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REFRESH RECORD**SECTION 1. CHEMICAL IDENTIFICATION****CHEMINFO Record Number:** 313**CCOHS Chemical Name:** Hydrogen sulfide**Synonyms:**

Acide sulfhydrique
H₂S

Hydrogen sulphide
Hydrogene sulfure
Hydrosulfuric acid
Sewer gas
Sour gas
Stink damp
Sulfur hydride
Dihydrogen monosulfide
Dihydrogen sulfide
Sulfureted hydrogen

Chemical Name French: Sulfure d'hydrogène

Chemical Name Spanish: sulfuro de hidrogeno

CAS Registry Number: 7783-06-4

UN/NA Number(s): 1053

RTECS Number(s): MX1225000

EU EINECS/ELINCS Number: 231-977-3

Chemical Family: Inorganic gas / inorganic sulfide / hydrogen sulfide

Molecular Formula: H₂S

Structural Formula: H-S-H

Status of Record:

The CHEMINFO record for this chemical is complete. The full format provides a detailed evaluation of health, fire and reactivity hazards, as well as recommendations on topics such as handling and storage, personal protective equipment, accidental release and first aid.

SECTION 2. DESCRIPTION

Appearance and Odour:

Colourless gas. Colourless liquid at extremely low temperatures or under very high pressure. Odour of rotten eggs at very low concentrations.(1,20,58) Sickening sweet odour at 30-100 ppm.(1) The ability to smell H₂S can begin to dull at 50 ppm and can be completely lost.(20)

Odour Threshold:

Values vary widely. Range of acceptable values: 0.001-0.13 ppm (detection). Geometric mean air odour thresholds: 0.0094 ppm (detection); 0.0045 ppm (recognition).(59) Loss of ability to smell H₂S begins at 50 ppm (20); exposures above 100 ppm may rapidly (2-15 minutes) deaden the sense of smell.(1,33) Reduced ability to smell (olfactory fatigue) may also result from prolonged exposure to concentrations below 100 ppm.(60)

Warning Properties:

POOR - Detection through odour is not reliable. Olfactory fatigue may result from prolonged exposure to concentrations below 100 ppm. The sense of smell is deadened above 100 ppm.

Composition/Purity:

Hydrogen sulfide (H₂S) is most commonly encountered occupationally as an environmental contaminant (see Uses and Occurrences). However, it is also available commercially in grades of 99-99.99 mole% minimum H₂S (liquid phase). Most H₂S is made and used captively (i.e. at the site of production) or transported over several kilometres by pipeline. It is also transported in authorized cylinders, tank cars and cargo tanks (tank trucks) as a flammable liquefied compressed gas under its own vapour pressure.(1,20,60) It is also available as a mixture in nitrogen or hydrogen gases. Special steel or stainless steel suitable for use with H₂S can be used for transportation, storage vessels and pipes, pipelines and oil and natural gas wells. (20,61) Since H₂S can react with iron in the presence of moisture, the steel used must be chosen carefully.(20)

Uses and Occurrences:

H₂S is encountered most commonly as an environmental contaminant. It occurs naturally in crude petroleum, natural gas, sour gases, in salt mines, in volcanic gases, hot sulfur springs, lakes, salt water ponds, undersea vents, marine sediments, swamps, stagnant bodies of water, and as an occluded gas in some minerals. It is formed as a result of bacterial breakdown of organic matter containing sulfur and can be formed by bacteria in the digestive tract. It can be found in sewage treatment facilities and in livestock barns and manure.(1,20,33) It is also a by-product of many industrial operations, such as petroleum refineries, petrochemical plants, natural gas plants, Kraft paper mills, iron smelters, coke ovens, food processing plants and tanneries.(1,33)

The major industrial use of H₂S is in the production of elemental sulfur and sulfuric acid. It is also used for the production of thioorganic compounds and sodium sulfide and sodium hydrosulfide; for purification of hydrochloric and sulfuric acids; to replenish sulfide content in Kraft pulping; for the purification of ores by selective flotation; in metallurgy to precipitate copper, nickel and cobalt sulfides from ores; in the removal of copper, cadmium and titanium from spent catalysts; for catalyst activation, such as presulfiding petroleum cracking catalysts, and catalyst poisoning; in the production of extreme pressure lubricants; in the formulation of rare earth phosphors for use in colour television tubes; for treatment of metal surfaces; for passivation of the walls of reactors operating at high temperatures in petroleum operations; to form a layer of sulfide on the surface of steel wires or plates that are to be coated with paint or plastic; in the production of heavy water for the nuclear industry; in analytical chemistry; and as an additive in cutting oils.(1,20,33,60,61)

Historically, H₂S was used as an agricultural disinfectant.(33)

SECTION 3. HAZARDS IDENTIFICATION**EMERGENCY OVERVIEW:**

Colourless gas. Colourless liquid at extremely low temperatures or under very high pressure. Odour of rotten eggs at very low concentrations. Sickening sweet odour at 30-100 ppm. The ability to smell H₂S can begin to dull at 50 ppm and can be completely lost. EXTREMELY FLAMMABLE GAS. Forms explosive mixtures with air over a wide concentration range. Very low ignition energy. Gas is heavier than air and may hug the ground. Distant ignition and flashback are possible. During a fire, irritating/toxic sulfur dioxide may be generated. Confined space hazard. Can accumulate in confined spaces, especially in low-lying, poorly ventilated areas,

producing a fire/toxicity/explosion hazard. COMPRESSED GAS. Cylinders and closed containers may rupture violently if heated, releasing large amounts of flammable gas or may cause cylinder to rocket. May ignite in contact with some metal oxides and oxidants. VERY TOXIC. May be fatal if inhaled. EYE IRRITANT. Gas may be severely irritating to the eyes and respiratory tract. Causes lung injury-effects may be delayed. Inhalation of high concentrations may cause respiratory paralysis, irregular heartbeat, collapse and death. May cause nervous system effects. Liquefied escaping from cylinder can cause frostbite.

POTENTIAL HEALTH EFFECTS

Effects of Short-Term (Acute) Exposure

Inhalation:

Hydrogen sulfide (H₂S) is a very toxic gas at normal temperatures. It poses a very serious inhalation hazard.

There is a large amount of information on human exposures. However, in most cases, the exposure levels and exposure durations are unknown or crudely estimated. Effects at various exposure levels are believed to be as follows: 0.001-0.13 ppm - odour threshold (highly variable); 1-5 ppm - moderately offensive odour, possibly with nausea, or headaches with prolonged exposure; 20-50 ppm - nose, throat and lung irritation, digestive upset and loss of appetite, sense of smell starts to become "fatigued", odour cannot be relied upon as a warning of exposure; 100 -200 ppm - severe nose, throat and lung irritation, ability to smell odour completely disappears; 250-500 ppm - potentially fatal build-up of fluid in the lungs (pulmonary edema) in the absence of central nervous system effects (headache, nausea, dizziness), especially if exposure is prolonged; 500 ppm - severe lung irritation, excitement, headache, dizziness, staggering, sudden collapse ("knockdown"), unconsciousness and death within 4-8 hours, loss of memory for period of exposure; 500-1000 ppm - respiratory paralysis, irregular heart beat, collapse, and death.(2,6,12,13,24) It is important to note that the symptoms of pulmonary edema, such as chest pain and shortness of breath, can be delayed for up to 48 hours after exposure.

Prolonged exposure (for several hours or days) to concentrations as low as 50-100 ppm can cause a runny nose, cough, hoarseness, and shortness of breath. Prolonged exposure to higher concentrations can produce bronchitis, pneumonia and a potentially fatal build-up of fluid in the lungs (pulmonary edema).(2,13,35)

There are numerous case reports of deaths, especially among workers in the petroleum, sewage treatment, and agricultural industries.(2,16) Most fatalities have occurred in relatively confined spaces (e.g. sewers, sludge tanks, cesspools, or H₂S collecting in pits or dips on open land or in buildings).(33) In many cases, multiple deaths have occurred at a single site. Rescuers, attempting to save an unconscious co-worker, have entered a hazardous and/or confined area without respiratory protection or safety lines. They, in turn, have been overcome by H₂S.

Workers who survive a serious short-term H₂S exposure may recover completely (12,13) or may experience long-term effects. Nervous system and

respiratory effects have been described in small human population studies or case reports. Permanent or persistent nervous system effects have included fatigue, anxiety, irritability, intellectual decline, reduced attention span, impaired learning and memory, altered sense of smell, and motor deficits. (6,21,29,30,32,33,54) Some of the nervous system effects may be due to a lack of oxygen reaching the brain cells during a severe H₂S exposure. (2,12,30) Respiratory effects have included symptoms (shortness of breath upon exertion, chest tightness or wheezing) consistent with hypersensitivity of the airways (Reactive Airways Dysfunction) (28); permanent lung damage (pulmonary fibrosis) (31) and significant reductions in residual volume (one measure of lung function) (39).

