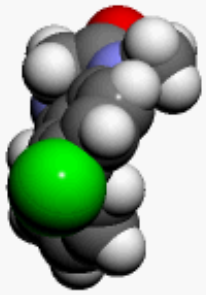




- Pralidoxime (2-pyridine aldoxime methyl chloride,) or 2-PAM
- Removes the nerve agent from the active site of acetylcholinesterase, restoring the enzyme to more normal levels
- Too slow to work well alone
- Works best when administered with atropine, which acts more quickly, giving the slower-acting 2-PAM time to work.
- Does not make it through the blood-brain barrier, so does not alleviate problems within the central nervous system.

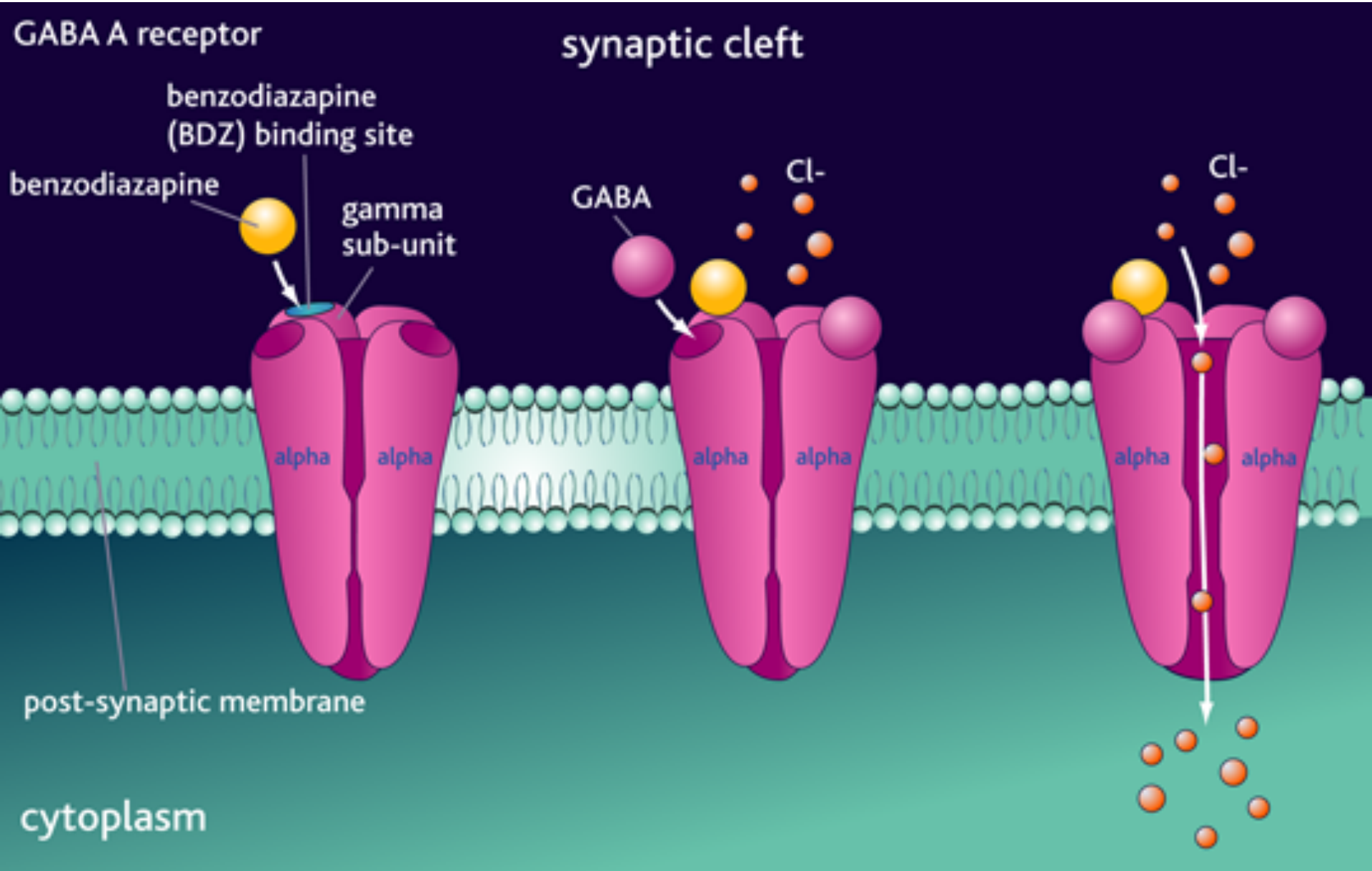
Diazepam (Valium)





- Anticonvulsant
- Enhances the effect of the neurotransmitter GABA, which slows the transfer of nerve information.
  - Nerve firing is caused by buildup of positive ions in nerve cells.
  - GABA triggers movement of Cl^- ions into nerve cell, slowing the buildup of positive charge and slowing the firing of the cells.
  - Valium and other benzodiazapines make it easier for GABA to work.

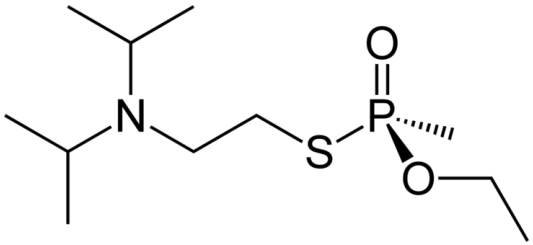
Diazepam (Valium)

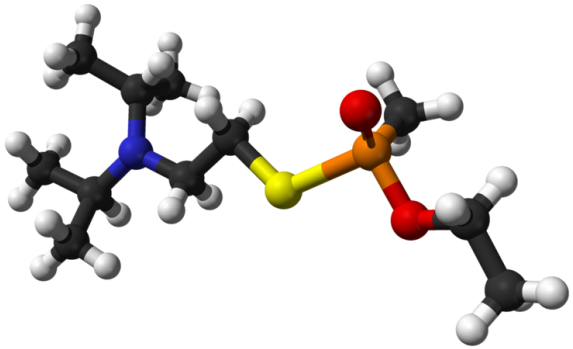


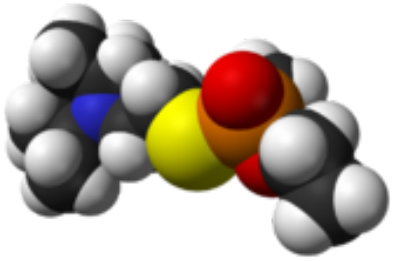
Treatment for Nerve Agent Exposure

- An individual who is known to be exposed to a nerve agent or who exhibits definite signs or symptoms of nerve-agent exposure should have an immediate injection of the antidotes atropine and pralidoxime (2-PAM) and a sedative/antiepileptic drug, such as diazepam (Valium).
- Can be administered with an autoinjector, such as the United States military Mark I NAAK and CANA (Convulsive Antidote, Nerve Agent).
- Remove as much of the nerve agent as possible before moving to a non-contaminated area.
- Rinse with household bleach and rinse with water.
- Remove contaminated clothing and rinse skin again.

