

# Hydrogen sulfide

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**Hydrogen sulfide** (or **hydrogen sulphide**) is the chemical compound with the formula H<sub>2</sub>S. This colorless, toxic and flammable gas is partially responsible for the foul odor of rotten eggs and flatulence.

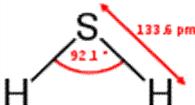
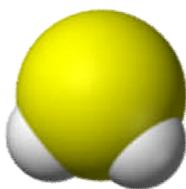
It often results from the bacterial break down of sulfites in nonorganic matter in the absence of oxygen, such as in swamps and sewers (anaerobic digestion). It also occurs in volcanic gases, natural gas and some well waters. The odor of H<sub>2</sub>S is commonly misattributed to elemental sulfur, which is in fact odorless. Hydrogen sulfide has numerous names, some of which are archaic (see table).

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## Production

Hydrogen sulfide is obtained by its separation from sour gas, which is natural gas with high content of H<sub>2</sub>S. It can be produced by reacting hydrogen gas with molten elemental sulfur at about 450 °C.

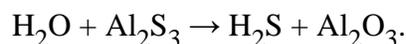
Hydrogen sulfide	
	
IUPAC name	Hydrogen sulfide, sulfane
Other names	Sulfuretted hydrogen; sulfane; Hydrogen Sulfide; sulfur hydride; sulfurated hydrogen; hydrosulfuric acid; sewer gas; stink damp; rotten egg gas; brimstone
Identifiers	
CAS number	7783-06-4 <span style="color: green;">✓</span>
PubChem	402
EC number	231-977-3
UN number	1053
RTECS number	MX1225000
ChemSpider ID	391
Properties	
Molecular formula	H <sub>2</sub> S
Molar mass	34.082 g/mol
Appearance	Colorless gas.
Density	1.363 g/L, gas.
Melting point	-82.30 °C (190.85 K)
Boiling point	-60.28 °C (212.87 K)
Solubility in water	0.4 g/100 mL (20 °C) 0.25 g/100 mL (40 °C)
Solubility	soluble in CS <sub>2</sub> , methanol, acetone; very soluble in alkanolamine
Acidity (p <i>K</i> <sub>a</sub> )	6.89 19±2 ( <i>see text</i> )
Refractive index ( <i>n</i> <sub>D</sub> )	1.000644 (0 °C) <sup>[1]</sup>
Structure	
Molecular shape	Bent
Dipole moment	0.97 D
Thermochemistry	
Std enthalpy of formation Δ <sub>f</sub> <i>H</i> <sup>∘</sup> <sub>298</sub>	-0.6044 kJ/g

Hydrocarbons can replace hydrogen in this process.<sup>[2]</sup>

Sulfate-reducing bacteria produce hydrogen sulfide under ambient conditions by the reduction of sulfate from elemental sulfur.

The standard lab preparation is to gently heat iron sulfide (FeS) with a strong acid in a Kipp generator.

A less well known and more convenient alternative is to react aluminium sulfide with water:



Hydrogen sulfide is also a byproduct of some reactions and caution should be used when production is likely as exposure can be fatal.

## Occurrence



Deposit of sulfur on a rock, caused by volcanic gases

Specific heat capacity, <i>C</i>	1.003 J/g K
<b>Hazards</b>	
EU Index	016-001-00-4
EU classification	Highly Flammable ( <b>F+</b> ) Very Toxic ( <b>T+</b> ) Dangerous for the environment ( <b>N</b> )
R-phrases	<a href="#">R12</a> , <a href="#">R26</a> , <a href="#">R50</a>
S-phrases	<a href="#">(S1/2)</a> , <a href="#">S9</a> , <a href="#">S16</a> , <a href="#">S36</a> , <a href="#">S38</a> , <a href="#">S45</a> , <a href="#">S61</a>
NFPA 704	
Flash point	flammable gas
Autoignition temperature	260 °C
Explosive limits	4.3–46%
<b>Related compounds</b>	
Related hydrogen chalcogenides	Water Hydrogen selenide Hydrogen telluride Hydrogen disulfide
Related compounds	Phosphine
<span style="color: green;">✓</span> (what is this?) (verify) Except where noted otherwise, data are given for materials in their standard state (at 25 °C, 100 kPa)	
Infobox references	

Small amounts of hydrogen sulfide occur in crude petroleum but natural gas can contain up to 90%.<sup>[3]</sup> Volcanoes and some hot springs (as well as cold springs) emit some H<sub>2</sub>S, where it probably arises via the hydrolysis of sulfide minerals, i.e. MS + H<sub>2</sub>O → MO + H<sub>2</sub>S.