Skin Contact:

Direct contact with liquefied H₂S escaping from a cylinder can cause frostbite (freezing of the tissue). Symptoms of frostbite include numbness, prickling and itching of the affected area. The skin may become white or yellow. In severe cases there may be blistering and tissue death (necrosis). Any skin contact will also involve significant inhalation exposure. Refer to "Inhalation" above.

H₂S gas has only limited potential to be absorbed through the skin and skin absorption does not contribute significantly to exposure.(2,24,25)

Eye Contact:

The most commonly reported effect of H₂S exposure is eye irritation. (13,17,35) Inflammation and irritation of the eyes has been reported at very low airborne concentrations, sometimes below 10 ppm.(2,6,24) However, eye irritation at these low concentrations seems to result from combined exposures, in particular with carbon disulfide.

There is little reliable information about the irritancy of H₂S at concentrations below 100 ppm.(82) "Gas eyes" or "sore eyes" with scratchiness, irritation, tearing, burning, sensitivity to light, rainbow-like halos around lights, blurred vision and ulceration are reported in many cases of exposure. However the concentrations at which this happens are not well defined and the changes are usually reversible.(17,83,84,85) Male volunteers exposed to 100-150 ppm for as little as 2-15 minutes experienced eye irritation, and after 1-4 hours the pain was reported as sharp.(86) H₂S appears to dull the sensory nerves, so pain cannot be relied upon as a warning of exposure.

Direct contact with liquefied H₂S escaping from a cylinder can freeze the eye and cause severe damage or blindness.

Ingestion:

Ingestion is not an applicable route of exposure for gases.

Effects of Long-Term (Chronic) Exposure

Long-term H₂S exposure has mainly been associated with nervous and respiratory system and eye effects. However, controversy exists as to whether or not long-term exposure to H₂S causes any significant health effects.(2,22) The disagreement centres on the quality of the research and the nature of some of the reported symptoms, which include fatigue, headache, dizziness, irritability, and loss of appetite. These symptoms are not specific to H₂S exposure and could be due to a number of other causes.

There are a few studies that have evaluated the potential effects of long-term environmental exposure to H₂S. These studies are not reviewed here, since they are limited by factors such as concurrent exposures to many other chemicals, and self-reporting biases.

Nervous System:

Firm conclusions cannot be drawn from limited studies that describe neurobehavioural effects following long-term exposure.

Thirteen former employees and 22 residents living downwind from a crude oil processing plant were studied. The former employees had been employed for 1.5-3 years. Environmental exposures outside of the plant showed a 24-hour average of 0-8.8 ppm H₂S. Mercaptans, carbon-oxide-sulfide and total reduced sulfur were also detected. Neurobehavioural functions and a profile of mood states were examined and compared to 32 matched controls.

Statistically significant differences were noted with simple reaction time, balance, colour discrimination, and psychomotor speed. Significantly elevated mood state scores included anger, confusion, depression, tension/anxiety and fatigue.(50) It is difficult to draw specific conclusions from this study regarding the potential effects of H₂S because of limitations such as the relatively small number of people studied, the possibility of self-reporting biases, and concurrent exposures to other potentially harmful chemicals.

In another study, two groups of workers were compared. Group 1 (459 men) were exposed to H₂S in their daily work - often at concentrations exceeding 20 ppm (cited as 0.002%). Group 2 (384 men) were generally not exposed. Group 1 more frequently reported symptoms such as fatigue, loss of appetite, headache, irritability, poor memory, dizziness and itching.(32) Limitations of this study include the lack of statistical analysis, possible self-reporting biases and lack of control over potential confounding factors.

Four workers who had experienced a severe short-term exposure (without losing consciousness), as well as long-term ("months"), low-level exposure to H₂S developed impaired ability to smell. Medical evaluation confirmed a reduced sensitivity to odour in all 4 employees.(21) Further study of these workers included a series of physical, neurologic, psychiatric and chemosensory tests. All 4 had abnormal brain waves and met diagnostic criteria for 3-8 H₂S-induced neuropsychiatric disorders.(87) These studies are limited by factors such as the small number of employees evaluated, lack of control over other potential causal factors (e.g. alcohol consumption), and lack of exposure information.

Nineteen people with short- and long-term exposures to H₂S were compared with 202 unexposed people. Exposure was long-term (7 months-9 years) in 10 people and these people were studied 4 months-10 years after exposures. Overall, there were significant differences in reaction times, balance, visual performance, colour discrimination, cognitive performance, and significantly elevated mood state scores for tension, depression, anger, fatigue and confusion. The duration of exposure was not associated with the results.(88) It is difficult to draw conclusions from this study because of the relatively small numbers of people evaluated, the combination of short- and long-term exposures and the lack of exposure information.

In animal studies, subtle evidence of mild brain dysfunction was observed in male rats exposed to a relatively high concentration of H₂S (125 ppm) for 11 weeks. Loss of sensory neurons in the nasal cavity was observed in male rats exposed to 30 or 80 ppm for 10 weeks.

Lungs/Respiratory System:

Firm conclusions cannot be drawn from limited studies that indicate respiratory effects in workers from long-term exposure to H₂S.

A limited study suggests that long-term, low-level exposure to H₂S may be associated with reduced lung function. The respiratory function of 68 sewer workers (who were assumed to be exposed to H₂S) was measured and compared with results for 60 water workers (who were assumed not to be exposed to H₂S). Significantly poorer lung function was noted in the sewer workers, particularly those assumed to have "high" H₂S exposure.(18) A large number of workers were excluded from the study due to the poor quality of their lung function test results. Other study limitations include the lack of exposure monitoring, and the potential for exposure to other chemicals (e.g. chlorine).

No significant changes in lung function were observed in 26 male pulp mill workers with daily exposure to H₂S usually below 10 ppm (duration of exposure not provided).(34)

The respiratory function of 69 male workers exposed to sour gas plant emissions (most likely H₂S) for an average of 4.5 years, were compared with 34 unexposed controls. There was no significant difference in the measured pulmonary function between the 2 groups. However, there was an increase in self-reported respiratory symptoms in the exposed group (37.7% vs 23.3%, significance not reported).(89) This study is limited by lack of information on H₂S exposure, by self-reporting bias and lack of statistical evaluation for respiratory symptoms.

In animals, increased bronchial responsiveness was observed in individual rats exposed to 1-100 ppm for 5 weeks.

Skin Sensitization:

H₂S is not an occupational skin sensitizer. Only one non-occupational case report of sensitization was located.

A woman with several pre-existing health problems developed a severe skin reaction (a red, scaling rash on her eyelids, neck, arms and chest) following non-occupational exposure to airborne H₂S. The woman had a pre-existing allergy to sulfur.(14)

Heart/Blood Vessels:

It is not possible to draw any conclusions from the one limited study available. A slight increase in the number of deaths, especially cardiovascular deaths, was observed in sulfate mill workers exposed to H₂S and organic sulfide compounds. In general, the excess risk of cardiovascular death was small and in most subgroups the effect was not statistically significant. The workers had been employed for at least one year between 1945-1961. Death rates were compared to national rates and were followed until 1981. Exposure monitoring conducted in the early 1980s showed exposures to 0-20 ppm H₂S, 0-15 ppm methyl mercaptan, 0-12 ppm dimethyl sulfide and 0-1.5 ppm dimethyl disulfide.(57) This study is limited by factors such as the lack of control over other potential causes of cardiovascular disease.

Eyes/Vision:

Evaluation of 123 male viscose rayon workers exposed to H₂S and/or carbon disulfide for at least one year showed a significantly higher incidence of eye pain, burning and sensitivity to light compared to unexposed workers. Exposures varied from 1.3-36 ppm for carbon disulfide and 0.14-6 ppm for H₂S. Some workers had only carbon disulfide exposure, while no one had

only H₂S exposure. It is not possible to determine if H₂S, carbon disulfide or the combined exposure resulted in the reported eye effects.(9) Although, based on information available for short-term exposures, it is likely that the combined exposure resulted in the observed effects. This study is limited by factors such as the combined exposure, the relatively small number of workers studied and the possibility of self-reporting biases.

Carcinogenicity:

Hydrogen sulfide is not known to cause cancer. No human or animal information was located.

The International Agency for Research on Cancer (IARC) has not evaluated the carcinogenicity of this chemical.