VX



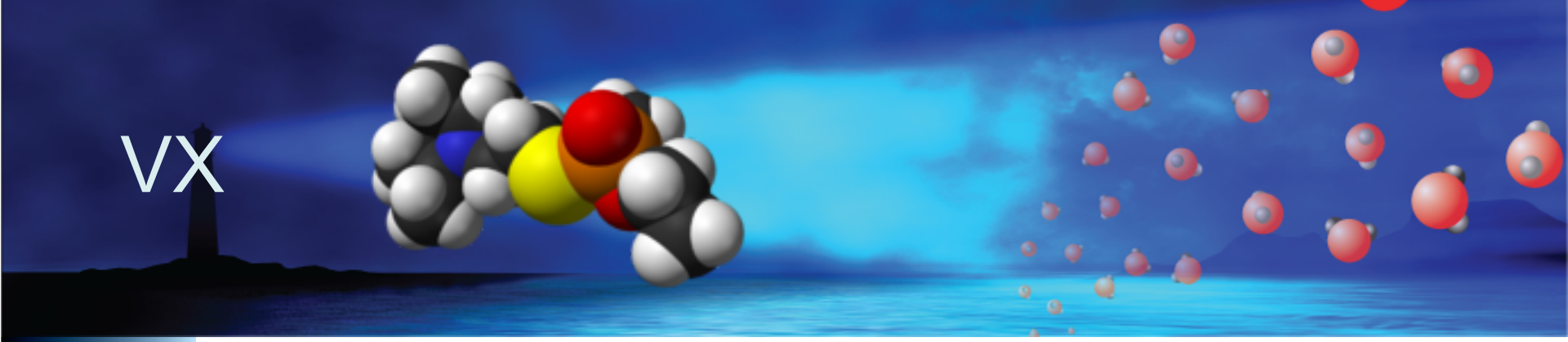




- One of several similar substances that were considered “venomous” and called V-agents.
- First produced in England in 1954
- Odorless liquid, slightly more dense than water, with a viscosity similar to motor oil.

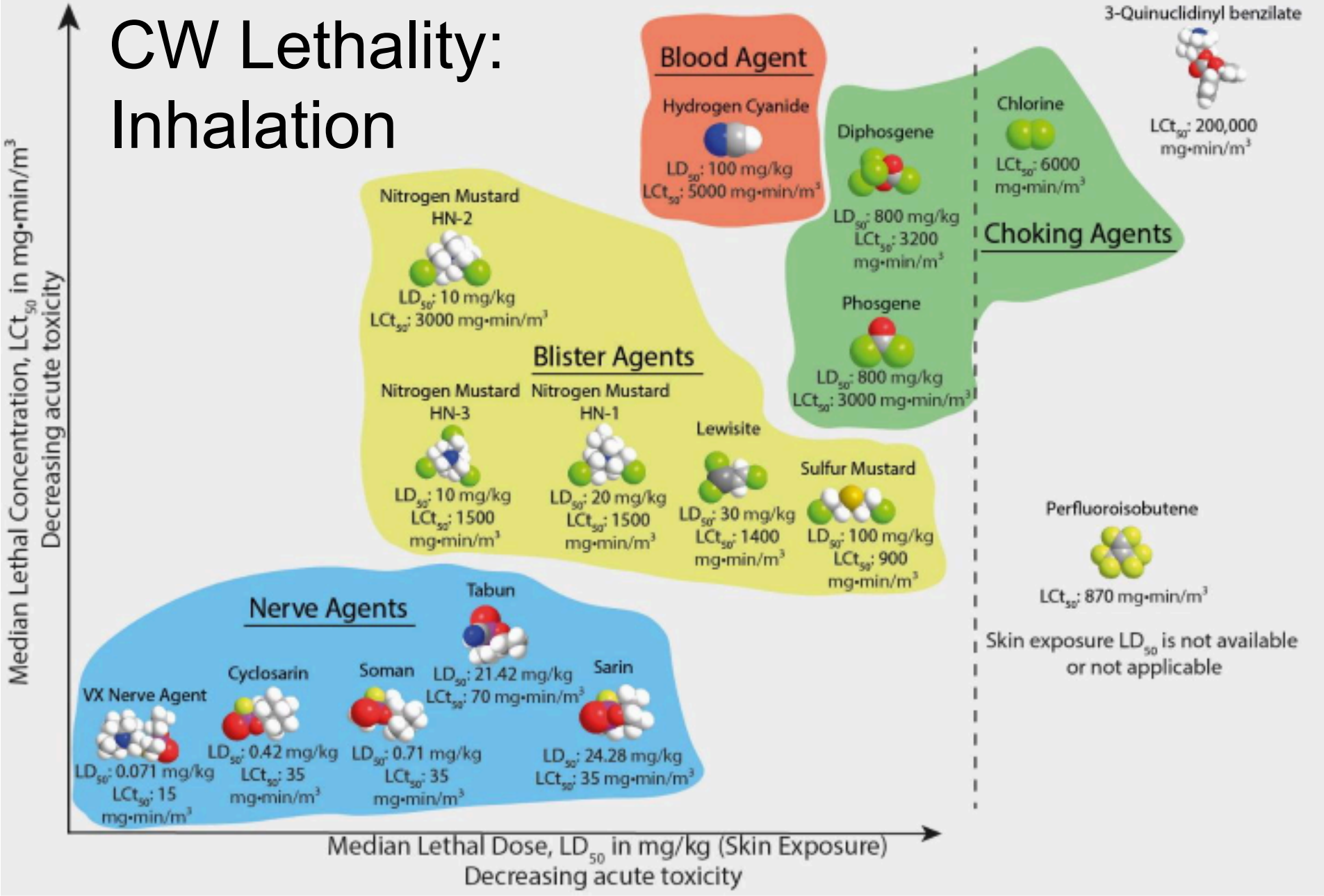
http://chemapps.stolaf.edu/jmol/jmol.php?model=CCOP%28C%29%28%3DO%29SCCN%28C%28C%29C%29C%28C%29C

