

Mustard Gas

Safety Data Sheet

Division of Occupational Health and Safety
National Institutes of Health



WARNING!

This compound is a strong blister-producing and eye- and lung-damaging agent in liquid or vapor form.

Handle with extreme care.

In case of fire, use water, foam, dry chemical, or carbon dioxide fire extinguisher.

Avoid skin and eye contact.

This compound is toxic and carcinogenic in animals and man.

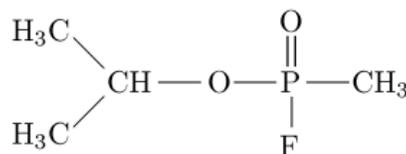
A. Background

Mustard gas, in pure form, is an oily, colorless, and odorless liquid. It is a powerful vesicant and may produce permanent eye damage and respiratory impairment. As an alkylating agent it is mutagenic for microorganisms and mammals. It is rapidly absorbed by the skin and respiratory mucosa but its effects are delayed. Mustard gas was used as a vesicant during World War I and in Ethiopia, and as a model compound in biological studies on alkylating agents; in the latter use it has been largely superseded by the more easily handled (water soluble) nitrogen mustards. Mustard gas has been identified by an IARC Working Group as a being carcinogenic for humans ("Group 1") (Althouse *et al.*, 1980).

B. Chemical and Physical Data

1. Chemical Abstract No.: 505-60-2.
2. Synonyms: Bis (2-chloroethyl)sulfide; bis (β -chloroethyl)sulfide; 1-chloro-2-(β -chloroethyl-thio)ethane; 2, 2'-dichlorodiethyl sulfide; β , β' -dichloroethyl sulfide; ethane, 1, 1'-thiobis (2-chloro); H; HD; Schwefel-Lost; S-Lost; sulfure mustard, Yellow Cross Liquid; Yperite.
3. Chemical formula, molecular weight and chemical structure:

$C_4H_8Cl_2S$; 159.1



4. Density: $d_4^{20} = 1.274$ (liquid); 5.4 (vapor).

5. Absorption spectroscopy: Ultraviolet absorption maximum (with $\log \epsilon$) in ethanol and hexane at 202 nm (3.5-3.6) (Mohler, 1937).
6. Volatility: steam volatile; vapor pressure: 0.025 mm Hg at 0°C, 0.09 mm Hg at 30°C. Constants for the calculation of vapor pressures in the range of 0-60°C (Redeman *et al.*, 1948) and 14-80°C (Balson *et al.*, 1947) have been reported.
7. Solubility: sparingly soluble in water (0.68 g/l at 25°C with hydrolysis); soluble in fat solvents, ethanol, ether, acetone, benzene, and other organic solvents. (Solutions in propylene glycol or triacetin have been often used for animal experimentation.)
8. Description: colorless, odorless, oily liquid in pure form; crystallizes in prisms. Turns yellow on standing or in presence of impurities and acquires characteristic odor of mustard or garlic.
9. Boiling point: 217°C at 760 mm Hg; 98°C at 10 mm Hg; melting point: 13-14°C.
10. Stability: sulfur mustard is stable on storage in dry glass containers but is rapidly hydrolyzed in aqueous solution; half time of decomposition is about 15 min at 20°C (Mohler and Hartnagel, 1941) and 5 min at 37°C (Berenblum, 1935). This reaction is pH-independent, and is slowed down considerably in alcoholic solutions. Mustard vapor is not appreciably hydrolyzed in moist air (Price and Wakefield, 1947). Heating to decomposition results in highly toxic and corrosive products (chlorine, sulfur oxides).
11. Chemical reactivity: sulfur mustard reacts vigorously with oxidizing agents (bleaching powder, hypochlorite, ozone). Reacts with thiols (especially thiosulfate), and alkylates α -amino, imidazole, and phenolic groups in model compounds and biological material. Much of its toxic action has been ascribed to reaction with guanyl groups of DNA, resulting in cross linking.
12. Flash point: 221°F (Sax, 1975).
13. Autoignition temperature: no data.
14. Explosive limits in air: no data.