The American Conference of Governmental Industrial Hygienists (ACGIH) has not assigned a carcinogenicity designation to this chemical.

The US National Toxicology Program (NTP) has not listed this chemical in its report on carcinogens.

Teratogenicity and Embryotoxicity:

There is insufficient information available to conclude that H₂S is a developmental toxin. No conclusions can be drawn from 2 studies in humans, which have limitations such as mixed exposures, lack of exposure information and possible self-reporting bias. No significant developmental effects were observed in rat studies with inhalation exposures of up to 100 ppm. Studies designed to evaluate subtle changes in blood or brain biochemistry have shown some effects in the pups. The clinical significance of some of the changes is not known. Sometimes the pup effects were observed in the presence of biochemical changes in the mothers. In other cases, maternal toxicity was not evaluated. No conclusions can be drawn based on the other limited studies available.

In a large human population study, with 2,853 female petrochemical workers studied, an increased risk of miscarriages (8.8%) was associated with exposure to petrochemicals. Frequent exposure chemicals were identified from information on a job history questionnaire, including benzene, gasoline, and H₂S. Of 106 women exposed to H₂S, 13 reported a miscarriage (Odds Ratio: 2.3, 95% CI 1.2-4.4).(51,90) No specific conclusions can be drawn from this study regarding H₂S because of limitations such as possible self-reporting bias, concurrent exposure to other potentially harmful chemicals and lack of specific exposure information.

In an industrial community in Finland, the miscarriage rate was examined in relation to the mothers or fathers occupation and assumed levels of residential environmental pollution. It was found that women employed in viscose rayon textile and paper products jobs had an increased rate of miscarriages (10.3 and 16.7%), as did women whose husbands worked in viscose rayon textile and chemical processing jobs. There was no specific information available on possible chemical exposures in these industries. Possible environmental chemical exposures were to sulfur dioxide, hydrogen sulfide and carbon disulfide. There was no clear evidence that environmental exposure to these chemicals was associated with an increased risk of

miscarriage.(52) It is not possible to draw firm conclusions from this study due to factors such as the lack of specific exposure information and the possible concurrent to other potentially harmful chemicals.

Reproductive Toxicity:

There is insufficient information available to conclude that H₂S is a reproductive toxin. No conclusions can be drawn based on the limited human information available. In animals, no significant reproductive effects were observed in one study with rats exposed by inhalation to up to 80 ppm. No conclusion can be drawn from a study of limited quality which suggested that long-term exposure to H₂S might affect the menstrual function of female workers.(11) The validity of this report is questionable because of limitations such as concurrent exposure to carbon disulfide, poor reporting of study methods and lack of control over confounding factors. No conclusions can be drawn from a single report which suggested that retarded development and listlessness of breast-fed infants of mothers working in rayon factories was due to H₂S.(24, unconfirmed) The original report is not available in English.

Mutagenicity:

The limited information available does not suggest that H₂S is mutagenic. There is no human information available. Negative results were obtained in one study using live animals and one bacteria test.

Toxicologically Synergistic Materials:

No information was located.

Potential for Accumulation:

H₂S is readily absorbed following inhalation. Absorption through the skin appears to be minimal. H₂S is rapidly eliminated from the body and does not accumulate.(2,24)

Health Comments:

In the past, it has been reported that persons with perforated eardrums may be exposed to H₂S leaking through the eardrum, even if appropriate respiratory protection is worn. A thorough review on this subject has concluded that the presence of an eardrum defect does NOT significantly reduce the effectiveness of respiratory protection against H₂S. Furthermore, no medical literature or personal reports documenting H₂S toxicity due to exposure via an eardrum perforation were located.(54)

H₂S inhibits the enzyme cytochrome oxidase, which prevents body cells from using oxygen. Thus, H₂S impairs the body's ability to use oxygen and the primary target organs for acute toxicity are the central nervous system and the heart. It also has direct toxicity by disrupting macromolecules.(90)

SECTION 4. FIRST AID MEASURES**Inhalation:**

This chemical is extremely flammable and very toxic. Take proper precautions to ensure your own safety before attempting rescue (e.g. remove any sources of ignition, wear appropriate protective equipment, use the buddy system). Remove source of contamination or move victim to fresh air. If breathing is difficult, trained personnel should administer emergency oxygen. DO NOT allow victim to move about unnecessarily. Symptoms of pulmonary edema can be delayed up to 48 hours after exposure. If breathing has stopped, trained personnel should begin artificial respiration (AR) or, if the heart has stopped, cardiopulmonary resuscitation (CPR) or automated external defibrillation (AED) immediately. Avoid mouth-to-mouth contact by using mouth guards or shields. Quickly transport victim to an emergency care facility. NOTE: Victims who have been exposed to 500 ppm or higher may pose a threat to responders due to H₂S released from their clothing, skin and exhaled air.(81)

Skin Contact:

GAS: Remove, double bag, seal, label and leave contaminated clothing, shoes and leather goods at the scene for safe disposal. Any skin contact will involve significant inhalation exposure. See "Inhalation" above. LIQUEFIED GAS: Quickly remove victim from source of contamination and briefly flush with lukewarm, gently flowing water. DO NOT attempt to rewarm the affected area on site. DO NOT rub area or apply dry heat. Gently remove clothing or jewelry that may restrict circulation. Carefully cut around clothing that sticks to the skin and remove the rest of the garment. Loosely cover the affected area with a sterile dressing. DO NOT allow the victim to drink alcohol or smoke. Quickly transport victim to an emergency care facility. Double bag, seal, label and leave contaminated clothing, shoes and leather goods at the scene for safe disposal.

Eye Contact:

GAS: If irritation occurs, immediately flush the contaminated eye(s) with lukewarm, gently flowing water for 15-20 minutes, while holding the eyelid(s) open. Immediately obtain medical attention. Any eye contact will also involve significant inhalation exposure. See "Inhalation" above. LIQUEFIED GAS: Quickly remove victim from source of contamination. Immediately and briefly flush eye(s) with lukewarm, gently flowing water until the chemical is removed. DO NOT attempt to rewarm. Cover both eyes with a sterile dressing. DO NOT allow victim to drink alcohol or smoke. Quickly transport victim to an emergency care facility.

Ingestion:

Ingestion is not an applicable route of exposure for gases.

First Aid Comments:

Provide general supportive measures (comfort, warmth, rest). Consult a doctor and/or the nearest Poison Control Centre for all exposures. Some first aid procedures recommended above require advanced first aid training. Protocols for undertaking advanced procedures must be developed in consultation with a doctor and routinely reviewed. All first aid procedures should be periodically reviewed by a doctor familiar with the material and its conditions of use in the workplace.

Note to Physicians:

NOTE: Amyl nitrite has been recommended as an antidote to hydrogen sulfide toxicity. However, its use is controversial, as researchers have concluded that it can

only be effective within the first few minutes following exposure and may actually slow sulfide removal thereafter.(12) A recent review concludes that nitrite therapy, although not entirely free of controversy, should be considered if the level of medical preparedness and supervision is sufficient to carry out this procedure safely and efficiently.(13)

SECTION 5. FIRE FIGHTING MEASURES

Flash Point:

Flammable gas.

Lower Flammable (Explosive) Limit (LFL/LEL):

4.0 % (20,62)

Upper Flammable (Explosive) Limit (UFL/UEL):

46% (1,62)

Autoignition (Ignition) Temperature:

260 deg C (500 deg F) (1,60); also reported as 290 deg C (554 deg F) (62)

Sensitivity to Mechanical Impact:

Probably not sensitive. Stable material.

Sensitivity to Static Charge:

Liquid H₂S will not accumulate static charge since it has medium to high electrical conductivity.(64) The gas can be ignited by a static discharge of sufficient energy.

Electrical Conductivity:

1000 pS/m (liquid in cylinder at boiling point) (65,66)

Minimum Ignition Energy:

0.068 millijoules.(63,66,67)

Combustion and Thermal Decomposition Products:

Sulfur oxides (mainly sulfur dioxide), water, and deposits of sulfur.(2) H₂S can dissociate at very high temperatures (above 850 deg C) into hydrogen and sulfur.(1)

Fire Hazard Summary:

FLAMMABLE GAS. Burns with a pale blue flame. Form explosive mixtures with air over a wide range. Very low ignition energy. Ignites spontaneously at 260 deg C (500 deg F). Leaking gas will be initially colder and heavier than air, and may hug the ground and travel a considerable distance to a source of ignition and flash back to a leak. During a fire, irritating/toxic sulfur oxides (mainly sulfur dioxide) may be generated. Can accumulate in confined spaces, especially in low-lying, poorly ventilated areas, producing a fire/toxicity/explosion hazard. Compressed gas. Heat from fire can cause a rapid build-up of pressure inside cylinders, which may cause explosive rupture and a

sudden release of large amounts of flammable gas or may cause cylinder to rocket.

