

5. Gas

Pressure gas is that in which pressure (differential pressure with atmospheric pressure) is more than 1MPa (approximately 10 atm) in standard temperature (acetylene is more than 0.2MPa, approximately 2 atm), while liquefied gas is that in which pressure is more than 0.2MPa (approximately 2 atm) in standard temperature; both are called high-pressure gases.

High pressure gas is regulated under the High Pressure Gas Safety Law and the General High Pressure Gas Preservation Rule in regard to producing, storing and handling.

When gases are produced or modified, please contact the high pressure gas production safety manager (see safety-related pages).

When a special material or poisonous gas is used, please contact the high pressure gas person in charge (see safety-related pages).

< General Information >

- (1) Gases are classified as “high-pressure gases” or “other gases.”
- (2) When producing gases in which the product of pressure and cubic measure would be over $4\text{MPa} \cdot \ell$ (approximately $40\text{kg/cm}^2\text{G}$), please contact the high-pressure gas production safety manager.

Gas Handling

1. Properties of some gases

The following properties of some gases involve safety concerns.

(1) Flammable gases

A flammable gas can combust when it reaches a given density in the air. This is called the combustion range or the explosion range, and when the combustion speed in this range exceeds sonic speed, it is called the detonation. The ranges for common gases are shown below.

Name	Density g/l standard state 0 1atm (specific gravity to air)	combustion zone (%) (Detonation)
Hydrogen (H ₂)	0.0899 (0.0695)	4.0 - 75 (18 - 59)
Methane (CH ₄)	0.717 (0.555)	5.3 - 14
Ammonia(NH ₃)	0.771 (0.597)	16 - 25
Acetylene(C ₂ H ₂)	1.17 (0.907)	2.5 - 81
Propane(C ₃ H ₈)	2.02 (1.56)	2.1 - 9.5
Butane(C ₄ H ₁₀)	2.69 (2.08)	1.8 - 8.4

The following points should be kept in mind.

- 1) There is a danger of ignition even in a container that appears empty.
- 2) Please ensure proper ventilation.
- 3) Possible ignition sources must be removed from the area when working with flammable gases. Please be especially careful of sparks and open flames.

(2) Toxic fumes

Toxic gases commonly used in a laboratory are carbon monoxide, chlorine, and ammonia. If someone loses consciousness from breathing toxic fumes, his/her head should be leant back to prevent suffocation; they should then be placed in a lying position until the arrival of an ambulance or doctor. Please note that there are a large number of combustible materials in toxic fumes.

(3) Oxidizing gases

The main oxidizing gas is oxygen. Air, fluorine, and chlorine are also considered oxidizing gases. Pure oxygen is especially dangerous even though oxygen is neither combustible nor toxic. Almost all materials ignite in high-density oxygen. Materials can ignite even from the grease on the cap of a gas cylinder.

- 1) Because liquid air evaporates first from nitrogen, oxygen might remain.
- 2) Both low density and high density oxygen can cause harm to the human body. The density of oxygen in the work place must be kept at more than 18%. In addition, if a person breathes high-density oxygen of 60% for 12 hours, it will congest the lungs and could cause blindness or even death.

(4) Hypoxia

When a large amount of gases (excepting oxygen) leak out, there is the possibility that breathing will become impossible even if the gas is not poisonous. To avoid this possibility, do not work with gases in confined spaces.

- 1) The lowest permissible range of oxygen density for the human body is 18%. We lose consciousness after a while with breaths of air with 6% oxygen density or less.
- 2) Be especially careful when handling liquid nitrogen and carbon dioxide.

**Additionally, please refer to the chapter on hypoxia.*

(5) Special material gases

The Institution for Safety of High-Pressure Gas Engineering has designated 39 kinds of gas as having extremely high toxicity among new gases that have not been industrially used so far or being dangerous due to the possibility of autogenous ignition or resolution explosion; these gases are termed “special material gases.”

The special material gases are as follows:

I. Silicone group

Silane, Dichlorosilane, Trichlorosilane, Silicon Tetrachloride, Silicon Tetrafluoride, and Disilane

II. Arsenic group

Arsine, Arsenic Trifluoride, Arsenic Pentafluoride, Arsenic Trichloride, and Arsenic Pentachloride

III. Phosphorus group

Phosphine, Phosphorus Trifluoride, Phosphorus Pentafluoride, Phosphorus Trichloride, Phosphorus Pentachloride, and Phosphorous Oxychloride

IV. Boron group

Diborane, Boron Trifluoride, Boron Trichloride, and Boron Tribromide

V. Metal hydride

Hydrogen selenide, Germane, Hydrogen Telluride, Stibine, and Stannane

VI. Halid

Nitrogen Trifluoride, Sulfur Tetrafluoride, Tungsten Hexafluoride, Molybdenum Hexafluoride, Germanium Tetrachloride, Stannic Chloride, Antimony Pentachloride, Tungsten Hexachloride, and Molybdenum Pentachloride

VII. Organic metallic compound

Trimethylgallium, Triethylgallium, Trimethylindium, and Triethylindium

Production and consumption of 7 kinds of high pressure gases (Monosilane, Disilane, Arsine, Phosphine, Diborane, Hydrogen Selenide, and Germane), which are flammable and have strong toxicity, are restricted by the High Pressure Gas Safety Law.