About 10% of total global emissions of H<sub>2</sub>S is due to human activity. By far the largest industrial route to H<sub>2</sub>S occurs in petroleum refineries: the hydrodesulfurization process liberates sulfur from petroleum by the action of hydrogen. The resulting H<sub>2</sub>S is converted to elemental sulfur by partial combustion via the Claus process, which is a major source of elemental sulfur. Other anthropogenic sources of hydrogen sulfide include coke ovens, paper mills (using the sulfate method), and tanneries. H<sub>2</sub>S arises from virtually anywhere where elemental sulfur comes into contact with organic material, especially at high temperatures.

Hydrogen sulfide can be present naturally in well water. In such cases, ozone is often used for its removal. An alternative method uses a filter with manganese dioxide. Both methods oxidize sulfides to less toxic sulfates.

## Uses

### Production of thioorganic compounds

Several organosulfur compounds are produced using hydrogen sulfide. These include methanethiol, ethanethiol, and thioglycolic acid.

### Alkali metal sulfides

Upon combining with alkali metal bases, hydrogen sulfide converts to alkali hydrosulfides such as sodium hydrosulfide and sodium sulfide, which are used in the degradation of biopolymers. The depilation of hides and the delignification of pulp by the Kraft process both are effected by alkali sulfides.

### In analytical chemistry

Hydrogen sulfide used to have importance in analytical chemistry for well over a century, in the qualitative inorganic analysis of metal ions. For such small-scale laboratory use, H<sub>2</sub>S was made as needed in a Kipp generator by reaction of sulfuric acid (H<sub>2</sub>SO<sub>4</sub>) with ferrous sulfide FeS. Kipp generators were superseded by the use of thioacetamide, an organic solid that converts in water to H<sub>2</sub>S. In these analyses, heavy metal (and nonmetal) ions (e.g. Pb(II), Cu(II), Hg(II), As(III)) are precipitated from solution upon exposure to H<sub>2</sub>S. The components of the resulting precipitate redissolve with some selectivity.

### A precursor to metal sulfides

As indicated above, many metal ions react with hydrogen sulfide to give the corresponding metal sulfides. This conversion is widely exploited. In the purification of metal ores by flotation, mineral powders are often treated with hydrogen sulfide to enhance the separation. Metal parts are sometimes passivated with hydrogen sulfide. Catalysts used in hydrodesulfurization are routinely activated with hydrogen sulfide, and the behavior of metallic catalysts used in other parts of a refinery is also modified using hydrogen sulfide.

### Miscellaneous applications

Hydrogen sulfide is also used in the separation of deuterium oxide, i.e. heavy water, from normal water via the Girdler Sulfide process.

## Safety

Hydrogen sulfide is a highly toxic and flammable gas. Being heavier than air, it tends to accumulate at the bottom of poorly ventilated spaces. Although very pungent at first, it quickly deadens the sense of smell, so potential victims may be unaware of its presence until it is too late. For safe handling procedures, a hydrogen sulfide material safety data sheet (MSDS) should be consulted.<sup>[4]</sup>

## Toxicity

Hydrogen sulfide is considered a broad-spectrum poison, meaning that it can poison several different systems in the body, although the nervous system is most affected. The toxicity of H<sub>2</sub>S is comparable with that of hydrogen cyanide. It forms a complex bond with iron in the mitochondrial cytochrome enzymes, thereby blocking oxygen from binding and stopping cellular respiration. Since hydrogen sulfide occurs naturally in the environment and the gut, enzymes exist in the body capable of detoxifying it by oxidation to (harmless) sulfate.<sup>[5]</sup> Hence, low levels of sulfide may be tolerated indefinitely.