Extinguishing Media:

Carbon dioxide, dry chemical powder, water spray or fog.(62,63)

Fire Fighting Instructions:

Extreme caution is required in a fire situation. Evacuate area and fight fire from a safe distance or a protected location. Approach fire from upwind to avoid extremely hazardous gas and toxic decomposition products.

For fires involving flammable gases, the best procedure is to stop the flow of gas before attempting to extinguish the fire. It is extremely dangerous to extinguish the fire while allowing continued flow of the gas. The gas could form an explosive mixture with air and reignite, which may cause far more damage than if the original fire had been allowed to burn. In some cases, extinguishing the fire with carbon dioxide or dry chemical powder may be necessary to permit immediate access to valves to shut off the flow of gas. However, this must be done carefully. If it is not possible to stop the flow of gas and if there is no risk to the surrounding area, allow the fire to continue burning while protecting exposed materials with water spray, to prevent ignition of other combustible materials. Gas clouds may be controlled by water spray or fog.

Isolate containers exposed to heat, but not directly involved in the fire and protect personnel. Move cylinders/containers from fire area, if this can be done without risk. Handle damaged cylinders with extreme care. Otherwise, fire-exposed containers, cylinders, tanks or pipelines should be cooled by application of hose streams and this should begin as soon as possible (within the first several minutes) and should concentrate on any unwetted portions. No part of a cylinder should be subjected to a temperature higher than 52 deg C (approximately 125 deg F). If this is not possible, use unmanned monitor nozzles and immediately evacuate the area.

DO NOT direct water at open or leaking containers or cylinders and take precautions not to get water inside a container or cylinder. Reverse flow into cylinder may cause rupture. Take care not to block pressure relief valves.

If possible, avoid spraying cold areas of equipment to avoid rapid freezing of water, which can result in heavy icing and possible blockage of pressure release valves.

May cause dense fog, reducing visibility.

For a massive fire in a large area, use unmanned hose holder or monitor nozzles; if this is not possible withdraw from fire area and allow fire to burn. Stay away from ends of tanks, but be aware that flying material from ruptured tanks may travel in any direction. Withdraw immediately in case of rising sound from venting safety device or any discolouration of tank due to fire. After the fire has been extinguished, explosive, toxic atmospheres may linger. Before entering such an area, especially confined areas, check the atmosphere with an appropriate monitoring device.

Protection of Fire Fighters:

Hydrogen sulfide is an extremely toxic, flammable gas. The combustion products of hydrogen sulfide (e.g., sulfur dioxide) are skin contact and inhalation hazards. Do not enter without wearing specialized equipment suitable for the situation.

Firefighter's normal protective clothing (Bunker Gear) will not provide adequate protection. Chemical protective clothing (e.g. chemical splash suit) and positive pressure self-contained breathing apparatus (NIOSH approved or equivalent) may be necessary.

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA) HAZARD IDENTIFICATION

NFPA - Health:	4 - Very short exposure could cause death or major residual injury.
NFPA - Flammability:	4 - Will rapidly or completely vaporize at atmospheric pressure and normal ambient temperature, or readily disperse in air and burn readily.
NFPA - Instability:	0 - Normally stable, even under fire conditions, and not reactive with water.

SECTION 6. ACCIDENTAL RELEASE MEASURES**Spill Precautions:**

Evacuate all unprotected personnel from area. Evacuate down-wind locations. Restrict access to area until completion of clean-up. Ensure clean-up is conducted by trained personnel only. Wear adequate personal protective equipment. Ventilate area. Extinguish or remove all ignition sources. Notify government occupational and environmental authorities.

Clean-up:

Liquid H₂S: Do not touch spilled material. Prevent material from entering sewers or confined spaces.
Stop or reduce leak if safe to do so. If not, allow liquid to vapourize.
Gaseous H₂S: Stop or reduce leak if safe to do so. If source of the leak is a cylinder and the leak cannot be stopped safely, move the cylinder to a safe place in the open air. If possible, repair the leak or allow the cylinder to empty.

SECTION 7. HANDLING AND STORAGE**Handling:**

This material is an EXTREMELY FLAMMABLE GAS. (It can also be a COMPRESSED GAS.) It is VERY TOXIC INHALATION HAZARD and an EYE IRRITANT. This material is also a significant confined space hazard (toxicity, flammability, explosion). Liquefied hydrogen sulfide escaping from a cylinder can cause frostbite.

Before handling, it is extremely important that engineering controls are operating and that protective equipment requirements and personal hygiene measures are being followed. People working with this chemical must be properly trained regarding its hazards and its safe use. Maintenance and emergency personnel should be advised of potential hazards.

Never work alone with this chemical. Another person must be in view at all times and must be equipped and trained to rescue. In case of leaks or spills, immediately put on a suitable respirator and leave the area until the severity of the release is determined. Hydrogen sulfide has very poor warning properties -- Do not rely on sense of smell. If

hydrogen sulfide is released, immediately evacuate the area. Escape-type respiratory protective equipment should be available in the work area.

Immediately report leaks, spills or ventilation failures.

Be aware of typical signs and symptoms of poisoning and first aid procedures. Any signs of illness should be reported immediately to supervisory personnel. Seek medical attention for all exposures even if an exposure did not seem excessive. Symptoms of a severe exposure can be delayed. Unprotected persons should avoid contact with this chemical.

Prevent release of gas into workplace air. Closed handling systems for processes involving this material should be used where possible. If this is not possible, use material in smallest possible amounts in a well-ventilated area, separate from the storage area.

Use non-sparking and corrosion-resistant ventilation systems, approved explosion-proof equipment and intrinsically safe electrical systems in areas of use. Keep aisles and exits free of obstruction. Bond and ground all cylinders, lines and equipment associated with hydrogen sulfide. Eliminate all ignition sources, (e.g. sparks, open flames, static discharge, hot surfaces). Keep away from heat. Post "NO-SMOKING" signs. It is very important to keep areas where this material is used clear of other materials which can burn (e.g. cardboard, sawdust). For large-scale operations, consider the installation of leak and fire detection equipment along with a suitable, automatic fire suppression system.

Do not use with incompatible materials such as metal oxides and oxidants. See Incompatibilities - Materials to Avoid section for more information.

Ensure that storage vessels and pipes are carefully selected and made of appropriate materials (see Corrosivity to Metals section). Hydrogen sulfide can rapidly corrode many metals.

Leave cylinder cap on cylinder until cylinder is secured and ready for use. Before connecting the cylinder for use, make sure that back feed from the system into the cylinder is prevented. Always secure cylinders to a wall, rack or other solid structure in an upright position. Use the appropriate pressure regulator. Ensure equipment is compatible with cylinder pressure and contents. Follow supplier recommendations. Make sure valves on gas cylinders are fully opened when gas is used. Open and shut valves at least once a day, while cylinder is in use, to avoid valve 'freezing'. Shut flow off at cylinder valve and not just at the regulator after use. Do not heat compressed gas cylinders. No part of a hydrogen sulfide cylinder should be subjected to a temperature greater than 52 deg C. Do not open cylinder if damaged. Do not drop cylinders or permit them to bang against each other. Avoid damaging cylinders. Do not use cylinders as rollers or for any other purpose than to contain the gas as supplied. Regularly check cylinders for evidence of corrosion or leakage. Make sure cylinders are labelled clearly. Move cylinders by hand truck or cart designed for that purpose. Keep empty cylinders under slightly positive pressure.

Have suitable emergency equipment for fires, spills and leaks readily available. Practice good housekeeping. Maintain handling equipment. Comply with applicable regulations. Follow handling precautions on Material Safety Data Sheet.

Storage:

Store in a cool, dry, well-ventilated area and out of direct sunlight. Keep quantity stored as small as possible. Keep away from heat, static discharge, sparks and open flames. Bond and ground metal cylinders and storage vessels in storage area. No part of a cylinder should be subjected to a temperature greater than 52 deg C. Lighted cigarettes, matches, or any other ignition sources should not be allowed around indoor or outdoor storage areas. Post "NO SMOKING" signs. Keep storage area clear of burnable materials (e.g. old rags, cardboard).

Store away from metal oxides and oxidants. See Incompatibilities - Materials to Avoid

section for more information.

Storage area should be clearly identified, clear of obstruction and accessible only to trained and authorized personnel. Post warning signs. Use a grounded, non-sparking and corrosion-resistant ventilation system, approved explosion-proof equipment and intrinsically safe electrical systems. Keep storage area separate from work areas. Store away from work process and production areas, elevators, building and room exits or main aisles leading to exits. This material is heavier and colder than air. Leaked gas can accumulate in low areas. Do not store below ground level.

