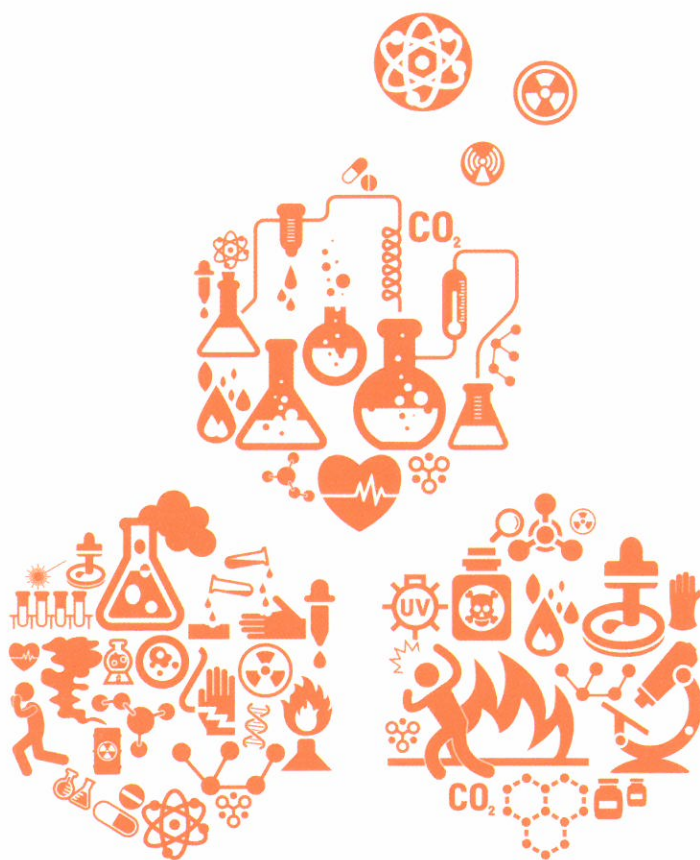


## Standard Textbook for Safety in Laboratory

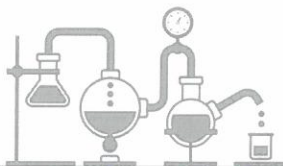
## Safety for Chemistry & Gas





All research and development start from performing safe experiment.

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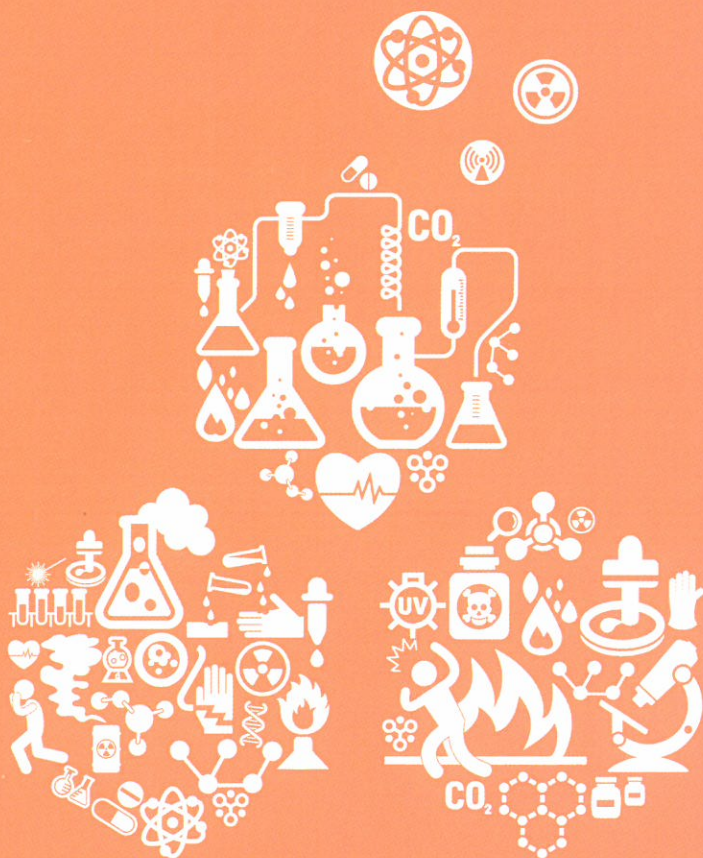
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# Safety for Chemistry & Gas



