



CODE OF PRACTICE ARSINE

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EUROPEAN INDUSTRIAL GASES ASSOCIATION AISBL

AVENUE DE L'ASTRONOMIE 30 • B – 1210 BRUSSELS
Tel: +32 2 217 70 98

E-mail: info@eiga.eu • Internet: www.eiga.eu



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CODE OF PRACTICE ARSINE

As part of a programme of harmonisation of industry standards, the European Industrial Gases Association (EIGA) has issued *Code of Practice Arsine*, jointly produced by members of the International Harmonisation Council and originally published by the Asia Industrial Gases Association, (AIGA) as AIGA 050, *Code of Practice Arsine* and the Japanese Industrial and Medical Gases Association (JIMGA) as JIMGA-T-S/37, *Arsine*.

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Amendments from 163/10

Section	Change
	Editorial to align style with IHC associations
3	Publication terminology added
3.2	Definitions updated
	General update
5.2.1	Removal of ACGIH reference

Note: Technical changes from the previous edition are underlined

1 Introduction

Arsine is a toxic, colourless gas with a garlic-like odour. It is shipped as a liquefied compressed gas under its own vapour pressure of 1.515 MPa, abs (219.7 psia). It is also supplied in a gaseous state, diluted with other gases under pressure. It is flammable and highly toxic. The issue of the safe handling of arsine is a very important and relevant topic to the compressed gas industry as well as the user community of this specialty gas.

Arsine is used as a doping agent for silicon-based solid-state electronic devices. It is thermally diffused into the silicon layer using furnaces or by an ion implantation system (n-type dopant). It is also used to manufacture compound semiconductors such as light-emitting diodes (LEDs) by reaction with a metal organic such as trimethyl gallium forming a gallium arsenide layer. Arsine can be inadvertently generated in mining and manufacturing processes involving arsenic compounds and paints and herbicides containing arsenic compounds.

Arsine can be safely handled if equipment is properly designed, maintained, and employees are trained. As a minimum, all personnel shall have access to an arsine safety data sheet (SDS) and training in the use of the SDS and other reference materials.

NOTE In this publication, arsine is understood to be in the gaseous phase unless otherwise stated.

2 Scope and purpose

2.1 Scope

This publication is intended for the suppliers, distributors, and users of arsine and its handling equipment. The publication includes guidance for design of equipment, selection of cylinders and valves, and handling controls and safety practices. Guidelines on the operational steps associated with the use of arsine and arsine mixtures as well as fire protection, gas detection, ventilation, and related safeguards are also included. The manufacture, purification, and analysis of arsine is beyond the scope of this publication, although the general guidance given is also relevant to these processes.

2.2 Purpose

This publication was written to address the high toxicity and flammability of arsine where the consequences of improperly handling arsine could cause injury, death, and/or facility damage. This publication provides an understanding of the potential hazards involved in handling arsine and the guidelines to take to minimize risk potential.

3 Definitions

For the purpose of this publication, the following definitions apply.

3.1 Publication terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May

Indicates that the procedure is optional.

3.1.4 Will

Is used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability.

3.2 Technical definitions

3.2.1 Absolute pressure

Based on a zero-reference point, the perfect vacuum. Measured from this reference, the standard atmospheric pressure at sea level is 101.325 kPa, abs (14.696 psia); however, local atmospheric pressure can deviate from this standard value because of weather conditions and the elevation above or below sea level.

3.2.2 Apparatus

Accessory equipment such as valves, pressure relief devices (PRDs), regulators, and non-return valves (check valves) used with compressed gas.

3.2.3 Containers

Vessels of various shapes, sizes, and materials of construction such as cylinders, portable tanks, or stationary tanks, and of designs meeting the specifications of American Society of Mechanical Engineers (ASME), Transport Canada (TC), United States Department of Transportation (DOT), European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR), Japanese Industrial Standard (JIS), or national authorities and are filled with compressed gases.

3.2.4 Critical temperature

Temperature above which a pure gas cannot be liquefied, regardless of the degree of compression.