Storage facilities should be made of fire and corrosion-resistant materials. Special steel or stainless steel suitable for use with hydrogen sulfide can be used for storage vessels and pipes. Since hydrogen sulfide in the presence of moisture can react with iron, the steel used for hydrogen sulfide storage vessels and pipes must be chosen carefully. See Reference 20 for more information.

Avoid bulk storage indoors. Store in isolated fireproof building, if possible. For large-scale storage, consider the installation of leak and fire detection equipment along with a suitable, automatic fire suppression system. Storage tanks for liquid hydrogen sulfide should be equipped with a safety device system.

Inspect storage area periodically for damage or leaks. Inspect all incoming containers to ensure they are undamaged and properly labelled. Always check cylinder valve for evidence of damage, rust or dirt which may inhibit operation. Store cylinders in a secure and upright position with cylinder valve cover on. Protect from damage. Protect cylinder bottoms from corrosion by keeping the storage area dry. Store empty cylinders separate from full ones with valves shut off, cap secure and labelled EMPTY or "MT".

Have appropriate fire extinguishers and spill clean-up equipment in or near storage area. Follow any special instructions for storage on Material Safety Data Sheet (e.g. maximum storage quantities and temperature requirements). Comply with all applicable regulations regarding storage of compressed gases and flammable materials.

SECTION 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

NOTE: Exposure to this material can be controlled in many ways. The measures appropriate for a particular worksite depend on how this material is used and on the extent of exposure. This general information can be used to help develop specific control measures. Ensure that control systems are properly designed and maintained. Comply with occupational, environmental, fire, and other applicable regulations.

Sampling and Analysis:

Use appropriate instrumentation and sampling strategy (location, timing, duration, frequency, and number of samples). Interpretation of the sampling results is related to these variables and the analytical method. Sampling should be carried out by trained personnel. Prior to any entry and work in a confined space, measure the toxicity, flammability and oxygen levels of the air with an appropriate monitoring device. Ensure that this testing is conducted by a competent individual.

OSHA Analytical Methods:

OSHA METHOD ID -141. OSHA Analytical Methods Manual. 2nd ed. Part 2. Vol. 1 (79). Fully validated method. Collection on silver nitrate impregnated cellulose filter. Analysis of sulfide by differential pulse polarography (DPP). Detection limits (based on 2-L air sample): 0.4 ppm (qualitative); 0.9 ppm (quantitative).

NIOSH Analytical Methods:

NIOSH METHOD 6013 - NIOSH Manual of Analytical Methods. 4th ed. Vol. 2. (80). Fully evaluated method. Collection on coconut shell activated charcoal sorbent tube. Desorption with ammonium hydroxide (0.2M) + hydrogen peroxide (30%). Analysis by ion chromatography (IC), conductivity detection. Estimated detection limit: 11 ug.

Direct Reading Instrumentation:

Methods of detection in commercially available devices which may be suitable: Electrical conductivity analyzer, coulometric analyzer, colorimetric analyzer, ultraviolet and visible light photometer, photoionization analyzer, portable gas chromatograph, flame photometric analyzer.

Colorimetric Detector Tubes:

Commercially available.

Engineering Controls:

Engineering methods to control hazardous conditions are preferred. Methods include mechanical ventilation (dilution and local exhaust), process or personnel enclosure, control of process conditions, and process modification (e.g. substitution of a less hazardous material). Administrative controls and personal protective equipment may also be required.

Because of the high potential hazard of hydrogen sulfide (toxicity, flammability and strong offensive odour), stringent control measures such as enclosure (closed handling system) or isolation may be necessary. When hydrogen sulfide is formed as a by-product of chemical or biological processes, local exhaust ventilation with or without process enclosure may be necessary.

Use a non-sparking, grounded, corrosion-resistant ventilation system separate from other exhaust ventilation systems. Exhaust through a scrubber directly to the outside. Use approved explosion-proof equipment and intrinsically safe electrical systems in areas of use.

For large-scale operations, consider the installation of leak and fire detection equipment along with a suitable, automatic fire suppression system.

Personal Protective Equipment:

If engineering controls and work practices are not effective in controlling exposure to this material, then wear suitable personal protective equipment including approved respiratory protection. Have appropriate equipment available for use in emergencies. If respiratory protection is required, institute a complete respiratory protection program including selection, fit testing, training, maintenance and inspection. Refer to the CSA Standard Z94.4-93, "Selection, Use and Care of Respirators," available from the Canadian Standards Association, Rexdale, Ontario, M9W 1R3.

Respiratory Protection Guidelines:

NIOSH RECOMMENDATIONS FOR HYDROGEN SULFIDE CONCENTRATIONS IN AIR (7):

UP TO 100 ppm: Powered air-purifying respirator with cartridge(s) to protect against hydrogen sulfide; or gas mask with canister to protect against hydrogen sulfide; or SAR*; or full-facepiece SCBA.

EMERGENCY OR PLANNED ENTRY INTO UNKNOWN CONCENTRATIONS OR IDLH CONDITIONS: Positive pressure, full-facepiece SCBA; or positive pressure, full-facepiece SAR with an auxiliary positive pressure SCBA.

ESCAPE: Gas mask with canister to protect against hydrogen sulfide; or escape-type SCBA.

NOTE: The IDLH concentration for hydrogen sulfide is 100 ppm.

*NOTE: Substance reported to cause eye irritation or damage; may require eye protection.

ABBREVIATIONS: SAR = supplied-air respirator; SCBA = self-contained breathing apparatus. IDLH = Immediately Dangerous to Life or Health.

NOTE: The purpose of establishing an IDLH value is to ensure that the worker can escape from a given contaminated environment in the event of failure of the most protective respiratory protection equipment. In the event of failure of respiratory equipment every effort should be made to exit immediately.

Recommendations apply only to NIOSH approved respirators.

Eye/Face Protection:

Chemical safety goggles. A face shield may also be necessary if there is potential for contact with liquid hydrogen sulfide.

Skin Protection:

Chemical protective gloves, coveralls, boots, and/or other chemical protective clothing should be worn if there is potential for contact with the liquid. A chemical protective full-body encapsulating suit and respiratory protection may be required in some operations.

Have a safety shower/eye-wash fountain readily available in the immediate work area.

Resistance of Materials for Protective Clothing:

Guidelines for hydrogen sulfide:(8)

RECOMMENDED (resistance to breakthrough longer than 8 hours): Tychem(TM) BR/LV, Tychem(TM) Responder(TM), Tychem(TM) TK.

NOT RECOMMENDED for use (resistance to breakthrough less than 1 hour): Tychem(TM) CPF 3.

There is evidence that this material can cause serious skin injury (e.g. corrosion or absorption hazard).

Resistance of specific materials can vary from product to product. Breakthrough times are obtained under conditions of continuous contact, generally at room temperature. Evaluate resistance under conditions of use and maintain clothing carefully.

Personal Hygiene:

Remove contaminated clothing promptly. Cut around any clothing which sticks to the skin. Keep contaminated clothing in closed containers. Discard or launder before rewearing. Inform laundry personnel of contaminant's hazards. Do not eat, drink or smoke in work areas. Wash hands thoroughly after handling this material. Maintain good housekeeping.

EXPOSURE GUIDELINES

THRESHOLD LIMIT VALUES (TLVs) / AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH) / 2008

Time-Weighted Average (TLV-TWA): (10 ppm)*
Short-Term Exposure Limit (TLV-STEL): (15 ppm) *
TLV Basis - Critical Effect(s): Irritation
CNS - central nervous system

TLV Proposed Changes:

*NOTICE OF INTENDED CHANGE: A reduction of the TLV-TWA to 1 ppm, and a reduction in the STEL to 5 ppm are proposed.

TLV Comments:

NOTE: In many jurisdictions, exposure limits are similar to the ACGIH TLVs. Since the manner in which exposure limits are established, interpreted, and implemented can vary, obtain detailed information from the appropriate government agency in each jurisdiction.

PERMISSIBLE EXPOSURE LIMITS (PELs) / FINAL RULE LIMITS / US OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA)

Time-Weighted Average (PEL-TWA): 10 ppm
Short-Term Exposure Limit (PEL-STEL): 15 ppm

NOTE: The OSHA PEL Final Rule Limits are currently non-enforceable due to a court decision. The OSHA PEL Transitional Limits are now in force.