CHAPTER

3

**Chemical and Gas Safety  
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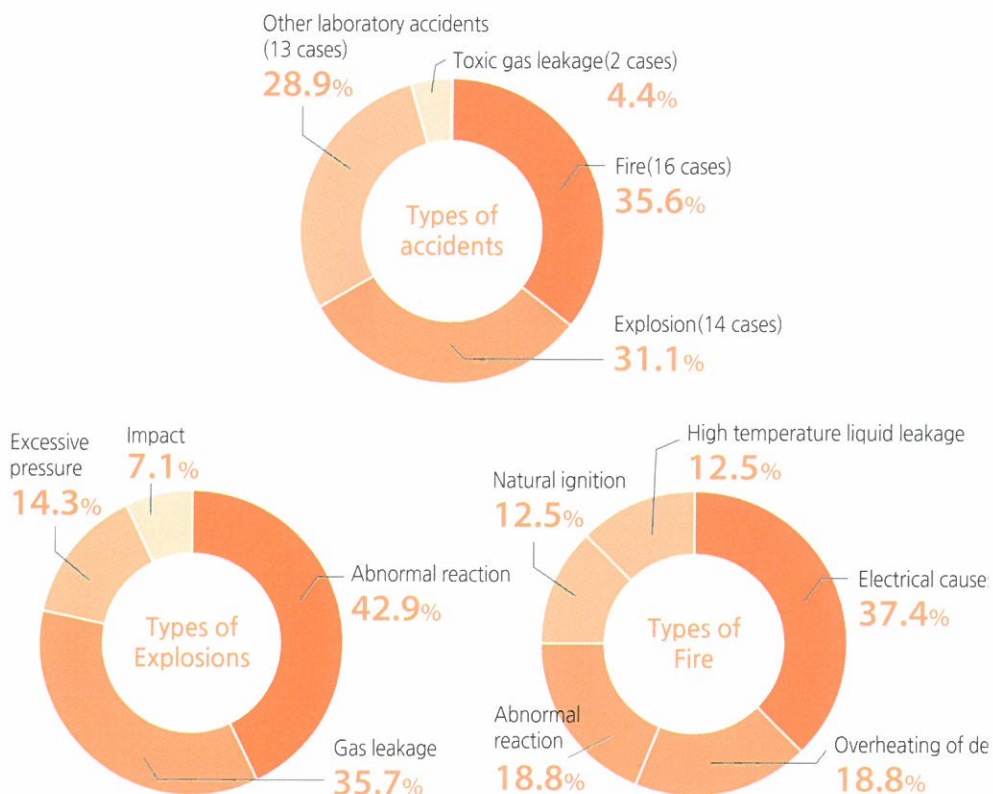


## Introduction

It is estimated that the total number of research and development personnel in the areas of science & technology in Korea is approximately 1.15 million and the number of the laboratories at universities and research institutions is known to be approximately 63,000. With recent activation of R&D in Korea, laboratories are using even more diversified range of chemical substances chemical substances and gaseous substances in experiments. However, damages arising from accidents due to failure to abide by the safety rules when using such substances are increasing continuously. According to the data from Ministry of Education, Science & Technology and the Korea Engineering & Consulting Association obtained through survey on the universities and research institutes during 2000~2010, majority of the safety accidents occurring in the laboratories are closely related to the chemical substances and gas, and the most frequent format of laboratory accidents were also found to be fire and explosion accidents (67%). When the corresponding causes of the accidents are examined in more detail, in the case of explosion that can lead to serious accidents accompanied by substantial material and human casualties, accidents associated with the chemical substances and gaseous substances including abnormal reaction (43%) and gas leakage (36%) accidents accounting for the majority. In the case of fire, although the electrical cause (37%) is the most frequent, overheating of the devices and abnormal reactions also accounted for 19% of all the accidents each.