3.2.5 Cylinder

Transportable pressure receptacle having a water capacity that does not exceed 150 L (5.3 ft³) that can be filled with a gas under pressure.

3.2.6 Filling ratio

Ratio of the mass of liquefied gas introduced in a container to the mass of water at 15 °C (59 °F) that would fill the same container fitted ready for use.

NOTE Also known as fill density, filling factor, maximum fill degree, or maximum fill pressure.

3.2.7 Flammable gas

Mixture of 13% or less (by volume) with air ignitable at 0.101 MPa, abs (14.696 psia) or a flammable range with air of at least 12%, regardless of the lower limit. These limits shall be determined at 0.101 MPa, abs (14.696 psia) pressure and at a temperature of 20 °C (68 °F).

3.2.8 Gas

Gas or gas under pressure as defined in the United Nations (UN) *Recommendations on the Transport of Dangerous Goods, Model Regulations* and in *Globally Harmonized System of Classification and Labelling of Chemicals* (GHS) [1, 2].

A gas is a substance that (a) At 50 °C has a vapour pressure greater than 300 kPa; or (b) Is completely

gaseous at 20 °C at a standard pressure of 101.3 kPa.

3.2.9 Gas supplier

Business that produces, fills, and/or distributes compressed gases and compressed gas containers.

3.2.10 Handling

Moving, connecting, or disconnecting a gas container under normal conditions.

3.2.11 Hazard

Any condition that could cause injury to personnel or property.

3.2.12 Highly toxic

Gases that have an LC₅₀ in air less than or equal to 200 parts per million (ppm) for a 1 hr exposure, which includes gases classified as Acute Toxicity Category 1 according to UN GHS [2]. Refer to LC₅₀ definition.

NOTE In this publication, parts per million (ppm) means parts per million by volume (ppmv).

3.2.13 Hot zone

Area immediately around the chemical spill and the surrounding region that may be in serious danger from physical hazards such as fire, explosion, or chemical exposure.

NOTE Generally, only firefighters and emergency response team who are members of a specialized hazmat team will enter the hot zone.

3.2.14 Inert gas

Gas that is not toxic, does not support human breathing, and reacts scarcely or not at all with other substances.

3.2.15 Lethal concentration 50 (LC₅₀)

Concentration of a substance in air, exposure to which for a specified length of time is expected to cause the death of 50% of the entire defined experimental animal population.

NOTE Usually measured as ppm or mg/m³.

3.2.16 Lower flammable limit or lower flammability limit (LFL)

Lower limit of flammability (point at which a flame just starts to propagate) of a gas or vapour at ordinary ambient temperatures and pressures expressed in percent of the gas or vapour in air by volume. The LFL will vary with temperature and pressure.

NOTE Also referred to as lower explosive limit (LEL).

3.2.17 National standards, guidelines, regulations

Technical standards set by the regulatory authorities of the country in which the equipment/facility is used, with respect to their design, construction, testing, and use. Where available and applicable, these standards shall be followed.

3.2.18 Oxidizer

Gas or gas mixture that is able, at atmospheric pressure, to support the combustion more than a reference oxidizer consisting of 23.5% oxygen in nitrogen (for example, gaseous oxygen, nitrous oxide, or fluorine).

3.2.19 Pressure

Force per unit of area exerted by a gas to its surroundings. The term megapascal (MPa) is the standard term for pressures used in this publication. 1 MPa = 1000 kPa = 20,885.4 psf = 145 psi = 10 bar.

3.2.20 Pressure relief device (PRD)

Pressure and/or temperature activated device that may be used to prevent the pressure from rising above a predetermined maximum and thereby prevent equipment or container failure due to over pressurization.

3.2.21 Safety data sheet (SDS)

Written or printed information concerning a hazardous material (properties, precautions, etc.) following national regulations.

3.2.22 Test pressure

Pressure at which the container is hydraulically or pneumatically tested and is the pressure that shall not be exceeded under any foreseeable normal operating conditions (for example, during filling).