2. Handling of high-pressure gas cylinders

(1) Notes on handling

- 1) Please use the gas cylinder in the "Gas cylinder fixation place" in the laboratory as a rule.
- 2) When gas cylinders are stored or used, please secure them with the fixing bracket so they do not overturn.

- 3) Please return empty gas cylinders or the gas cylinder that have not been used for a long time to the "Joint keeping place" (the north outdoor area of the M laboratory and the north outdoor area of the AVF preparatory).
- 4) When you use a flammable gas (hydrogen, acetylene, etc.), please have an extinguisher nearby.
- 5) If necessary, please check active utilities to see if there is a gas leakage.
- 6) A normal and appropriate regulator (pressure gauge and adjustment machine) must be used.
- 7) Please attach the protective instrument, display the warning sign, etc. when the rubber hose is placed across the passage.
- 8) Make sure to always install the valve opening and shutting steering wheel in the gas cylinder in use. (Open times are within 1.5 rotations.)
- 9) There is a danger of ignition if a film of oil or fat comes into contact with oxygen; do not use oxygen cylinders or apparatuses bare-handed or with gloves that oils and fats can adhere to.
- 10) The user must wear protective gear (safety shoes, goggles, gloves, etc.).

(2) Purchase

- 1) Acceptance and purchase of gases must be arranged by the person in charge at RCNP. The purchase applicant must submit a prescribed purchase application form and purchase request to the person in charge.
- 2) The person in charge of gas at RCNP must do the following:
 - A) Order from the trader
 - B) Be present when a gas cylinder is brought in, and unlock the management boundary fence.
 - C) Attach a tag that records the purchase applicant to the gas cylinder.
 - D) Return empty gas cylinders to the trader.
 - E) Fill in the purchase and return logs.
- 3) The person in charge should be present when a gas cylinder is brought in, though in an emergency the presence of only the purchase applicant is sufficient. In this case, please inform the person in charge as soon as possible.
- 4) Do not purchase excessive preliminary gas cylinders.
(Please use a common preliminary gas cylinder.)

5) Please contact the person in charge of the gas before the purchase or use of toxic fumes or flammable gases.

(3) Indication of the sole owner

A tag must be attached to each gas cylinder when it is purchased, and must specify the sole owner.

3. Low temperature liquefied gas

(1) Notes on handling

1) Low temperature liquefied gas is literally gas at a low temperature, and it evaporates easily. The pressure inside a container of such gas will build up; please release the pressure by deflation except in special cases (a reservoir is needed in the case of ignitable or toxic materials) Do not touch such a gas with bare hands; rather, wear protective gloves so as not to cause frostbite, as even the liquid and evaporating gas are at a very low temperature.

2) Breathing evaporating gas can cause you injury due to lack of oxygen; do not look into the container and keep your head away from evaporating gas and steam.

3) Please keep in mind that since the evaporating gas expands by nearly 1000 times, you must ensure ventilation when working in confined spaces. Be careful as an overturned container or gas leak can often damage paint or surfaces.

(2) Properties of liquefied gas

Physical descriptions of common liquefaction gases are as follows:

Liquefied gas	Boiling point K	Heat of evaporation kJ/l	Liquid density Kg/l	Gas/liquid volume ratio
Oxygen	90.19	300	1.14	875
Nitrogen	77.35	161	0.81	710
Hydrogen	20.40	31.6	0.07	780
Helium	4.22	3.1	0.125	780

(3) Liquid oxygen

This is high chemical revitalization when oxygen is in the liquid state. It may explode due to a mechanical impact when coexisting with aluminum, titanium, or an organic compound.

(4) Liquid nitrogen

When pure liquid nitrogen comes into contact with air, it absorbs oxygen rapidly. Dissolution is also possible at 90.16K. Please ensure proper ventilation, and be aware of the danger of hypoxia.

(5) Liquid hydrogen

Liquid hydrogen's combustibility is high, and the stable combustion zone is wide. Evaporating hydrogen is very dangerous because it is 14 times lighter than air and the diffusion speed is very fast.