VX



- Three times more toxic that sarin when inhaled and a thousand times more toxic when absorbed by the skin. A small drop on the skin could kill an adult in fifteen minutes.
- Dispersed as an airborne mist or course spray.
- Clings to whatever it hits
- When sprayed on the ground, remains lethal for up to three weeks, so it is an *area denial weapon*.
- Used to kill Kim Jong-nam, half brother to North Korean leader Kim Jong-un, 13 February 2017 in the Kuala Kumpur International Airport Malaysia.

CW Lethality: Inhalation

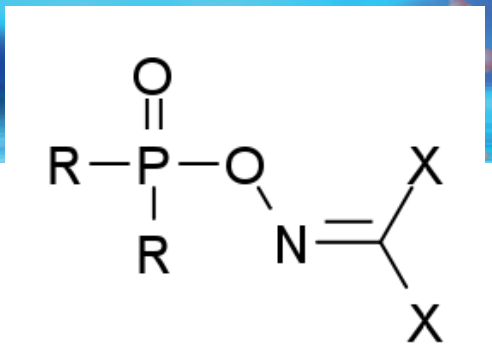


Source: Organisation for the Prohibition of Chemical Weapons (OPCW)

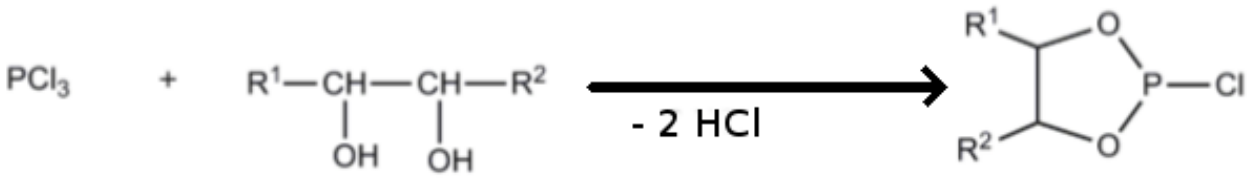
Sarin or VX?

- Sarin –
  - Deadly so inflict high casualties
  - Evaporates about as rapidly as water and reacts fairly quickly with water to form less harmful substances, allowing attacking force to seize territory without major risk to its own troops.
  - Compared to VX nerve agent, sarin is also relatively easy to disseminate.
- VX
  - Due to its viscous nature, VX requires some sort of aerosolization.
  - As little as one drop of VX on skin can be fatal, unless very swift medical treatment.
  - VX nerve agent would require labor-intensive and time-consuming decontamination procedures.

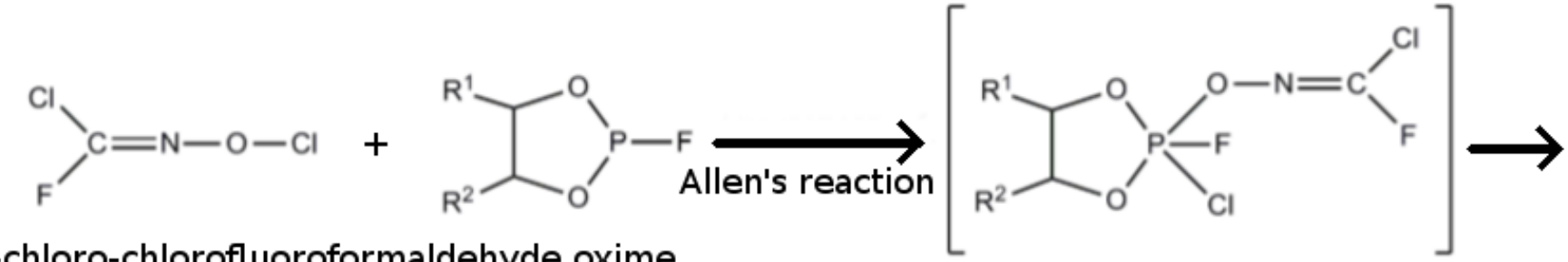
Russia's Novichok



- Alleged Soviet secret program called Foliant
- Novichok (new guy or newcomer) – a category of nerve agents developed in the 1970s and 1980s
- Intent was to develop binary agents that could be made from relatively safe substances similar to normal industrial substances, making it easier to conceal the production
- Allegedly more lethal than VX
- Resistant to treatment

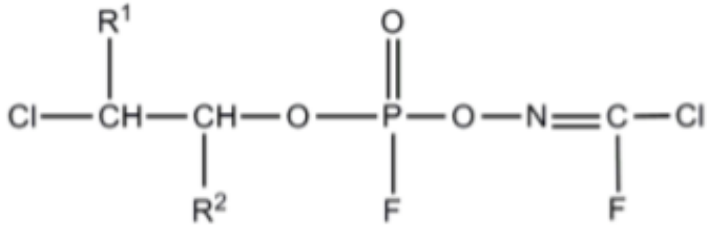


4,5-dialkyl-2-chloro-1,3,2-dioxaphospholane



O-chloro-chlorofluoroformaldehyde oxime

R^1	R^2	
H	H	A 230
H	CH_3	A 232
CH_3	CH_3	A 234



[chloro(fluoro)methylidene]amino (1,2-dialkyl-2-chloroethyl) fluorophosphonate

Russia's Novichok

- A-234 thought to be used in the Salisbury, UK attack on the former Russian military intelligence (GRU) officer Sergei Skripal and his daughter Yulia.
- Czech Republic admitted to making a small quantity of A-230.
- In 2016, Iranian scientists produced five Novichok agents and generated mass spectral data that makes identifying Novichoks easier.