3.2.23 Threshold limit value—Time weighted average (TLV®-TWA)

Concentration to which a person may be exposed, 8 hours a day, 40 hours a week, without harm [3].

3.2.24 Toxic gas

Compressed gas that has a LC₅₀ in air of less than or equal to 5000 ppm but greater than 200 ppm for a 1 hr exposure, which includes gases classified as Acute Toxic Category 2 and 3 according to UN GHS [2].

3.2.25 Upper flammable limit or upper flammability limit (UFL)

Upper limit of flammability (point at which a flame can still nominally propagate) of a gas or vapour at ordinary ambient temperatures and pressures expressed in percent of the gas or vapour in air by volume. The UFL will vary with temperature and pressure.

NOTE Also referred to as upper explosive limit (UEL).

3.2.26 Valve outlet caps and plugs

Removable attachments that usually form a gas-tight seal on valve outlets provided by the gas supplier with certain gases.

NOTE—Some caps are designed only for valve thread protection and are not gas-tight.

3.2.27 Valve protection cap

Rigid removable cover provided for container valve protection during handling, transportation, and storage.

4 Gas properties

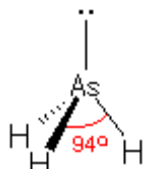
4.1 General

Arsine is a metal hydride gas with the chemical formula AsH_3 . It is highly toxic with an LC50 1 hour of 178 ppm and LC₅₀ 4 hour of 89 ppm. In addition to its toxicity, it is also flammable and is capable of forming flammable mixtures when mixed with air. It is not considered to be corrosive. It possesses a garlic-like odour [4, 5, 6].

Arsine is routinely shipped in seamless steel or aluminium alloy cylinders. For reasons of safety, cylinders used for arsine will have a test pressure of 4.2 MPa (609 psi). Some national bodies mandate higher test pressures. The vapour pressure of arsine is approximately 1.515 MPa, abs at 21.1 °C (219.7 psia at 70 °F) [4].

Table 1 shows properties of arsine.

Table 1 Properties of arsine

Property	SI Units	U.S. Units	Reference
Synonyms	arsenic trihydride, hydrogen arsenide, arsenic hydride, arsenous hydride		
Chemical formula	AsH ₃		
CAS number	7784-42-1		
UN number	UN 2188		
Physical state	Gas		
Colour	Colourless		[4, 5, 6]
Odour	Garlic-like odour		[4, 5, 6]
Molecular weight	77.945		
Boiling point at 1 atm	−62.5 °C	−80.5 °F	[4]
Freezing point at 1 atm	−116.9 °C	−178.4 °F	[4]
Decomposition temperature range	230 °C to 300 °C	446 °F to 572 °F	[4, 6, 10, 11]
Critical temperature	99.9 °C	211.8 °F	[4]
Critical pressure	6599 kPa, abs	957 psia	[4]
Critical volume	132.5 cm ³ /mol	8.086 in ³ /mol	[4]
Critical density	588.3 kg/m ³	36.73 lb/ft ³	[4]
Critical compressibility factor	0.274		[10]
Density of liquid at 21.1 °C (70 °F)	1.335 kg/m ³	83.55 lb/ft ³	[4]
Density of gas at 20 °C (68 °F) and 1 atm	3.24 kg/m ³	0.2025 lb/ft ³	[4]
Specific density of the gas at 21.1 °C (70 °F) and 1 atm (air=1)	2.69		[4]
Specific volume of the gas at 21.1 °C (70 °F) and 1 atm	5.0 ft ³ /lb		
Vapour pressure at 21.1 °C (70 °F)	1.515 Mpa, abs	219.7 psia	[4]
Solubility in water (vol gas/vol water)	0.23 in ³ /in ³		[4]
pH	Not applicable		
Volatility	Not applicable		
Odour threshold (varies with impurities)	0.5 ppm		[11, 13]
Evaporation rate	Not applicable		
Flash point	Not applicable		
Flammable limits in air (% by volume)	3.9% to 78%		[4, 16]
Latent heat of vaporization at −62.48 °C (−80.46 °F)	214 kJ/kg	92 Btu/lb	
Autoignition temperature	285 °C	545 °F	[8, 9]
Molecular shape	trigonal pyramidal		
Dipole moment	0.20 D		[3]
Standard enthalpy of formation at 25 °C, Δ _f H ⁰ _{gas}	+66.44 kJ/mol		[3]
Structure			

4.2 Physical properties

Decomposition of arsine is possible in the presence of light.