PERMISSIBLE EXPOSURE LIMITS (PELs) / TRANSITIONAL LIMITS / US OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA)

Ceiling Exposure Limit (PEL-C): 20 ppm

Transitional Limit PEL Comments:

Acceptable maximum peak above the acceptable ceiling concentration for an 8-hour shift: 50 ppm (10 minutes duration once, only if no other measurable exposure occurs).

These Permissible Exposure Limits are taken from 29 CFR 1910.1000 Table Z - 2.

EMERGENCY RESPONSE PLANNING GUIDELINES (ERPGs) / AMERICAN INDUSTRIAL HYGIENE ASSOCIATION (AIHA) / 2008

ERPG-1: 0.1 ppm
ERPG-2: 30 ppm
ERPG-3: 100 ppm

The ERPG-1 is the maximum airborne concentration below which it is believed

that nearly all individuals could be exposed for up to 1 hr without experiencing other than mild transient adverse health effects or perceiving a clearly defined, objectionable odor.

The ERPG-2 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.

The ERPG-3 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing or developing life-threatening health effects.

NOTE: Users of the ERPG values are strongly encouraged to consult the documentation before use.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

Molecular Weight: 34.08

Conversion Factor:

1 ppm = 1.4 mg/m³; 1 mg/m³ = 0.717 ppm at 25 deg C (calculated)

Physical State:	Gas
Melting Point:	-85.5 deg C (-122 deg F) (1,65)
Boiling Point:	-60.3 deg C (-76.6 deg F) (1,65)
Relative Density (Specific Gravity):	Not applicable (gas)
Solubility in Water:	Slightly soluble (398 mg/100 g at 20 deg C (1); 290 mL/100 mL at 20 deg C(2))
Solubility in Other Liquids:	Very soluble in alkanolamines; soluble in ethanol, methanol, acetone, diethyl ether, glycerol, glycol ethers, N-methylpyrrolidone, propylene carbonate, gasoline, kerosene, carbon disulfide and crude oil; moderately soluble in hexane and benzene.(1,2)
Coefficient of Oil/Water Distribution (Partition Coefficient):	Log P(oct) = -1.38 (experimental) (70)
pH Value:	Not applicable (gas); 4.1 (0.1N aqueous solution) (61)
Acidity:	Anhydrous hydrogen sulfide gas is practically non-acidic. Water solutions are weakly acidic.(1,20)
Viscosity-Dynamic:	Not applicable
Surface Tension:	Not applicable
Vapour Density:	1.177 at 21.1 deg C and 101.3 kPa (air = 1) (58)
Vapour Pressure:	Absolute vapour pressure in cylinder: 1823.3 kPa, abs (18 atm) at 21.1 deg C (60); also reported as 1814 kPa (17.9 atm) at 20 deg C (1)

Vapour Pressure at 50 deg C:	3553.3 kPa (35.1 atm) at 50 deg C (from experimentally-derived coefficients) (65)
Saturation Vapour Concentration:	Not applicable (gas)
Evaporation Rate:	Not applicable (gas)
Henry's Law Constant:	$8.67 \times 10(2)$ Pa.m ³ /mol (cited as $8.56 \times 10(-3)$ atm.m ³ /mol) at 20 deg C (71); log H = -0.45 (dimensionless constant; calculated)
Critical Temperature:	100.4 deg C (212.7 deg F) (1,65)
Critical Pressure:	9006-9008 kPa (88.9 atm) (1,60)

Other Physical Properties:

TRIPLE POINT: -85.5 deg C (-122 deg F) at 23.2 kPa (20)

SECTION 10. STABILITY AND REACTIVITY**Stability:**

Normally stable.

Hazardous Polymerization:

Will not occur.

Incompatibility - Materials to Avoid:

NOTE: Chemical reactions that could result in a hazardous situation (e.g. generation of flammable or toxic chemicals, fire or detonation) are listed here. Many of these reactions can be done safely if specific control measures (e.g. cooling of the reaction) are in place. Although not intended to be complete, an overview of important reactions involving common chemicals is provided to assist in the development of safe work practices.

Hydrogen sulfide (H₂S) is a strong reducing agent and is highly reactive.(1,20,60)
METAL OXIDES (e.g. barium peroxide, chromium trioxide, copper oxide, lead dioxide, manganese dioxide, nickel oxide, silver oxides and sodium peroxide) - may ignite on contact.(63,72,73)

RUST - H₂S may ignite if passed through rusty iron pipes.(72,73)

OXIDANTS (e.g. bromine pentafluoride, copper chromate, fluorine, lead hypochlorite, fuming nitric acid and sodium peroxide) - ignite on contact. Chlorine trifluoride and dichlorine oxide explode on contact.(63,72,73)

OXYGEN - mixtures are explosive between 280 and 360 deg C; extensive self-heating occurs.(72,73)

SODIUM - melts and ignites in the presence of moist H₂S.(73)

COPPER POWDER - may ignite and explode.(63,72,73)

TUNGSTEN - finely divided tungsten glows red hot in a stream of H₂S.(72,73)

SODA-LIME, or SODIUM AND POTASSIUM HYDROXIDES - exothermic reaction, accompanied by incandescence in the presence of air; may result in a violent explosion.(63,72,73)

ACETALDEHYDE - reaction can be violent.(63)

SILVER FULMINATE - explodes violently at room temperature.(72,73)

4-BROMOBENZENEDIAZONIUM CHLORIDE - forms an explosive compound.(63,72,73)

Hazardous Decomposition Products:

None reported

Conditions to Avoid:

Flames, sparks, static discharge, heat and other ignition sources.

Corrosivity to Metals:

H₂S is corrosive to some metals under some conditions (e.g. moisture and temperature). Wet or moist H₂S is corrosive to copper, brass, bronze, cast iron, types 1010 and 1020 carbon steel (100% concentration at temperatures of 21-65.5 deg C (70-150 deg F), lead, Monel and 400 series stainless steels.(61,74- 76) It has been reported that wet H₂S can corrode carbon steel at corrosion rates that can exceed 2.5 mm/year, depending on temperature and concentration (sulfide stress cracking and hydrogen embrittlement may occur).(1,20,61,75) Wet H₂S is not corrosive to types 3003 and Cast B-365 aluminum, high nickel cast iron (Ni-Resist), high silicon cast iron, 300 series stainless steels, nickel-based alloys (like Inconel and Incoloy) at room temperature.(61,74,75,76) It is not corrosive at high temperatures (up to 150 deg C) to Incoloy, tantalum and titanium.(75) Anhydrous (dry) H₂S is corrosive to ductile cast iron, copper, silicon-copper, aluminum bronze and silicon bronze.(61,74,75) Dry H₂S can severely attack carbon steel at temperatures greater than 260 deg C.(1) Dry H₂S is not corrosive to types 1075 and 1095 carbon steel, stainless steel (types 305, 446 and Carpenter-20 Cb-3), types 3003 and 6061-T6 aluminum, nickel and nickel-based alloys at room temperature.(60,61,74,75) It is not corrosive at high temperatures (up to 315 deg C) to types 316 and 317 stainless steels, chromium-molybdenum alloy steels, high nickel cast iron (Ni-Resist), Monel, and tantalum.(1,75)

Corrosivity to Non-Metals:

Dry H₂S can attack plastics, like nylon and polyurethane, and elastomers, like Viton A, chlorinated polyethylene, hard rubber, polyacrylate and silicone VMQ.(68,74,77) Wet H₂S can attack plastics, like acetal, nylon and polyurethane, and elastomers, like Viton A, chlorinated polyethylene, natural rubber, soft rubber, isoprene, Nitrile Buna-N (NBR), styrene-butadiene (SBR), polyacrylate, polyurethane and silicone VMQ.(68,74,77) Dry and wet H₂S do not attack plastics, like chlorinated polyvinyl chloride (CPVC), Teflon and other fluorocarbons, like Kynar (PVDF), polyethylene, polypropylene, polystyrene, polyvinyl chloride (PVC), and elastomers, like ethylene propylene, ethylene propylene diene, chloroprene, Butyl rubber (isobutylene-isoprene), Hypalon (chloro-sulfonyl-polyethylene (CSM)), neoprene, and ethylene vinyl acetate.(68,74,77)

SECTION 11. TOXICOLOGICAL INFORMATION

LC₅₀ (rat): 444 ppm (4-hour exposure) (10)

LC₅₀ (mouse): 335 ppm (4-hour exposure); cited as 673 ppm (1-hour exposure) (3)

LC₅₀ (rat): 415 ppm (4-hour exposure); cited as 587 ppm (2-hour exposure) (40)*

LC₅₀ (rat): 501 ppm (4-hour exposure) (40)*

LC₅₀ (rat): 410 ppm (4-hour exposure); cited as 335 ppm (6-hour exposure) (40)*

*All rats that died had fluid build-up in the lungs (pulmonary edema). (40)

Eye Irritation:

Hydrogen sulfide (H₂S) gas is irritating to the eyes.