At some threshold level, the oxidative enzymes will be overwhelmed. This threshold level is believed to average around 300–350 ppm. Many personal safety gas detectors, such as those used by utility, sewage and petrochemical workers, are set to alarm at as low as 5 to 10 ppm and to go into high alarm at 15 ppm.

An interesting diagnostic clue of extreme poisoning by H<sub>2</sub>S is the discoloration of copper coins in the pockets of the victim. Treatment involves immediate inhalation of amyl nitrite, injections of sodium nitrite, inhalation of pure oxygen, administration of bronchodilators to overcome eventual bronchospasm, and in some cases hyperbaric oxygen therapy (HBO). HBO therapy has anecdotal support and remains controversial.<sup>[6][7][8]</sup>

Exposure to lower concentrations can result in eye irritation, a sore throat and cough, nausea, shortness of breath, and fluid in the lungs. These symptoms usually go away in a few weeks. Long-term, low-level exposure may result in fatigue, loss of appetite, headaches, irritability, poor memory, and dizziness. Chronic exposures to low level H<sub>2</sub>S (around 2 ppm) has been implicated in increased miscarriage and reproductive health issues amongst Russian and Finnish wood pulp workers, but the reports hadn't (as of circa 1995) been replicated. Higher concentrations of 700–800 ppm tend to be fatal.

- 0.0047 ppm is the recognition threshold, the concentration at which 50% of humans can detect the characteristic odor of hydrogen sulfide [1], normally described as resembling "a rotten egg".
- Less than 10 ppm has an exposure limit of 8 hours per day.
- 10–20 ppm is the borderline concentration for eye irritation.
- 50–100 ppm leads to eye damage.
- At 150–250 ppm the olfactory nerve is paralyzed after a few inhalations, and the sense of smell disappears, often together with awareness of danger,
- 320–530 ppm leads to pulmonary edema with the possibility of death.
- 530–1000 ppm causes strong stimulation of the central nervous system and rapid breathing, leading to loss of breathing;
  - 800 ppm is the lethal concentration for 50% of humans for 5 minutes exposure(LC50).
- Concentrations over 1000 ppm cause immediate collapse with loss of breathing, even after inhalation of a single breath.

Hydrogen sulfide was used by the British as a chemical agent during World War One. It was not considered to be an ideal war gas, but while other gasses were in short supply it was used on two occasions in 1916.<sup>[9]</sup>

A series of suicide cases in Japan in which the victims killed themselves by producing toxic hydrogen sulfide fumes by mixing common household cleaning products have highlighted the danger posed by commonly used substances and prompted censorship of internet sites who posted advice for aspiring suicides.<sup>[10]</sup>

## Function in the body

Hydrogen sulfide is produced in small amounts by some cells of the mammalian body and has a number of biological functions. It is produced from cysteine by various enzymes. It acts as a vasodilator and is also active in the brain, where it increases the response of the NMDA receptor and facilitates long term potentiation, which is involved in the formation of memory. Eventually the gas is converted to sulfites and further oxidized to thiosulfate and sulfate. Due to its effects similar to NO (without its potential to form peroxides by interacting with superoxide), hydrogen sulfide is now recognized as a potential cardioprotective agent.<sup>[11]</sup> Vasoactivity of garlic is caused by catabolism of the polysulfide group in allicin to H<sub>2</sub>S, a reaction which could depend on reduction mediated by glutathione.<sup>[12]</sup> In trisomy 21 (the most common form of Down syndrome) the body produces an excess of hydrogen sulfide.