Arsine is decomposed by the effect of ultraviolet rays and it decomposes more rapidly as the ultraviolet ray intensity increases [7].

Although arsine has positive heat of formation (+66.44 kJ/mol), stability tests showed that even with input of 100 J decomposition did not take place in the cylinder.

Avoid sources of ignition, sparks, and flames due to the flammable properties of arsine. Arsine poses a severe fire hazard and a moderate explosion risk. Refer to Table 1.

A flammable mixture of arsine in air requires an ignition source to ignite because it is not pyrophoric. The autoignition temperature of arsine is 285 °C (545 °F) [8, 9].

Arsine is stable at room temperature and begins to decompose at approximately 230 °C (446 °F) with complete decomposition at approximately 300 °C (572 °F) [5, 10, 11, 12, 13].

4.3 Chemical properties

Arsine is incompatible with oxidizing materials, members of the halogen family, acids, and other combustible materials and will react slowly with water. Arsine is a strong reducing agent and reacts vigorously with oxidizers such as potassium permanganate, sodium hypochlorite, oxygen, ozone, chlorine, fluorine, and nitric oxide. Arsine can have some reaction with the alkali metal family.

Arsine is not known to polymerize.

4.4 Flammability properties

Refer to 5.1.

4.5 Health properties

Refer to 5.2.

4.6 Environmental properties

With controls, releases of arsine can be minimized. If arsine enters the environment through an accidental release, it can contaminate land, water, and air. Many countries have strict regulations and measures to be taken if a release occurs. The users of arsine shall review applicable regulations.

- Arsenic compounds including arsine are considered hazardous air pollutants (HAPs). These pollutants are known or suspected to cause cancer or other serious health effects such as reproductive effects and birth defects or adverse environmental effects [14];
- Arsine users should employ a variety of tools to prevent direct pollutant discharges into waterways, municipal wastewater treatment facilities, or allow polluted runoff;
- Emergency response programs are established and at times mandated to eliminate any danger to the public and the environment posed by hazardous substance releases. To help fulfil this mission, local governments may require that the person or organization responsible for arsine use notify the government when the amount on-site reaches a predetermined limit; Arsine is listed in Seveso III, Annex I, part 2, named substances.
- If a release or spill of arsine occurs, the government can require additional notifications be made. These requirements vary by governments;

- Guidance documents should be obtained from the local government agency to offer direction in following regulations and control emissions; and
- Risks to human health and the environment can vary considerably depending upon the type and extent of exposure. Arsine users are strongly encouraged to characterize risk on the basis of locally measured or predicted exposure scenarios.

Risk assessment values or other media quality standards may be used in countries to evaluate the health risks posed by exposures to toxic chemicals. These values are typically specified as concentration limits that shall not be exceeded to avoid health risk. These published values can be compared directly to information about the concentration of a chemical in the environment to identify potential health hazards. If a chemical concentration exceeds a relevant media quality standard, action to reduce environmental contamination or exposure is warranted.

Table 2 shows the published data for arsenic.

Figure 1 and Figure 2 show the arsine vapour pressure versus temperature using SI Units and U.S. customary units.

Table 2 Published data for arsenic

Arsenic CAS number: 7784-42-1			
Risk assessment values or standards	Value	Units	Reference
Inhalation cancer risk value (potency)	0.0043	ug/m ³	[16]
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) reporting limit	45 <u>100</u>	kg lb	[17]
Ingestion cancer risk value (potency)	1.5	mg/kg/day	[16]
Ingestion noncancer risk value (reference dose)	0.0003	mg/kg/day	[16]
National water quality standard	0.01	mg/L	[18]