Eye irritation was reported in rats exposed to 35-65 ppm for 4-8 hours and to 310 ppm for 2-3 minutes. Dogs exposed to 103 ppm for 4-8 hours or to 350 ppm for 2-30 minutes had tearing (lachrymation).(86) Exposure of dogs, cats, rabbits and guinea pigs to 50-100 ppm for several hours or days caused tearing, and reversible damage to the cells on the outer layer of the eye.(17, unconfirmed) Rats exposed to approximately 1300 ppm for 10 minutes or approximately 54 ppm for 3 hours developed lesions of the cornea.(2, unconfirmed)

Effects of Short-Term (Acute) Exposure:**Inhalation:**

In LC50 studies, the range of concentrations causing death is very small, indicating that H₂S has a very steep dose-response curve. For example, a 4-hour exposure to 400 ppm killed 3/10 rats, 500 ppm killed 8/10 rats and 600 ppm killed 10/10 rats.(10) Exposure of rats to 35-65 ppm continuously for 100 hours produced eye and nose irritation. Rats exposed to 100-140 ppm showed respiratory distress from 8 hours onwards and some died at 18-48 hours. With concentrations of 310-350 ppm or 190-240 ppm, respiratory distress was observed in rats within 30-60 minutes. Some animals exposed to 310-350 died from one hours onwards, while animals exposed to 190-240 ppm died at 8-18 hours. Exposure of two monkeys to 500 ppm produced unconsciousness and death in one animal within 35 minutes. The other monkey became unconscious and was removed from exposure after 22 minutes. It regained consciousness approximately 2.5 hours later, but showed incoordination, reduced activity, and loss of appetite for the following ten days, when the study was terminated. Exposure of rabbits to 470 ppm and 750 ppm caused fluid build up in the lungs, bleeding of internal organs, convulsions, collapse and death between 4.5 and 6.5 hours. Exposure to 750-1000 ppm has produced unconsciousness and death in several animal species within a few minutes. In general, sensitivity to the effects of H₂S is similar in most animal species.(26, unconfirmed) Male rats were exposed to 0, 10, 30 or 80 ppm (whole-body); 0, 30 and 80 ppm (nose-only) or 0, 30, 80, 200 or 400 ppm (nose-only) for 3 hours/day for 5 days. Learning and memory were not impaired with exposures up to 80 ppm. Exposure to 400 ppm did impair acquisition and retention. This may have been due to decreased motor activity and body temperature also observed in animals exposed to greater than 80 ppm.(23) Male rats were exposed to 0, 30, 80, 200 or 400 ppm (nose-only) for 1 or 5 days (3 hr/d). A dose-related increase in cell death (necrosis) in the olfactory epithelium was seen for single or multiple exposures to 80 ppm and higher. The olfactory epithelium was completely regenerated 6 weeks after treatment, although some abnormalities (e.g. small cysts) were still noted.(91)

Skin Contact:

Two studies indicate limited potential for H₂S gas to be absorbed very slowly through the skin. Exposure of approximately one-half of the body area to pure H₂S was lethal to two guinea pigs within 45 minutes, but was without effect in a dog. Precautions were taken to prevent inhalation exposure.(42) In rabbits, whole-body exposure (excluding head) of moist skin to H₂S gas resulted in the detection of sulfides in expired air. Two of three exposed rabbits died.(41)

Effects of Long-Term (Chronic) Exposure:

Inhalation exposure to 30 ppm or above has produced signs of irritation of the nasal passages, including sensory neuron loss in male rats, in rats and mice for 10-13 weeks. Increased bronchial responsiveness was observed in individual rats exposed to 1-100 ppm for 5 weeks. Subtle evidence of mild brain dysfunction was observed in male rats exposed to 125 ppm for 11 weeks.

Inhalation:

Male rats exposed to 0, 10, 30 or 80 ppm for 10 weeks showed lesions in the olfactory mucosa at 30 and 80 ppm. The lesions consisted of sensory neuron loss and increased cell growth in the olfactory region of the nasal cavity.(37,49) A subsequent study indicates that H₂S exposure damages most cell types in the olfactory epithelium, but there is probably a slower rate of replacement of the olfactory neurons.(91) Studies exposing rats to up 0, 10.1, 30.5 or 80 ppm for 90 days showed significant reductions in weight gain in males and females exposed to 80 ppm and reduced brain weight in males exposed to 80 ppm. No other abnormalities were noted. Mice exposed in a similar experiment showed inflammation of the nasal passages at 80 ppm.(5,15,33) Rats exposed to 0, 1, 10 or 100 ppm for 5 weeks showed no significant respiratory effects, except individual animals in all exposure groups showed a significant increase in bronchial responsiveness.(24,25-unconfirmed) Male rats were repeatedly exposed to 125 ppm for up to 11 weeks to evaluate potential effects on learning and memory. Exposure to H₂S did not produce any obvious signs of eye irritation, respiratory distress, behavioural dysfunction or impaired consciousness. There was, however, subtle evidence of a mild brain dysfunction.(27) Rats exposed to 14-28 ppm for 4 months developed dose-dependent lesions of the thyroid gland. However, no hormonal assays were done, so it cannot be concluded that there were functional changes.(2, unconfirmed) This study is not available in English, therefore cannot be evaluated.

Teratogenicity, Embryotoxicity and/or Fetotoxicity:

No significant developmental effects were observed in rat studies with inhalation exposures of up to 100 ppm. Studies designed to evaluate subtle changes in blood or brain biochemistry have shown some effects in the pups. The clinical significance of some of the changes is not known. Sometimes the pup effects were observed in the presence of biochemical changes in the mothers. In other cases, maternal toxicity was not evaluated.(36,45,46,47,56) No conclusions can be drawn based on the other limited studies available.(4,38)

Rats were exposed to 0, 20, 50, 75 ppm from day 6 of pregnancy to postnatal day 21. Maternal food intake was reduced during the first 4 days of exposure to 50 ppm and for the first 8 days of exposure to 75 ppm. The cholesterol content of maternal livers and brains was elevated at 75 ppm. There were no significant differences in length of gestation, litter size, pup birth weight, male to female pup ratio or viability.(44) In a preliminary study, rats (8-9/group) were exposed to 0, 50, 100 or 150 ppm during days 6-20 of pregnancy. Maternal weight gain was significantly reduced at 150 ppm. Pup body weight was reduced slightly, but significantly, in all exposure groups. In a follow-up experiment, 23 females were exposed to 100 ppm on days 6-20 of pregnancy. Neither maternal toxicity nor any adverse effects on the developing fetuses were observed.(43) Rats were exposed to 0, 10, 30 or 80 ppm for 2 weeks prior to breeding. Exposures continued during a 2-week mating period and then from days 0-19 of pregnancy. Exposure of dams and their pups resumed from postnatal day 5-18. Adult male rats were exposed for 70 consecutive days. There were no significant signs

of developmental toxicity (e.g. pup mortality, litter size, length of gestation, malformations or altered weight gain) or neurotoxicity (neuropathology, motor activity, passive avoidance, functional observation battery or acoustic startle response) in exposed pups. There was no maternal toxicity.(48) This study is somewhat limited by the relatively small number of animals exposed (12/sex/group).

Reproductive Toxicity:

No significant reproductive effects were observed in one study with rats exposed by inhalation to up to 80 ppm. No conclusions can be drawn from the other limited studies available.

Rats were exposed to 0, 10, 30 or 80 ppm for 2 weeks prior to breeding. Exposures continued during a 2-week mating period and then from days 0-19 of pregnancy. Exposure of dams and their pups resumed from postnatal day 5-18. Adult male rats were exposed for 70 consecutive days. No significant reproductive effects (e.g. mating index, fertility index, post-implantation loss/litter) were observed.(48) This study is somewhat limited by the small number of animals (12/sex/group). Rats were exposed to 0, 20, 50, 75 ppm from day 6 of pregnancy to postnatal day 21. Maternal food intake was reduced during the first 4 days of exposure to 50 ppm and for the first 8 days of exposure to 75 ppm. There were no other significant signs of maternal toxicity. A dose-dependent increase in parturition (delivery) time and difficult delivery was noted in the exposed animals (10, 20 and 42% longer than controls).(44) There was no statistical analysis of the data conducted. A few older studies.(2,4,11) cannot be taken as evidence that H₂S causes reproductive problems, because of limitations such as non-standard experimental designs, poorly reported methodology, flawed analysis of results, inadequate controls and/or concurrent exposure to other potentially harmful chemicals (e.g. carbon disulfide).