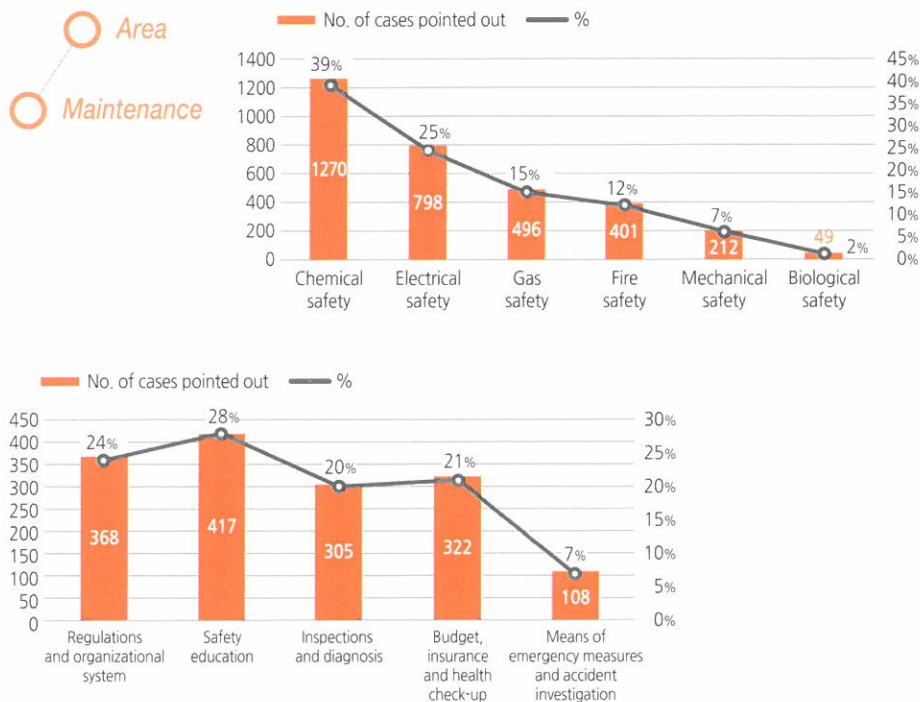
Meanwhile, according to the recent announce made by the Ministry of Science, ICT and Future Planning, the key cause of the laboratory safety accidents that occurs more than 100 times annually is the inadequate execution

## *Types of safety accidents occurring in the laboratories*



of safety education on the university and graduate students, and researchers, accounting for 28% (417 cases) of all the causes pointed out (1,520 cases), followed by inadequate safety organization system (24%, 368 cases), inadequacy in securing of budgets for insurance coverage, health check-up and safety (21%, 322 cases), failure to execute safety inspection (20%, 305 cases) and insufficient means of coping with emergency situations including establishment of emergency contact network, etc. (7%, 108 cases).

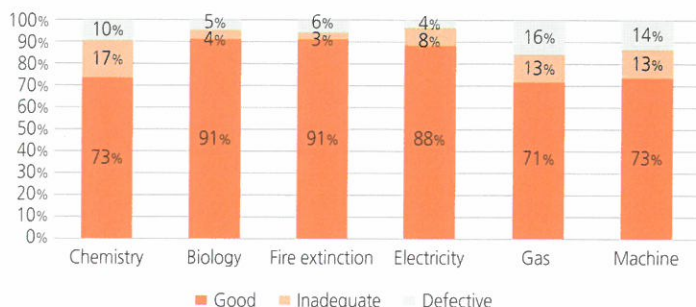
## Current status of inadequacies in laboratory safety management



In addition, as the result of the examination of the current status of detailed safety management on a total of 46 items in 6 categories including chemistry, electricity, fire extinction, biology, gas and machines at 1,042 laboratories of 211 institutions, inadequacies pointed out in the area of chemical safety were most frequent at 1,270 cases among the total of 3,226 cases, accounting for 39%, followed by 798 cases for electrical safety (25%), 496 cases of gas safety (15%), 401 cases of fire safety (12%), 212 cases of mechanical safety (7%) and 49 cases of biological safety (2%).

## *Current status of inadequacies in safety management pointed out for each of the areas*

### Management

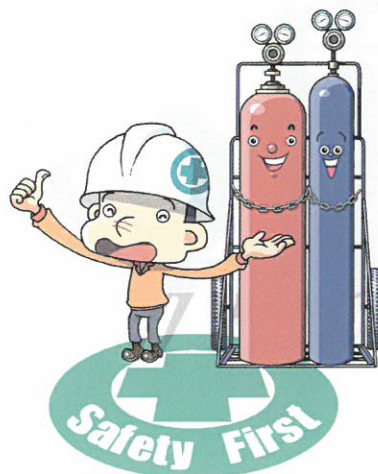


In particular, issues pointed out in the area of the chemical safety included failure to attach name plate for each of the specimens (22%, 231 laboratories), failure to furnish material safety data sheet (MSDS) (17%, 177 laboratories), non-installation of emergency cleaning facility (17%, 179 laboratories) and inadequacy in controlled wind speed of fume hood (15%, 155 laboratories), and etc., thereby resulting in the evaluation that there is a need for systemic management of the chemical substances dealt with given the characteristics of the research laboratories that handle small quantities of an extensive range of different chemical substances.