Handling of high-pressure gas cylinders

1. Transportation

- (1) Please close the container valve, and put the cap on.
- (2) Please do not handle the container roughly. Do not jerk or otherwise cause sudden movement.
- (3) Please use a basket, bag or special hanging tool when hanging the container by a crane. Never use the lifting magnet, and never hang the container with only one wire rope.
- (4) Please use the carrier (stand with caster) or place the container diagonally and use the rolling mechanism on the bottom to move it. Two people should not carry the container.

2. Storage

- (1) Please designate a safe storage place for the container before using it, taking into account direct sunlight and ventilation.
- (2) Please cap the container, use the gas cylinder stand to hold the container, and secure it with the proper chains and clamps to prevent it from falling. In particular, please take measures to protect the container in case of an earthquake.
- (3) Do not store the container using the stand with caster.
Please take measures to prevent a fall when using the container temporarily.
- (4) The container can only be placed in a horizontal position for a short amount of time. In this case, please take measures to prevent the container from rolling.
- (5) Any fires or open flames are strictly prohibited in the vicinity of containers of flammable gas or oxygen.
- (6) Do not place flammable oils/fats or pieces of cloth near containers of flammable gas or oxygen.
- (7) Do not place flammable gas containers near electric equipment, wiring, or ground wires.

- (8) Each kind of gas must be stored separately. In particular, do not store flammable gas containers and oxygen containers in the same place.
- (9) Please make sure the labels "Full" and "Empty" are clearly displayed, and keep containers in a separate place.
- (10) Please make sure the user or manager's names are displayed on the container.

3. Use

- (1) The container valve (former valve) must be opened and shut slowly and with great caution. It can ignite if opened quickly or roughly.
- (2) Please close the container valve firmly when the use of the gas is temporarily suspended or finished.
- (3) If the container valve is not in proper condition, do not use the container; in this case, contact the trader immediately.
- (4) If even a small amount of oil adheres to an oxygen container, the oxygen container can ignite. Do not handle it with bare hands, oily gloves, or any other oily equipment.
- (5) Pressure adjustment machine, pressure reducing valves, pressure gauges, and ducts must be specifically designed for the gas being used; do not use equipment deigned for use with other gases. Especially, please use the device bearing the label "Oil Prohibition" as the oxygen container.
- (6) When you warm the container and/or container valve, please use hot water with a temperature of less than 40 .
- (7) Transferring the gas between containers is prohibited by regulations.
- (8) Please return the container to the trader when not in use. In addition, when the container is used for construction, please instruct the vendor to retrieve it from the RCNP.
- (9) Please contact the appropriate supervisor immediately when encountering any container defects.

4. Handling of Special Material Gas:

- (1) When the special material gas is brought in and used, an “Application for special material gas and the toxicity gas use” must be submitted beforehand. In addition, please attach the document that describes its use, an equipment drawing, and its technological standard.
- (2) Any gas specified as a special high-pressure gas of the special material gases cannot be used as/in place of a high-pressure gas.
- (3) When discharging the special material gas, it must be ventilated from the designated duct after rendering it harmless, except in situations when doing so will damage the device.
- (4) If the gas leak detector goes off:
 - 1) Close the gas container valve as much as possible.
 - 2) Inform and evacuate anyone in the immediate vicinity.
 - 3) Extinguish all open flames.
 - 4) Contact the accelerator operating manager immediately

5. Handling of liquefied gas:

- (1) Concerning the handling of liquefied gas, please note the following:
 - 1) Increase pressure according to the rate of liquid evaporation.
 - 2) Be careful of adhesion and blocking by atmospheric freezing.
 - 3) Rising density of atmospheric oxygen by oxygen condensation which can cause leakage of liquefied gas and low temperature gas.
 - 4) Frostbite
 - 5) Hypoxia and injury by inhalation of low temperature gas
- (2) Always wear protective leather gloves when you work at low temperatures. However, do not wear army gloves as frozen liquefied gas will adhere to them.
- (3) Please move and transport any containers carefully as they are structurally weak at low temperatures.
- (4) Please do not use equipment made of glass to measure the insulated vacuum of a large-scale low-temperature device.
- (5) Please place the pressure measurement gauge on the inside in the low temperature device.

(6) Please be aware of hypoxia when discharging the liquefied and evaporated gas. Do not inhale the air that's oxygen density has been remarkably reduced by the inert gas (16% or less).

Reference document:

Physics and Chemistry Dictionary

Science chronology 2002

High-pressure gas security technology (middle class)

CRC Handbook