Toxins

- A **toxin** is a poisonous substance produced within living cells or organisms.
- Because toxins are chemicals produced by biological organisms, they can be considered chemical or biological weapons, the use of which would be a violation of both the CWC and the BWC (Biological Weapons Convention).
- As modern chemistry can synthesize an ever-growing number of toxins, they fall under the purview of the CWC.
- Two toxins, ricin and saxitoxin, are listed on Schedule 1 of the CWC.

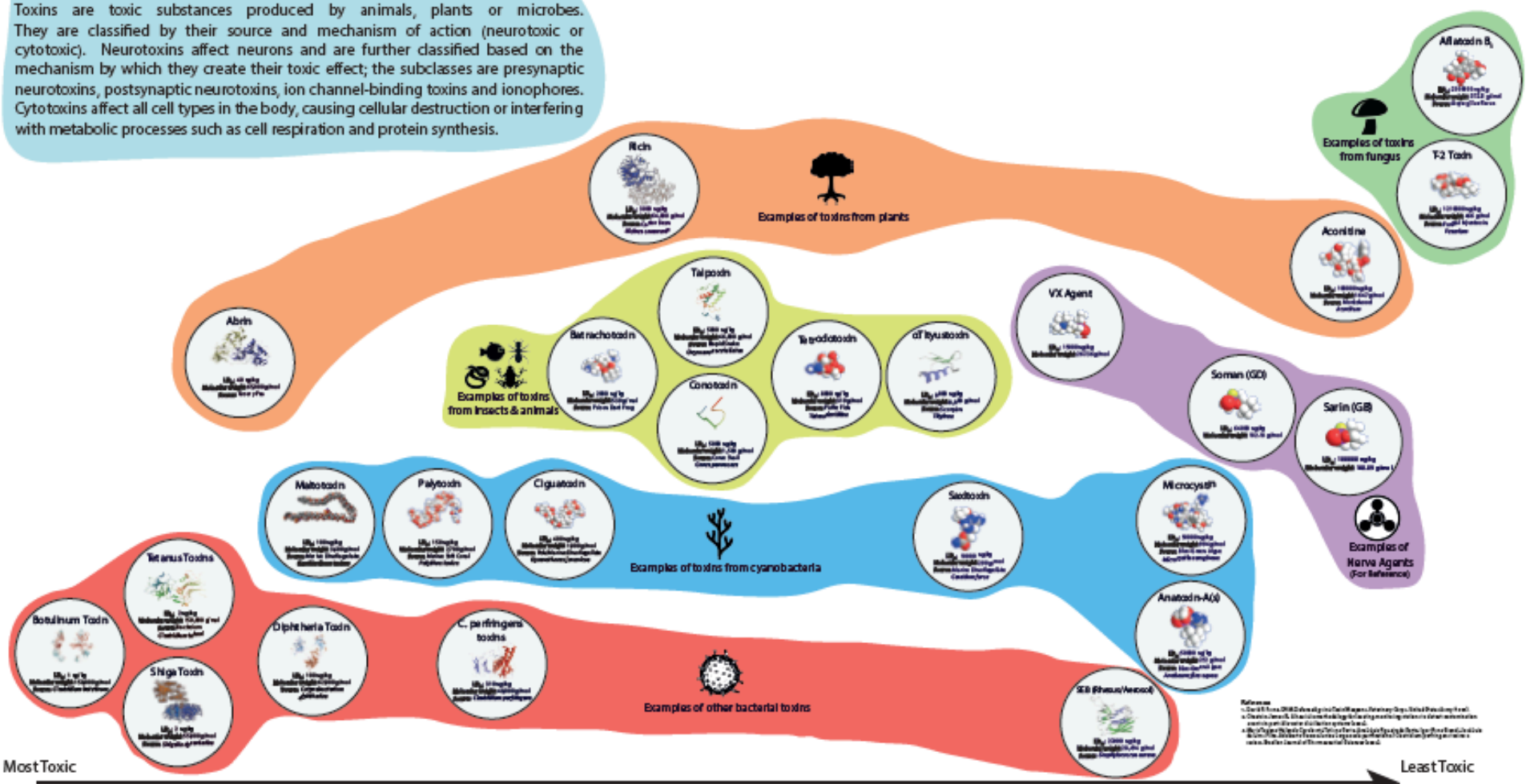
ORGANISATION FOR THE PROHIBITION OF CHEMICAL WEAPONS

Working Together for a World Free of Chemical Weapons

Biological Toxins and their Relative Toxicity

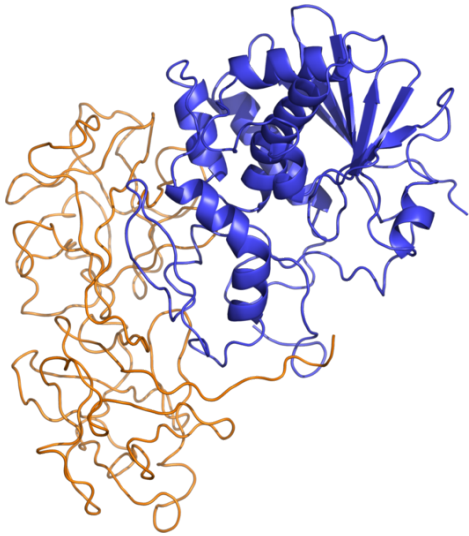
What are Toxins?

Toxins are toxic substances produced by animals, plants or microbes. They are classified by their source and mechanism of action (neurotoxic or cytotoxic). Neurotoxins affect neurons and are further classified based on the mechanism by which they create their toxic effect; the subclasses are presynaptic neurotoxins, postsynaptic neurotoxins, ion channel-binding toxins and ionophores. Cytotoxins affect all cell types in the body, causing cellular destruction or interfering with metabolic processes such as cell respiration and protein synthesis.