Accordingly, the main goal of this Standard text book is to secure laboratory safety by providing extensive knowledge on chemical safety and gas safety to those engaged in research activities, and to reinforce safety educations on the issues that were pointed out to be the most inadequate.

For the chemical safety, Material Safety Data Sheet (MSDS), which is the source of an extensive range of information on the properties of chemical substances, will be examined along with the meaning and significances of the information indicated on the label attached to the containers for chemical substances. In addition, methods of analysis and prevention of the causes of accidents that occur in the process of a diverse range of chemical experiments and experimental manipulation will be examined. Moreover, types and application methods of a diversified range of personal protection equipment for those engaged in research activities against accidents as well as the emergency measures to be taken at the time of accidents will be reviewed.

The chapter on the gas safety is aimed at establishing the environment for dealing with the gaseous substances safely by assessing the characteristics of the substances, examining the issues to be considered appropriately in storing, using and transferring, analyzing and obtaining lessons on the accidents and their causes associated with gaseous substances.



## Prevention of fire in buildings

- Do not pile up waste newspapers and cardboard boxes.
- Do not leave lighter or matches at locations with risk of fire due to chemical substances and gases.
- Do not leave the kitchen even for a short period while food is being cooked on the gas stove that is turned on
- Do not leave flammable liquid (alcohol and gasoline) or combustible gases (butane) unattended.
- Do not smoke in the laboratory.
- Do not leave electrical cables scattered around in locations that are not visible.



## Rules of Laboratory Safety

### ◦ Basic safety rules at the time of experiment and practicum

- If those engaged in research activities are injured in the laboratory, immediately report such incident to the administrator for laboratory safety.
- Always wear safety glasses with appropriate specifications in laboratory and storage spaces for chemical substances.
- Appropriate laboratory gown must be worn to cover the body, arms and legs to minimize the exposure to the hazardous chemical substances, and wear shoes that will fully cover the feet (high heels, shoes that expose toes, sandals and shoes made of straps are not allowed, and the laboratory gown must be separated from the personal laundry when washing them).
- Be aware of the physiochemical properties and hazardousness (example: corrosiveness, flammability, reactivity, toxicity, and etc.) of the chemical substances being used, and familiarize with the contents of the label or GHS/MSDS prior to handling hazardous chemical substances you are dealing with for the first time or not familiar with.
- Don't engage in mischievous activities, eat or drink, and strictly prohibit smoking in the laboratory that deals with or stores chemical substances.
- When handling hazardous substances, do not commence experiments without the approval of the safety administrator.
- Do not remove chemical substances or equipment from the laboratory without appropriate approval.
- Execute experiment only if there are more than two persons in the laboratory, and if it is unavoidable to perform experiment alone, notify such to the colleague or administrator for laboratory safety.
- Prior to leaving the laboratory or after having used laboratory gloves, make sure to clean face, hands, and arms with soap thoroughly.

# Rules of Laboratory Safety

## ◦ Safety rules when handling chemical substances

- Segregated storage

Chemical substances must be stored in appropriate location and the substances that are classified as deadly poison under the Law for management of harmful chemical substances must be stored separately from other substances in a storage cabinet with locking device. In addition, in the event of storing different types of toxic substances or chemical substances in the same storage facility, separate them by means of partition or division line drawn on the floor, and make sure to keep distance between them in storage.

- Airtight storage

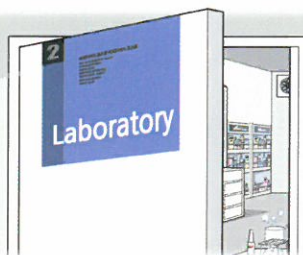
If there are concerns for the increased hazardousness due to the leakage and mixing of the chemical substances in the storage facility, do not keep or store them together. Check the cap of the container for all the reagents used to ensure that they are tightly closed and will not leak the contents. In particular, since strongly acidic solution generates lethal steam by reacting with the moisture in the air, make sure to tightly close the cap of the container for storage when not using.