Mutagenicity:

The limited information available does not suggest that H₂S is mutagenic. Negative results were obtained in a study in live rats and in an unconfirmed study in bacteria.

Negative results were obtained in a dominant lethal study where male rats were exposed to 220 ppm for 1 week and then mated over a 10-week period.(38)

Negative results (point mutations) were obtained in bacteria, both with and without metabolic activation. The concentration of H₂S gas was limited by its solubility in ethanol (the test solvent). The highest dose obtainable was 1750 microg/plate.(33, unconfirmed)

Toxicological Synergisms:

A limited study suggests that ethanol may increase susceptibility to H₂S toxicity. Injection with 330 or 660 mg/kg ethanol, with inhalation exposure to 800 ppm H₂S, shortened the mean time-to-unconsciousness in male rats.(55) Statistical evaluation of the results was not conducted.

SECTION 12. ECOLOGICAL INFORMATION

NOTE : Inclusion of Ecological Information on an MSDS is optional under the US Hazard Communication Standard and the Canadian Controlled Products Regulations (WHMIS). In other jurisdictions, inclusion of Ecological Information may be a requirement. For specific requirements, contact the relevant regulatory authorities in the jurisdiction where the MSDS is intended to be used.

The American National Standard for Hazardous Industrial Chemicals - Material Safety Data Sheets - Preparation (ANSI Z400.1-2004) provides advice on data that could be included in this section.

Databases in CCOHS's CD-ROM and Web collection which contain useful Ecological Information include [CESARS](#), [HSDB® \(Hazardous Substances Data Bank\)](#) and [CHRIS \(Chemical Hazards Response Information System\)](#).

SECTION 13. DISPOSAL CONSIDERATIONS

Review federal, provincial and local government requirements prior to disposal. It may be possible to make waste H₂S gas harmless by dissolving it in a sodium hydroxide scrubber, or by burning the H₂S and absorbing the resulting sulfur dioxide. Waste treatment procedures should be performed by trained, experienced personnel with appropriate protective equipment in approved treatment facilities.

SECTION 14. TRANSPORT INFORMATION

CANADIAN TRANSPORTATION OF DANGEROUS GOODS (TDG) SHIPPING INFORMATION

Shipping Name and Description: HYDROGEN SULFIDE; or HYDROGEN SULPHIDE

UN Number: UN1053

Class: 2.3, 2.1

Packing Group/Risk Group: ---

Special Provisions: ---

Passenger Carrying Road/Rail Limit: Forbidden

Marine Pollutant: ---

NOTE: This information incorporates the Transportation of Dangerous Goods Regulations SOR/2001-286, effective April 16, 2008.

US DEPARTMENT OF TRANSPORT (DOT) HAZARDOUS MATERIALS SHIPPING INFORMATION (49 CFR)

Shipping Name and Description: HYDROGEN SULFIDE

Hazard Class or Division: 2.3

Identification Number: UN1053

Packing Group: ---

NOTE: This information was taken from the US Code of Federal Regulations Title

49 - Transportation and is effective August 1, 2007.

SECTION 15. REGULATORY INFORMATION

CANADIAN WORKPLACE HAZARDOUS MATERIALS INFORMATION SYSTEM (WHMIS)

CCOHS WHMIS Classification:

A - Compressed gas
B1 - Flammable and combustible material - Flammable gas
D1A - Poisonous and infectious material - immediate and serious effects - Very toxic
D2B - Poisonous and infectious material - Other effects - Toxic

A B1 D1A D2B

WHMIS Health Effects Criteria Met by this Chemical:

D1A - Acute lethality - very toxic - immediate
D1A - TDG class 2.3 - very toxic - immediate
D2B - Eye irritation - toxic - other

WHMIS Ingredient Disclosure List:

Included for disclosure at 1% or greater.

Detailed WHMIS Classification According to Criteria:

Class A - Compressed Gas:

Meets criteria.
Absolute vapour pressure in cylinder at 21.1 deg C (70 deg F): 1823.3 kPa (18 atm); absolute vapour pressure at 50 deg C (122 deg F): 3700 kPa (36.5 atm);
TDG Class 2.1.

Class B - Flammable and Combustible Material:

Meets criteria for "Flammable gas".
Forms flammable mixture with air in a concentration of less than 13 per cent (4.3%) and over a flammable range of 41.7%; TDG Class 2.1

Class C - Oxidizing Material:

Does not meet criteria.

Class D - Poisonous and Infectious Material. Division 1 - Immediate and Serious Toxic Effects:

Meets criteria for "Very toxic material".

Acute Lethality:

"Very toxic".
LC50 (mouse): 335 ppm (4-hour exposure); cited as 673 ppm (1-hour

exposure).

Transportation of Dangerous Goods (TDG):

"Very toxic"; class 2.3

Class D - Poisonous and Infectious Material. Division 2 - Other Toxic Effects:

Meets criteria for "Toxic material".

See detailed evaluation below.

Chronic Health Effects:

Does not meet criteria.

Long-term exposure studies have not shown significant effects. Exposure to 30 ppm or above for 10-13 weeks has produced signs of irritation of the nasal passages, including sensory neuron loss in male rats, in rats and mice. Increased bronchial responsiveness was observed in individual rats exposed to 1-100 ppm for 5 weeks. Subtle evidence of mild brain dysfunction was observed in male rats exposed to 125 ppm for 11 weeks.

Carcinogenicity:

Does not meet criteria. Not included in standard reference lists.

Teratogenicity and Embryotoxicity:

Insufficient information.

No significant developmental effects were observed in rat studies with inhalation exposures of up to 100 ppm. Studies designed to evaluate subtle changes in blood or brain biochemistry have shown some effects in the pups. The clinical significance of some of the changes is not known. Sometimes the pup effects were observed in the presence of biochemical changes in the mothers. In other cases, maternal toxicity was not evaluated. No conclusions can be drawn based on the other limited studies available.

Reproductive Toxicity:

Insufficient information.

No significant reproductive effects were observed in one study with rats exposed by inhalation to up to 80 ppm. No conclusions can be drawn from the other limited studies available.

Mutagenicity:

Does not meet criteria.

The limited information available does not suggest that hydrogen sulfide is mutagenic.

Respiratory Tract Sensitization:

Does not meet criteria.

Not reported as a human respiratory sensitizer.

Skin Irritation:

Does not meet criteria.

Eye Irritation:

"Toxic".

Hydrogen sulfide gas is very irritating to the eyes.

Skin Sensitization:

Does not meet criteria.

No animal studies and only one non-occupational case report were located.

Class E - Corrosive Material:

Insufficient information for classification.

Wet hydrogen sulfide is reported to corrode carbon steel at corrosion rates that can exceed 2.5 mm/year (no temperature is given). It is not known whether the corrosion rate can exceed 6.25 mm/year at 55 deg C. Dry hydrogen sulfide is not corrosive to carbon steel. Dry and wet hydrogen sulfide are not corrosive to aluminum to any significant extent.

Class F - Dangerously Reactive Material:

Does not meet criteria.

US OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA) HAZARD COMMUNICATION STANDARD (29 CFR 1910.1200)

OSHA Hazard Communication Evaluation:

Meets criteria for hazardous material, as defined by 29 CFR 1910.1200.

EUROPEAN UNION (EU) CLASSIFICATION AND LABELLING INFORMATION

EU Classification:

Extremely flammable. Extremely flammable. [F+;R12] Very toxic. Very toxic by inhalation. [T+;R26] Dangerous for the Environment. Very toxic to aquatic organisms. [N;R50] (78)

EU Risk Phrases:

Extremely flammable. Very toxic by inhalation. Very toxic to aquatic organisms. [R:12-26-50]

EU Safety Phrases:

Keep locked up and out of the reach of children.* Keep container in a well ventilated place. Keep away from sources of ignition - No smoking. Wear suitable protective clothing. In case of insufficient ventilation, wear suitable respiratory equipment. In case of accident or if you feel unwell, seek medical advice immediately (show label where possible). Avoid release to the environment. Refer to special instructions/safety data sheet. [S:(1/2-)* 9-16-36-38-45-61]

*This safety phrase can be omitted from the label when the substance or preparation is sold for industrial use only.

EU Comments:

Safety phrases relate to the highest concentration division indicated, but may also be applicable to lower concentrations.

SECTION 16. OTHER INFORMATION

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Information on chemicals reviewed in the CHEMINFO database is drawn from a number of publicly available sources. A list of general references used to compile CHEMINFO records is available in the database Help.

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