C. Fire, Explosion, and Reactivity Hazards

1. Use water, foam, carbon dioxide, or dry chemical fire extinguishers. Fire-fighting personnel should wear full protective clothing with full face masks.
2. Exposure to high temperatures may result in the liberation of toxic and corrosive products (chlorine, sulfur oxides). There does not appear to be an explosive hazard.
3. No other conditions contributing to instability are known.
4. No hazardous decomposition products, other than those mentioned above, are known.
5. Do not expose to open flames. Non-spark tools are not required. Explosion-safe refrigerator only.

D. Operational Procedures

Laboratory operations should be carried out in a fume hood or glove box. Personnel should wear laboratory coats with plastic or rubber aprons and surgical gloves; coats and gloves should be changed immediately upon suspected vapor or liquid contamination. Eye protection such as goggles or face shields should be worn at all times.

1. Chemical inactivation: Usually carried out with bleaching powder or with sodium hypochlorite solution. A particularly effective (unpublished) inactivating mixture is a slurry of chloramine β in a solution of 50% water, 45% ethanol, and 5% zinc chloride (ratio of weight of solution to weight of solid = 2.77) Epstein, 1980).

2. Decontamination: The mixture described above may be used to decontaminate surfaces and glassware. Alternatively an alkaline solution such as 10% NaOH in 20% alcohol may be used (Note that an organic solvent such as alcohol is required to solubilize mustard gas; however, its concentration must not be too high to interfere with hydrolysis. Detergents should not be used.) Glassware in this procedure should be allowed to stand overnight before rinsing. All decontamination operations should be carried out in a hood by personnel wearing rubber gloves. Animal cages should be washed with hypochlorite solution. Animal carcasses, feces, and litter should be treated as carcinogenic toxic waste.
3. Disposal: Aqueous or organic waste solutions should be decontaminated as described above, or incinerated. (While there are no specific data for mustard gas, temperatures of 1000°C or higher, with retention time of 2 sec, are satisfactory for most organic compounds.) Waste solids, including animal bedding and carcasses, should be collected in disposal containers and incinerated.
4. Storage: Bulk samples should be stored in the cold in dry sealed ampoules or vials with Teflon cap liners. Samples in anhydrous organic solvents may be stored in bottles or vials with a silicone septum having a Teflon liner and sampled with syringe and needle. Do not store in metal containers.

E. Monitoring and Measurement Procedures Including Direct Field Measurements for Subsequent Laboratory Analysis

1. Sampling: Little has been published concerning this; mustard gas in the atmosphere may be collected in bubblers with critical orifices (Neale and Perry, 1959), or in detection tubes containing 4(4'-nitrobenzyl)pyridine (Koblin, 1958).
2. Analysis: Older methods include iodometric microtitration of the reaction product with chloramine T (range 0.2-200 µg) (Kinsey and Grant, 1946), and colorimetry of the product with 8-quinolinol (sensitivity 0.2 µmole per ml) (Trams, 1958). The color reaction of 4(4'-nitrobenzyl)pyridine with alkylating agents (Epstein *et al.*, 1955) while not specifically described for sulfur mustard, is also applicable to this compound (Epstein, 1980). At present the preferred method is gas chromatography of samples collected in organic solvents such as tetradecane (Erickson *et al.*, 1972) or diethyl succinate (Gibson *et al.*, 1974).

F. Biological Effects (Animal and Human)

1. Absorption: Sulfur mustard applied to skin produces not only severe vesication but also toxic systemic reactions and is therefore absorbed. It is also absorbed by inhalation, ingestion, and injection. Effects on the eye are probably local only.
2. Distribution: Intravenously injected ³⁵S-labeled mustard gas results in appearance of the radiolabel within 20 minutes in urine and bile. Considerable amounts are found in kidneys, lungs, and liver, mostly in "fixed" (probably protein-bound) form. Very small amounts are excreted in feces and expired (Bournsnel *et al.*, 1946; Davison *et al.*, 1960). Mustard gas, when applied to skin, is fixed in the epidermis and dermis, and when instilled in the eye is fixed primarily in the cornea with smaller amounts in the conjunctiva, iris, and lens.
3. Metabolism and Excretion: The metabolism of mustard gas in the animal body is partly by hydrolysis and by oxidation. The major hydrolysis products found in urine are thiodiglycol and conjugated glutathione-bis (β-chloroethyl)sulfide, bis(β-chloroethyl)-sulfone, glutathione-bis (β-chloroethyl)sulfone, and bis-cysteinyl ethyl sulfone. Small amounts of intermediary hydrolysis and/or oxidation products are also found (Davis *et al.*, 1960; Roberts and Warwick, 1963).