- Administration and responsibility

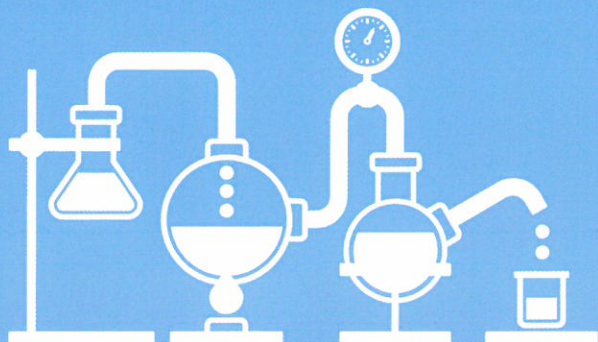
For the administration of the chemical substances, prepare for safety accidents by designating the personnel in charge of and personnel responsible for the administration. Storage cabinet for the reagent must be managed by putting identification marks for each of the reagents, and by recording the details of warehousing and use of the reagent in the ledger for management of reagent. Personnel in charge of administration shall accurately determine the quantities of the harmful chemical substances in the storage facility used and ensure that the stock and the remaining quantity recorded in the ledger coincide exactly.

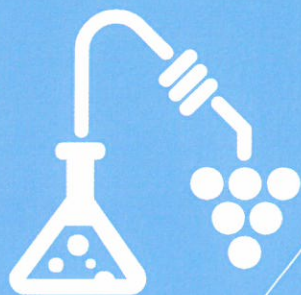


No Food or Drink Allowed



Standard Textbook for Safety in Laboratory  
Safety for Chemistry & Gas





CHAPTER

# 1

## Chemical Safety

1. Understanding information on the chemical substances
2. Protection from harmful chemical substances
3. Occurrence and preventive measures for chemical accidents
4. Occurrence of and preventive measures for chemical accidents



## 1

## CHAPTER

Safety for Chemistry &amp; Gas



# Chemical Safety

1.

## Understanding information on the chemical substances

### (1) GHS/MSDS

#### ① Material Safety Data Sheet (MSDS)

'Material Safety Data Sheet (MSDS)' refers to the data sheet that provides detailed explanations on the 16 categories of information on the chemical substances including the harmfulness & hazardousness, emergency measures and handling methods. It is occasionally referred to as the Chemical Safety Data Sheet (CSDS). In accordance with the regulations stipulated in the Article 41 of the [Industrial Safety & Health Law], those wishing to manufacture, import, use, store and transfer chemical substances must draft, furnish or post MSDS, and those assigning or providing chemical substances must do so along with MSDS. Information contained in the MSDS has been very useful as

the fundamental information in handling chemical substances particularly by the schools and research institutes with laboratories for chemistry and biology. However, there had also been difficulties in accurately providing information necessary for those engaged in research activities due to the differences in classification or details on the harmfulness of the chemical substances between the countries or companies, and, in particular, classification and warning signs for harmful-hazardous substances between the countries. Therefore, the need for establishment of integrated data that can resolve the existing problems of MSDS had been presented for some time.

## ② GHS System

In 1989, the International Labor Organization (ILO) passed the resolution to adopt classification and marking system necessary in unifying the classification and marking of, and contents of the and harmfulness and hazardousness information of chemical substances that can be used commonly by all the countries. In 2002, the International Environmental Summit Conference resolved to adopt such system as quickly as possible. Since then, the UN drafted the 'Globally Harmonized System of Classification and Labelling of Chemicals (GHS)' that can be understood and used commonly by all countries and recommended that all the countries in the world to adopt and implement this system by 2008.

The existing MSDS was first drafted by the Occupational Safety & Health Administration (OSHA) of the Employment Service of the USA and provides information on the harmfulness and hazardousness of the acute influence in the event of exposure of eyes or skin to, inhaling or consuming, or chronic symptoms arising from prolonged exposure to extensive range of the chemical substances along with the Chemical Abstract Service (CAS) registration number. On the other hand, GHS system classified the harmfulness and hazardousness of the chemical substances in greater detail into a total of 28 categories including 16 categories of physical hazardousness, 10 categories of human harmfulness and 2 categories of environmental harmfulness through a unified method. Moreover, GHS system enables the harmfulness and

hazardousness to be determined quickly by using pictorial symbols and sign languages. In addition, GHS system proposes utilization of the designated expressions for the measures necessary for prevention, coping with, storing and discarding of the chemical substances. Therefore, MSDS drafted by adopting the GHS system is equipped with the classification criteria, and harmfulness and hazardousness information that are unified throughout the world regardless of the language it is translated into. Therefore, GHS/MSDS is a very helpful guideline for those engaged in research activities to more easily and clearly understand and manage the characteristics of the chemical substances.