Ricin

- Naturally occurring protein.
- Can be extracted from castor beans
- The LD_{50} of ricin is around 22 micrograms per kilogram in humans if exposure is from injection or inhalation.
- Oral lethal dose is 20–30 milligrams per kilogram.
- The major reason ricin is a public health threat is that it is easy to obtain. (More than 1 million metric tons of castor beans are processed each year.)
- Low thermal stability makes it useless in munitions.
- Ricin is listed as a Schedule 1 controlled substance in the CWC.



http://en.wikipedia.org/wiki/Ricin

https://www.google.com/patents/US3060165

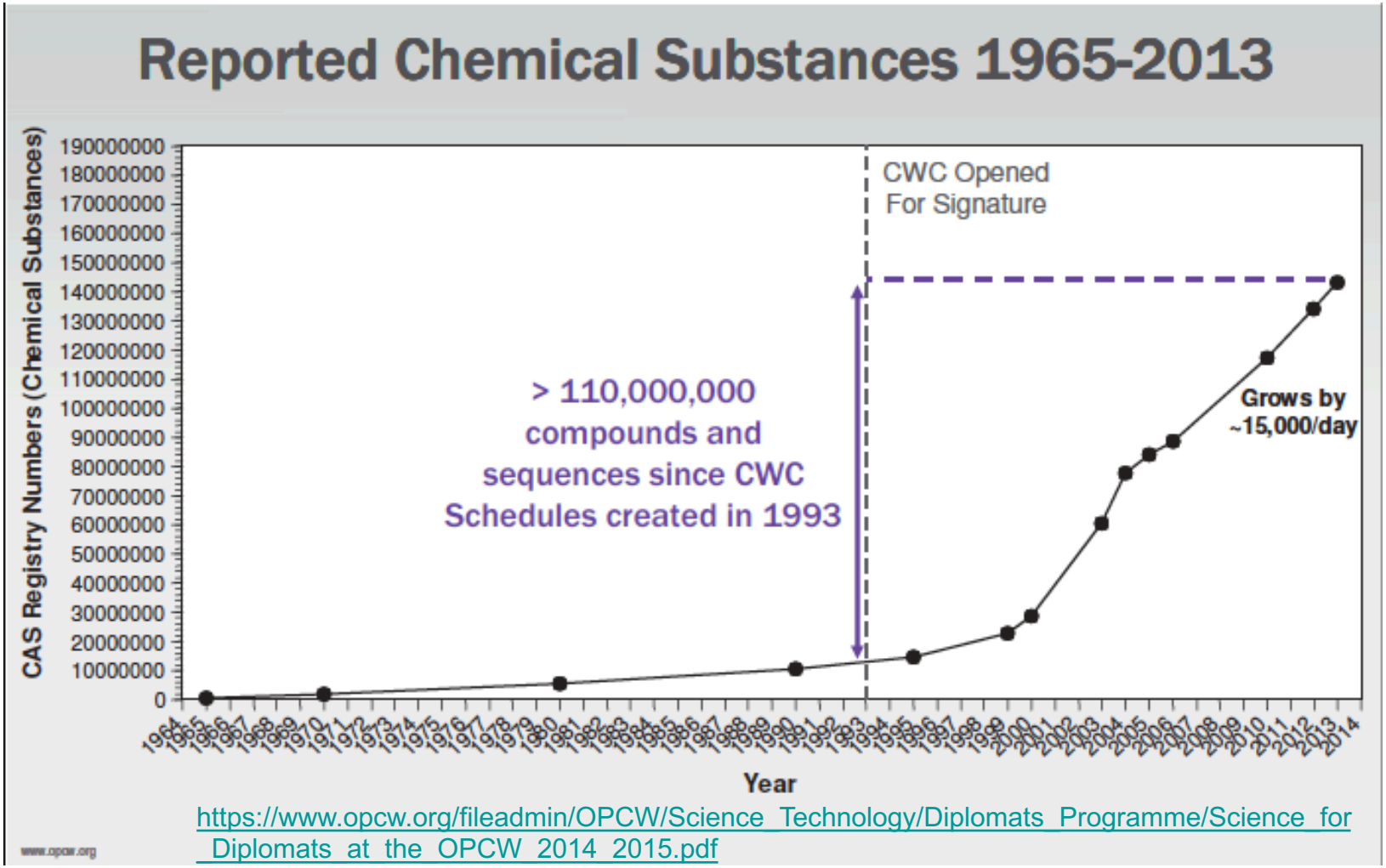
Ricin Physiological Effects

- Reacts with ribosomal RNA, deactivates the ribosome, and disrupts protein synthesis.
- Symptoms may take anywhere from hours to days to appear. Death typically occurs within 3–5 days of exposure.
- **Symptoms from inhalation**: respiratory distress (difficulty breathing), fever, cough, nausea, and tightness in the chest. Heavy sweating may follow as well as fluid building up in the lungs (pulmonary edema). Finally, low blood pressure and respiratory failure may occur, leading to death.
- **Symptoms from ingestion**: vomiting and diarrhea that may become bloody. Severe dehydration, followed by low blood pressure….hallucinations, seizures, and blood in the urine. Within several days, the person's liver, spleen, and kidneys might stop working, and the person could die.

Comparison of Toxins and Chemical Agents

Toxins	Chemical Agents
Natural Origin	Human-made
Difficult, small-scale production	Large-scale industrial production
None volatile	Many volatile
Many are more toxic	Less toxic than many toxins
Mostly not dermally active	Can be dermally active
Legitimate medical use	Almost no medical uses
Odorless and tasteless	Noticeable odor or taste
Diverse toxic effects	Fewer types of effects
Many are effective immunogens	Poor immunogens
Aerosol delivery	Mist/droplet/aerosol delivery

Many New Substances Created



https://www.opcw.org/fileadmin/OPCW/Science_Technology/Diplomats_Programme/Science_for_Diplomats_at_the_OPCW_2014_2015.pdf

Common CW Precursors

- Most precursors have legitimate commercial uses.
- Dual-use nature impedes detection of CW programs.
- Trade in precursors is monitored and controlled.