## Induced hypothermia

In 2005 it was shown that mice can be put into a state of suspended animation-like hypothermia by applying a low dosage of hydrogen sulfide (81 ppm H<sub>2</sub>S) in the air. The breathing rate of the animals sank from 120 to 10 breaths per minute and their temperature fell from 37 °C to just 2 °C above ambient temperature (in effect, they had become cold-blooded). The mice survived this procedure for 6 hours and afterwards showed no negative health consequences.<sup>[13]</sup> In 2006 it was shown that the blood pressure of mice treated in this fashion with hydrogen sulfide did not significantly decrease.<sup>[14]</sup>

A similar process known as hibernation occurs naturally in many mammals and also in toads, but not in mice. (Mice can fall into a state called clinical torpor when food shortage occurs). If the H<sub>2</sub>S-induced hibernation can be made to work in humans, it could be useful in the emergency management of severely injured patients, and in the conservation of donated organs. In 2008, hypothermia induced by hydrogen sulfide for 48 hours was shown to reduce the extent of brain damage caused by experimental stroke in rats.<sup>[15]</sup>

As mentioned above, hydrogen sulfide binds to cytochrome oxidase and thereby prevents oxygen from binding, which leads to the dramatic slowdown of metabolism. Animals and humans naturally produce some hydrogen sulfide in their body; researchers have proposed that the gas is used to regulate metabolic activity and body temperature, which would explain the above findings.<sup>[16]</sup>

However, a 2008 study failed to reproduce the effect in pigs, concluding that the effects seen in mice were not present in larger mammals.<sup>[17]</sup>

## Participant in the sulfur cycle

Hydrogen sulfide is a central participant in the sulfur cycle, the biogeochemical cycle of sulfur on Earth. As mentioned above, sulfur-reducing and sulfate-reducing bacteria derive energy from oxidizing hydrogen or organic molecules in the absence of oxygen by reducing sulfur or sulfate to hydrogen sulfide. Other bacteria liberate hydrogen sulfide from sulfur-containing amino acids. Several groups of bacteria can use hydrogen sulfide as fuel, oxidizing it to elemental sulfur or to sulfate by using dissolved oxygen, metal oxides (e.g. Fe oxyhydroxides and Mn oxides) or nitrate as oxidant<sup>[18]</sup>. The purple sulfur bacteria and the green sulfur bacteria use hydrogen sulfide as electron donor in photosynthesis, thereby producing elemental sulfur. (In fact, this mode of photosynthesis is older than the mode of cyanobacteria, algae and plants which uses water as electron donor and liberates oxygen.)

## H<sub>2</sub>S implicated in mass extinctions

Hydrogen sulfide has been implicated in some of the several mass extinctions that have occurred in the Earth's past. The Permian mass extinction (sometimes known as the "Great Dying") may have been caused by hydrogen sulfide. Organic residues from these extinction boundaries indicate that the oceans were anoxic (oxygen depleted) and had species of shallow plankton that metabolized H<sub>2</sub>S. The formation of H<sub>2</sub>S may have been initiated by massive volcanic eruptions, which emitted CO<sub>2</sub> and methane into the atmosphere which warmed the oceans, lowering their capacity to absorb oxygen which would otherwise oxidize H<sub>2</sub>S. The increased levels of hydrogen sulfide could have killed oxygen-generating plants as well as depleted the ozone layer causing further stress. Small H<sub>2</sub>S blooms have been detected in modern times in the Dead Sea and in the Atlantic ocean off the coast of Namibia.<sup>[19]</sup>

### See also

- Amine gas treating
- Induced hypothermia
- Jenkem
- Gasotransmitters

### References

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- <sup>^</sup> Jacques Tournier-Lasserre "Hydrogen Sulfide" in Ullmann's Encyclopedia of Chemical Industry
- <sup>^</sup> "Burden of the Beasts: Ranchers wonder why Their Livestock Suffer and Die," Houston Chronicle, <http://www.chron.com/content/chronicle/nation/h2s/alberta.html>
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14. ^ Gas induces 'suspended animation', BBC News, 9 October 2006
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## Additional resources

- "Hydrogen Sulfide", Committee on Medical and Biological Effects of Environmental Pollutants, University Park Press, 1979, Baltimore. ISBN 0-8391-0127-9

## External links

- International Chemical Safety Card 0165
- Concise International Chemical Assessment Document 53
- National Pollutant Inventory - Hydrogen sulfide fact sheet
- NIOSH Pocket Guide to Chemical Hazards
- MSDS safety data sheet
- Abstract of survey article on H<sub>2</sub>S as used by the body, by P. Kamoun
- Computational Chemistry Wiki
- NACE (National Association of Corrosion Epal)
- Access Safety (Online H2S Awareness Training)