### ③ Contents composition of the GHS/MSDS

Composition of the contents of the GHS/MSDS is as follows and is similar to the MSDS that had been used previously in terms of the number of items and the contents. Check the Appendix 1 of this text book.

- Information on the chemical products and companies (Identification)
- Harmfulness and hazardousness (Hazard identification)
- Name and contents of the constituting ingredients (Composition/ information on ingredients)
- First aid measures (First aid measures)
- Measures at the time of explosion and fire (Fire-fighting measures)
- Means of coping with leakage accidents (Accident release measures)
- Handling and storage methods (Handling and storage)
- Exposure prevention and personal protective devices (Exposure control/ personal protection)
- Physical and chemical characteristics (Physical and chemical information)
- Stability and reactivity (Stability and reactivity)
- Toxicological information (Toxicological information)

- Effects on the environment (Ecological information)
- Precautions in disposal (Disposal consideration)
- Information necessary for transportation (Transport information)
- Current status of legal regulations (Regulatory information)
- Other reference issues (Other information)

In the event of acknowledgement of the protection of the information as the confidential business information, it is possible not to disclose the ingredients and contents, effect on the human body and environment, physiochemical characteristics, how to cope with and emergency measures to be taken at the time of explosion, fire, and etc., along with the classification information on harmfulness and hazardousness, must be indicated in the GHS/MSDS in the event of needing safety and health precautions in handling

#### ④ Classification and information on harmfulness and hazardousness of GHS/MSDS

GHS/MSDS differs from the previous MSDS in that it is required that the harmfulness and hazardousness information in terms of composition ingredient information that were previously classified into 2 categories to be provided in more detail by classifying them into 3 categories in accordance with the criteria of the 'International harmonization system for the classification and labelling of the chemical substances' presented by the UN. The Ministry of Environment, therefore, subdivided the 16 categories of harmfulness under the existing law on management of the harmful chemical substances into 28 categories in compliance with the GHS system of the UN. The Ministry of Employment and Labor also subdivided the 10 previous categories of the health risks under the Industrial Safety & Health Law and Notification into 11 categories, and amended the contents of the environment harmfulness from 2 categories into 1 category in classifying the chemical substances into a total of 28 categories of harmfulness and hazardousness. The items and methods of listing the warning signs are generally similar to those presented by the GHS system of the UN.

Information on the harmfulness and hazardousness require inclusion of the product name, pictorial symbols, sign languages, description of harmfulness, preventive measures and supplier, emergency contact numbers. In the case of the mixed substances, the range of the contents must be specified and, in principle, classification must be made on the basis of the chemical substance with the highest content. However, if chemical substance with the highest level of harmfulness and hazardousness is contained, then, it is necessary to additionally indicate caution against such substance.

## ⑤ Time of implementation of GHS/MSDS

Drafting of GHS/MSDS on a substance has been implemented since July 1, 2010 while that for mixed substances since July 1, 2013. However, although the warning signs for the toxic substances are acknowledged as transitional provision in accordance with the Law on management of harmful chemical substances by the Ministry of Environment, all other MSDS are being implemented by transforming them into MSDS according to GHS. In addition, if warning signs on the hazardous substances have been posted according to the Industrial Safety & Health Law, it is acknowledged to have posted the warning sign in accordance with the Law on the safety management of hazardous substances.