In vitro, sulfur mustard at physiological pH and temperature reacts rapidly with DNA and RNA, almost entirely at the N-7 position of guanyl moieties. An important reaction product is di (guan-7-

yl)sulfide, produced by cross-linking of DNA strands which prevents DNA replication (Brookes and Lawley, 1961).

4. Toxic Effects: The acute intravenous LD50 in the mouse, rat, and rabbit is 8.6, 0.7, and 2.7 mg/kg; the percutaneous LD50 in the same species is 92, 9-18, and approximately 100 mg/kg; subcutaneous LD50 in the mouse and rat is 26 and 1.5-5 mg/kg. It is obvious that the rat is far more susceptible to lethal effects of mustard gas than the mouse. Variations are also found depending on the mode of administration, undiluted mustard gas being more toxic (on intravenous injection) than mustard in a solvent (Young, 1947; Anslow *et al.*, 1948). The most sensitive (animal and human) tissue is the eye; exposure to mustard results in conjunctivitis at low doses; higher dosages may lead to corneal opacity, severe conjunctival edema, and blindness. Effects on the skin are delayed and progress through reddening to formation of vesicles and necrosis. Inhaled mustard gas in man produces could and severe pulmonary impairment which may lead to bronchopneumonia. Ingestion may cause nausea and vomiting, distention of the stomach and intestine, and diarrhea. The cause of death from chronic exposure is largely cytotoxicity to rapidly renewing tissues including lymphoid, stomach, intestinal tissue, and bone marrow. It should be stressed that most or all of these toxic effects are delayed and may not be noticeable for several days after exposure.
5. Carcinogenic Effects: Mice exposed to mustard gas by inhalation (Heston, 1953) or intravenous administration (Heston, 1950) show significantly higher incidence of pulmonary tumors, with larger number of nodules per tumor, than do controls; subcutaneous mustard gas produces mainly sarcomas at the site of injection. The same observation has been made in men exposed to mustard gas (production or munition filling) (Wada *et al.*, 1918; Weiss and Weiss, 1975). The latter reference also notes the appearance of bladder carcinomas and leukemias; average induction time is 21.6 years.
6. Mutagenic and Teratogenic Effects: Mustard gas is mutagenic in *Drosophila* and in mice (Rozmiarek *et al.*, 1973). There is no evidence for teratogenicity (in contrast to nitrogen mustards).

G. Emergency Treatment and Medical Surveillance

1. In case of skin exposure to mustard gas in liquid and vapor form, remove contaminated clothing immediately. The skin should be washed with warm water and soap or with 2% sodium thiosulfate; this treatment is effective in preventing or decreasing blister formation only if applied within a few minutes after exposure. For eye exposure was immediately with copious quantities of boric acid solution or water. Refer to a physician.
2. If ingested, drink plenty of water or (preferably) milk.
3. If inhaled, remove promptly to clean air. Exposure with or without symptoms will require hospitalization because of the usually delayed effects. Apply oxygen and/or artificial respiration if needed.
4. Medical management of mustard exposures beyond the first-aid stage is described by Goodman and Gilman (1941) (Note: later editions do not carry this information). Surveillance is difficult because of the long delay of overt symptoms of mustard gas intoxication. Pre-employment examinations should exclude personnel with respiratory difficulties. Periodic eye and skin surveillance should be carried out during employment in work involving mustard gas and at regular intervals thereafter. The importance to personnel of immediately reporting to medical facilities following known or suspected contamination must be stressed.
5. There are no acute signs and symptoms except perhaps eye irritation.

H. References

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