Chmical Compound	***Commercial Uses***	***CW Agent***
Thiodiglycol	plastics, textile dyes, ink	Mustard agent
Phosphorus trichloride	plasticizers, insecticides	Sarin
Sodium cyanide	dyes & pigments, nylon, metal hardening	HCN
Methylphosphonic difluoride	organic synthesis	Sarin, VX
Phosphorus pentasulfide	insecticides, lubricants, pyrotechnics	VX

Australia Group

- Established 1985
- *"The Australia Group (AG) is an informal forum of countries which, through the harmonisation of export controls, seeks to ensure that exports do not contribute to the development of chemical or biological weapons. Coordination of national export control measures assists Australia Group participants to fulfill their obligations under the Chemical Weapons Convention and the Biological and Toxin Weapons Convention to the fullest extent possible."*

http://www.australiagroup.net/en/index.html

Australia Group

- *"The principal objective of Australia Group participants' is to use licensing measures to ensure that exports of certain chemicals, biological agents, and dual-use chemical and biological manufacturing facilities and equipment, do not contribute to the spread of CBW. The Group achieves this by harmonising participating countries' national export licensing measures. The Group's activities are especially important given that the international chemical and biotechnology industries are a target for proliferators as a source of materials for CBW programs."*
- Some of the controlled chemicals are not listed in the CWC.

http://www.australiagroup.net/en/objectives.html

Australia Group
43 Participants

- European Union (1985), Germany (1985), United States (1985), United Kingdom (1985), Italy (1985), Japan (1985), France (1985), Spain (1985), Sweden (1991), Poland (1994), Switzerland (1987), Netherlands (1985), Argentina (1993), Republic of Korea (1996), Australia (1985), Latvia (2004), Austria (1989), Lithuania (2004), Belgium (1985), Luxembourg (1985), Bulgaria (2001), Malta (2004), Canada (1985), Mexico (2013), Croatia (2007), New Zealand (1985), Republic of Cyprus (2000), Norway (1986), Czech Republic (1994), Denmark (1985), Portugal (1985), Estonia (2004), Romania (1995), Slovak Republic (1994), Finland (1991), Slovenia (2004), Greece (1985), Hungary (1993), Republic of Turkey (2000), Iceland (1993), Ukraine (2005), Ireland (1985), India (2018)

http://www.australiagroup.net/en/participants.html

Top 10 Chemical-Producing Countries

- In Australia Group:
  - 1. USA
  - 2. Germany
  - 5. Japan
  - 6. United Kingdom
  - 7. Italy
  - 8. France
  - 9. India
- Not in Australia Group:
  - 3. Russia
  - 4. China
  - 10. Brazil

http://www.australiagroup.net/en/participants.html

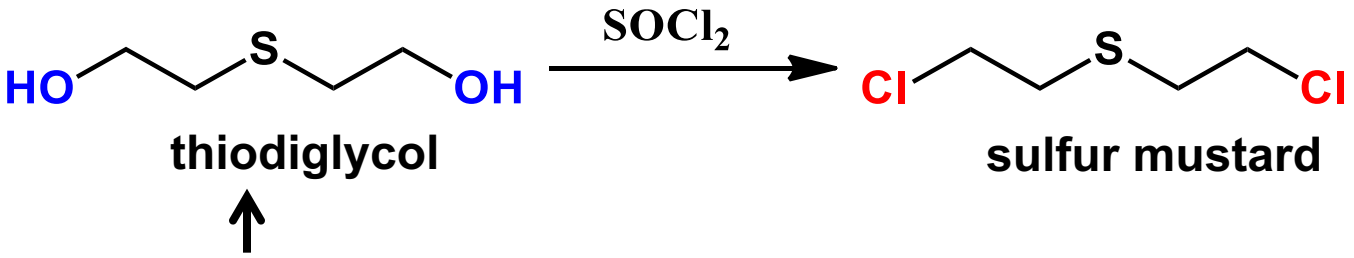
Ways to Circumvent Export Controls on Precursors

- Substitute uncontrolled chemical for controlled one.
- Purchase relatively small quantities from multiple sources
- Produce precursors from simpler, uncontrolled substances.
  - There are at least 9 ways to make sulfur mustard documented in the chemical literature, and some of these involve uncontrolled substances.

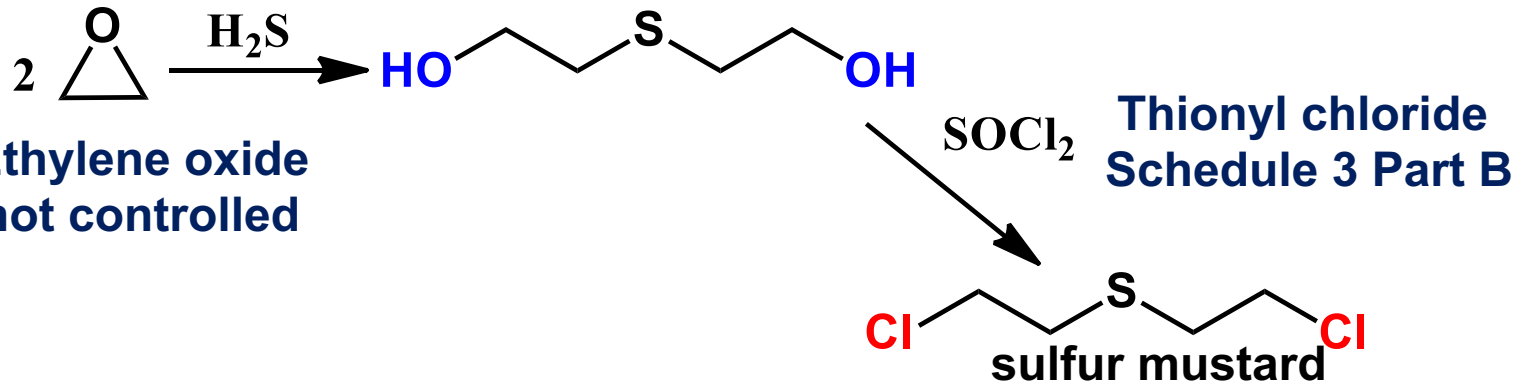
http://www.cwc2013.info/RG2013-by-doc/6/AG-precursors.pdf

Iraqi Mustard Program

Back-Integration = synthesizing precursor compounds from simpler ones that are not export controlled or are available from domestic sources



Embargo placed on this by Western Countries in early 80's



INCIDENT INVESTIGATION

WHAT – WHERE – WHO ?

Science for Diplomats 17 March 2015

www.opcw.org/fileadmin/OPCW/Science_Technology/Diplomats_Programme/Science_for_Diplomats_at_the_OPCW_2014_2015.pdf

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www.opcw.org/fileadmin/OPCW/Science_Technology/Diplomats_Programme/Science_for_Diplomats_at_the_OPCW_2014_2015.pdf

FIRST REPONSE

Science for Diplomats 17 March 2015

www.opcw.org/fileadmin/OPCW/Science_Technology/Diplomats_Programme/Science_for_Diplomats_at_the_OPCW_2014_2015.pdf

WORLD & NATION

Boston's Red-Light District Flickers

THE WASHINGTON POST BOSTON

It is known officially as the Lower Washington Street Adult Entertainment District, but everyone calls it the Combat Zone.