## ⑥ Provision of GHS/MSDS

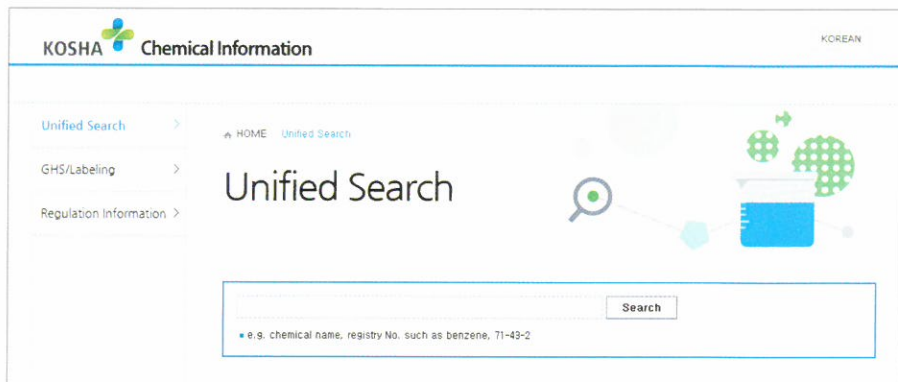
Korea Occupational Safety & Healthy Agency (KOSHA) of the Ministry of Employment and Labor have been providing GHS/MSDS on more than 10,000 items established since 2008 in accordance with the GHS system along with the MSDS on more than 50,000 items, which have been provided since 1996. However, the responsibilities for drafting and name under which the GHS/MSDS are given are those of the product suppliers (importers in the case of importing the product from overseas countries). Therefore, the appropriateness of the contents must be confirmed when quoting the data of KOSHA.

## ⑦ Language of GHS/MSDS

When drafting GHS/MSDS, although all the details need to be described in Korean language in principle, indication of the proper nouns including the names of chemical substances or names of foreign institutions in English is acknowledged. Moreover, GHS/MSDS drafted in English for the chemical substances supplied to the laboratories as reagents used for the purposes of test and research are acknowledged.

## ⑧ Items and issues to be included in GHS/MSDS

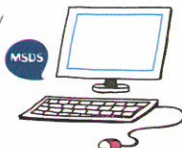
The following describes the issues to be included at the time of drafting GHS/MSDS in accordance with the Clause 1 of the Article 10 of Announcement No. 2013-37 by the Ministry of Employment and Labor. For an example of an actual MSDS on benzene drafted on the basis of above criteria is given in the Appendix 2 of this Standard Lesson Plan.



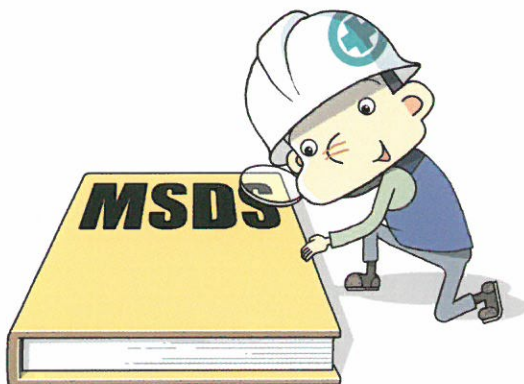
KOSHA is operating programs for drafting of GHS/MSDS. It is possible to easily search the general MSDS information of chemical substances necessary in the following websites even for ordinary users who are not manufacturer or supplier.

## MSDS information web site

- Information site in the website of KOSHA: [msds.kosha.or.kr/](http://msds.kosha.or.kr/)
- MSDS portal site: [ilpi.com/msds/index.html](http://ilpi.com/msds/index.html)
- MSDS solution center: [www.msds.com/](http://www.msds.com/)



As an example, the summary information of MSDS that can be obtained when the search word 'acetic acid' is search in the website of KOSHA is illustrated below.



## MSDS Summary Information








Name of the substance		Acetic acid	
1. General information			
CAS No.	64-19-7	KE No.	KE-00013
Physical state	Not available	Molecular weight	60.05
Boiling point	118°C	Melting point	17°C
Ignition point	39°C		
Key applications	Not available		
2. Material information			
Substance	CAS No.	Contents (%)	
Acetic acid	64-19-7	100%	
3. Pictorial symbols			
			