It is the place where the commercial sex industry finds its public, and where Boston — a city once synonymous with sexual prudery — has carried out a successful containment strategy by creating one of the few formal red-light districts in North America.

Now the red light is flickering, about to be extinguished by a convergence of trends here. The story of the Combat Zone's brief heyday, long decline, and imminent fall is an instructive tale of sex, money, violence and urban development.

The area acquired its name before it became zoned for sex. Initially, it was home to a number of small tailor shops, and troops shipped through Boston during World War II got their uniforms altered there. When members of different branches bumped into each other on the sidewalks, combat often erupted.

Later, during the 1950s and 1960s, Boston, like many cities, embarked on a large-scale "urban-renewal" effort, which involved leveling districts of the city and replacing them with new office towers and apartment buildings.

One of the last places to go under the wrecker's ball was Scollay Square, which had been home to Boston's burlesque houses. When the area was torn down to make way for the new City Hall and government center, the honky-tonk businesses migrated to the Combat Zone.

During the late 1980s, the Zone's fate was sealed, according to Robert Campbell, the architecture critic for *The Boston Globe* and a student of urban development.

Rushdie Asks France for Help In Ending Iranian Death Threat

LOS ANGELES TIMES PARIS

Salman Rushdie — the author whom Iran six years ago marked for death for his book *The Satanic Verses* — met France's highest politicians on Monday, winning assurances they would lead a European effort to persuade Iran to declare a "cease-fire" on him.

"I think we are at the beginning of a very serious step," Rushdie said after meeting with Prime Minister Edouard Balladur, Foreign Minister Alain Juppe and other top French officials.

"This is a situation that can be resolved, but what is needed is the will," the British writer told a well-guarded news conference at the French National Assembly. "And this visit has been an important step in creating the will to remove the deadlock."

After meeting with Rushdie, Juppe, the French foreign minister, said pressure on Iran had failed so far in Rushdie's case. But he declared that France was prepared to bring the issue up again next [illegible] European foreign ministers, which Juppe will chair.

"We are ready to take new pressures" might be necessary, if Iran did not comply, though he declined to say what those pressures might include sanctions or diplomatic isolation.

Suspect Captured in Fatal Tokyo Subway Gas Attack

By T.R. Reid
THE WASHINGTON POST TOKYO

Police reportedly had one suspect under guard Tuesday as they searched for a well-organized terrorist gang believed to be responsible for the release of poison gas on the Tokyo subway Monday, which left 8 dead, 76 critically injured and more than 600 hospitalized overnight.

According to the national police agency, the World War II-era nerve gas sarin apparently was released on at least five widely scattered trains during a half-hour period starting around 8 a.m. Monday. Handling this powerful poison — so potent that a single drop on the skin can be fatal — and coordinating its delivery around the city probably required a careful team effort, a police spokesman said.

No one claimed responsibility for the attack, which one official called "a case virtually unparalleled in the history of crime in this country." Police said they were reviewing several other recent cases in which noxious fumes were released — including an incident last June in which seven people died from inhaling what appeared to be the same substance released in the subways on Monday.

The Tokyo Shimbun newspaper reported Tuesday that passengers at the Kodenmacho station in downtown Tokyo spotted and chased a man who had left a vial of vaporous liquid on the train shortly after 8 a.m. The suspect was overcome by the fumes and could not get away. He is now under guard in a hospital, the newspaper said, but was too ill to be questioned Monday.

The poison gas attack was a shock in a country that itself on civility, courtesy and the lowest crime rate of any big city on Earth. [illegible] memories of the Army and other terrorist groups resorted to occasional violence in pursuit of various political aims.

There was little sign of panic in Tokyo following Monday morning's attacks. The thousands of people who came gasping and retching out of the subways — many temporarily blinded by the stinging gas — lined up and waited quietly for on-the-spot treatment or transport to hospitals.

Outside the subway station at Kasumigaseki, bureaucrats sat atop their briefcases while police gave them oxygen. Meanwhile, police and military personnel wearing gas masks and spacesuit-style protective gear searched inch-by-inch through trains and stations.

More than 4,600 people sought hospital treatment. At St. Luke's International Hospital downtown, beds lined the lobby and corridors as nurses washed the eyes of victims and gave them oxygen. Most victims left the hospital under their own power after a few hours. Police said 603 persons were hospitalized overnight.

Service was restored on all but one of the city's 12 subway lines by Monday afternoon, and officials said trains were as packed as usual during the evening rush hour. "Look, I've got to get home," said a woman on the Ginza subway line Monday night. "And it's probably worse if you go up (on the street) and take the bus."

Since the first day of spring is a national holiday in Japan, Tuesday morning was calm and quiet on the subways, with all lines running and all stations open.

In contrast to the delays and confusion that marked the government's response to the disastrous Kobe earthquake in January, rescue and relief efforts Monday seemed to be timely and adequate. Subway lines were shut within minutes after the case was discovered, and medical

U.S. government sources in Washington expressed some skepticism that the substance used in the attack was actually sarin. They said they understood that Japanese police had not completed testing needed to prove what chemical was used and that the data collected so far indicate the substance instead may have been a mixture of agricultural chemicals and other hazardous pesticide-like compounds. The U.S. officials also said they believe the number of deaths is low for a genuine sarin-like agent.

Experts said that sarin itself is in relatively scarce supply and would be difficult, though not impossible, for a terrorist group to make. But structurally similar compounds, with similarly lethal properties, can be made relatively easily and cheaply, according to chemists and other experts.

Other than the report that a suspect was under guard, police said almost nothing about their investigation, but other media reports indicated that there were several witnesses who saw unusual actions on the subways Monday morning.

At Nakameguro station, southwest of the city center on the Hibiya subway line, witnesses told police, a man about 40 years old jumped on the train just before 8 a.m. When he got off at Ebisu, the next stop, he left behind on the floor a plastic lunch box wrapped in newspaper. Within eight minutes, or three more stops, a sharp odor coming from the package forced everybody off the train.

At a train on the Marunouchi line, a wad of wet newspaper on the floor began giving off noxious fumes. A similar wad of papers was found inside a plastic trash bag on a different train.

Government and private experts said these reports suggested that the terrorist group may have brought sealed bottles of sarin into the trains, poured the clear, lethal liquid onto newspaper, then left the train.

Science for Diplomats 17 March 2015
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ENVIRONMENTAL SAMPLING

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OPCW Fact Finding Missions

- Collection of evidence
  - Environmental samples
  - Biomedical samples
  - Chain-of custody
  - Interviews
  - Photos, video
- On-site detectors, on-site analysis
- OPCW designated laboratory network

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Sample Types and Assumed Concentrations

- Environmental samples
  - “Neat” agent from a reactor or bomb
  - Residue from a reaction or waste container
  - Contaminated clothing, hair, soil, water, etc.
  - Concentrations usually expected >1 µg/g (ppm)
  - Survey analysis is possible
- Biomedical samples
  - Urine, blood, plasma, tissue, etc.
  - Intact chemical agent likely not present (degradation/reaction product or metabolite)
  - Concentration levels quite low, < 5 ng/g (ppb)
  - Survey analysis not possible; must use targeted analysis

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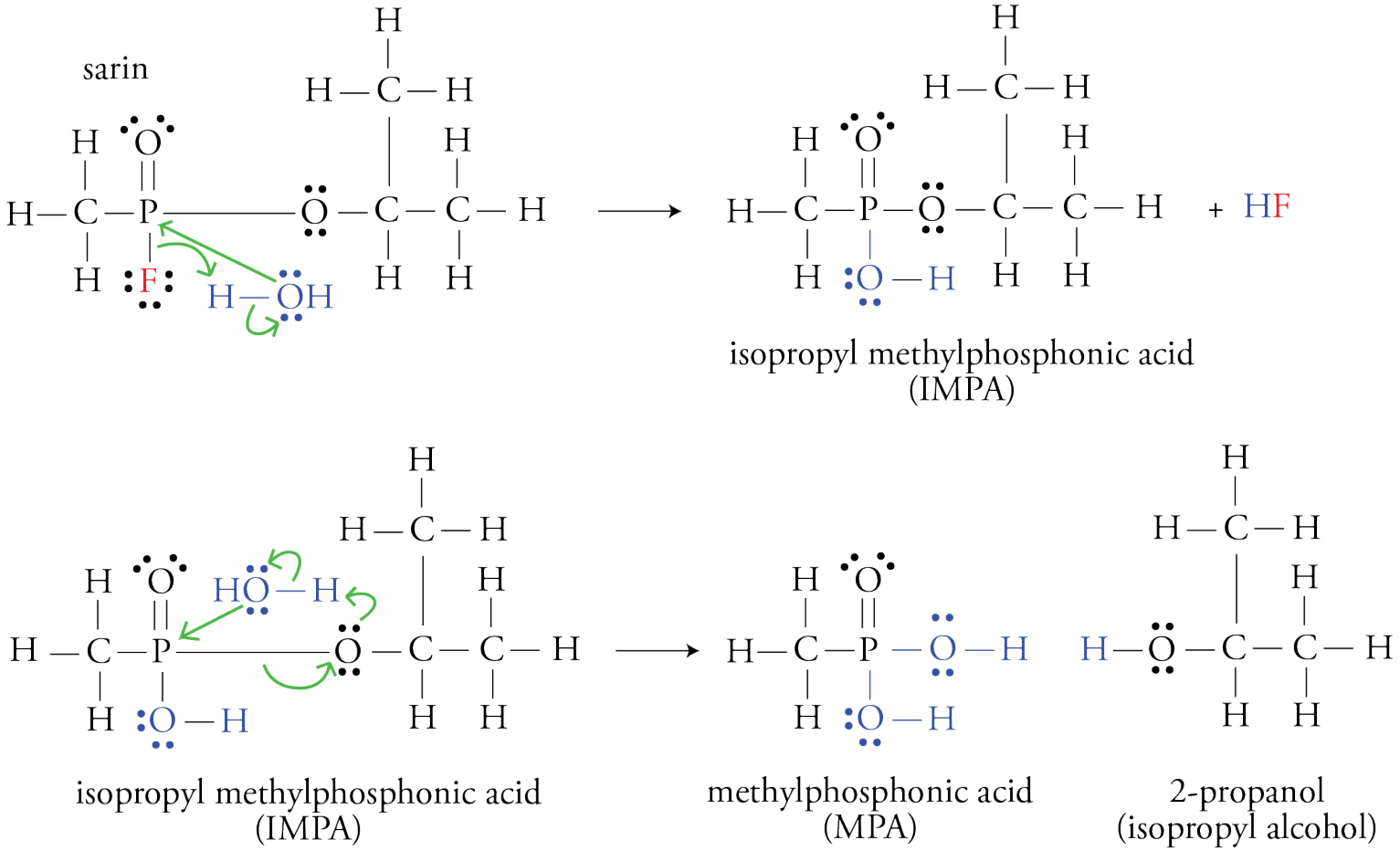
Hydrolysis of Sarin

Each arrow represents the movement of a pair of electrons as covalent bonds are broken and made.



Detection of Sarin Use

- The product of the first step in the hydrolysis of sarin, isopropyl methylphosphonic acid (IMPA), is a chemical that is not commonly found in nature, so if it is found at the site of a chemical weapons attack, it's an indication of the use of sarin.
- IMPA was detected in 20 of 42 reported environmental samples taken by the OPCW team in Ghouta, Syria.
- The final products of the hydrolysis of sarin are formed from the hydrolysis of other organophoshates.

Detection of Sarin Use in Biomedical Samples

- Urine or blood samples taken from exposed persons are more difficult than environmental samples to analyze because the chemical agent, its adducts, and metabolites degrade and are excreted from the body, giving a limited time window to collect and analyze samples.
- Concentration levels in these samples are likely to be in the parts per billion range, requiring a targeted rather than a survey approach to the analysis.
- Can look for IMPA and protein adducts, including sarin-AChE or sarin-BChE (butyrylcholinesterase), which may persist for several weeks.
- Unlike the sarin-AChE adduct, sarin-BChE is found in blood serum.

Detection of Sarin Use in Biomedical Samples

- Can look for protein fragments that come from the partial digestion of the sarin-BChE) in blood serum.
- These fragments can be in the sarin-fragment form or the aged form.