4. Descriptions of hazard risk			
Flammable liquid and vapor Hazardous if it comes in contact with skin Induces severe burn on skin and damages to the eyes Can cause allergic reaction, asthma or breathing difficulties if inhaled Cause damages to ( ) of the body Can cause damages to ( ) of the body			
5. Emergency measures to be taken			
If it enters the eyes	Please undergo emergency medical treatment If it comes in contact with eyes, carefully wash with water for several minutes. If possible, remove contact lens and continue to wash.		
When it comes in contact with skin	Please undergo emergency medical treatment Remove the contaminated cloths and shoes and isolate the contaminated area. In the case of burns, cool the corresponding area with cold water immediately for as long as possible and do not remove cloths that have adhered to the skin. If it comes into contact with skin (or hair), take off or discard all the contaminated cloths. Wash the skin with water / take shower. Wash the contaminated cloths prior to using it again		
When inhaled	Undergo medical examination at a medical institution (physician) immediately		
If swallowed	Please undergo emergency medical treatment If the substance has been swallowed or inhaled, perform artificial respiration by using appropriate medical respiratory equipment rather than the mouth to mouth method. If swallowed, wash out the mouth. Do not induce vomiting.		
6. Storage method			
Completely drain the empty drum and immediately return to the drum regulator or arrange appropriately after having appropriately cap the opening. Keep distance from heat, spark, fire and high temperature - no smoking Tightly close the container Store in location with locks Take precautions for the substances and conditions to be avoided Store at a location with good ventilation and keep at low temperature			
7. Conditions and substances to be avoided			
Conditions to be avoided	Keep distance from heat, spark, fire and high temperature - no smoking		
Substances to be avoided	No available data		
8. Means of coping with leakage and explosion and fire accidents			
Leakage	Do not touch or walk on the exposed substance. Remove all the sources of ignition since very fine particles can cause fire or explosion. Remove all the sources of ignition. Make sure to ground all equipment at the time of handling the substance. Immediately wipe off the substance that has been spilt and comply with the preventive measures under the section on protective devices If it is not dangerous, stop the leakage. Vapor inhibiting foam can be used in order to reduce the generation of vapor. Pay close attention to the substances and conditions to be avoided In the event of leakage without fire, wear vapor protection cloth that can cover all sides.		
9. Current status of legal regulations			
Exposure criteria	No data available		
Special health check-up interval	No data available		
Work environment assessment interval	6 months		
Industrial Safety & Health Law	Substances to be subjected to work environment assessment Harmful substances to be subjected to management		
Regulation in accordance with the Law on management of harmful chemical substances	No data available		
Regulations in accordance with the Law on safety management of hazardous materials	Class 4, type 2 petroleum product (water soluble liquid)		
10. Precautions to be taken at the time of handling			
Wear personal protective devices	Operate exhaust facility / tightly close the container	No smoking and keep distance from fire	
  			
Wear air supply type respirator in closed space Prohibit use of cotton mask and ordinary dust-proof and gas mask			
  			
Others and intoxication examples			
No data available			

Fig. 1-1

Actual summary of MSDS information on acetic acid

## (2) Label

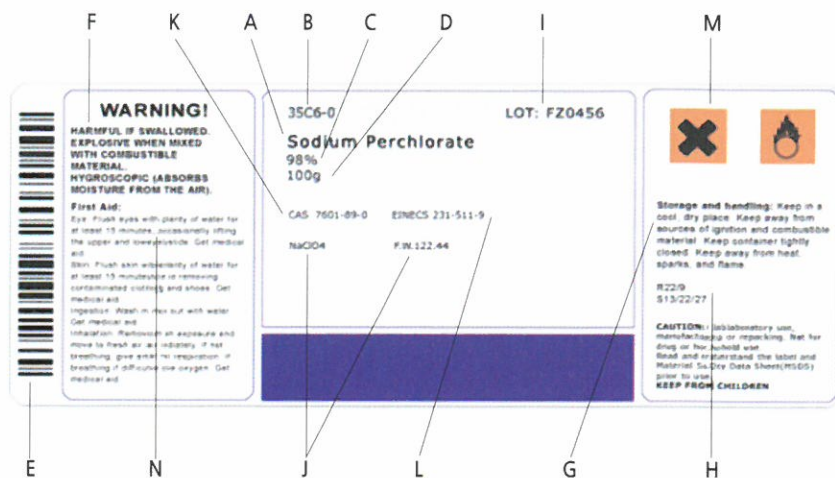
Attachment of label is an essential operation in the management of the safety of chemical substances in order to prevent erroneous use or mixing of chemical substances, or assist in proper storage of chemical substances that must not be stored together. In addition, proper attachment of label assists with the taking of prompt measures at the time of occurrence of accidents such as spilling, explosion, and etc., and enables conservation of the costs related to the disposal of the chemical substances. Therefore, the following information must be indicated on the label.

- Name of the chemical substance in the container
- Risks, warning and caution in accordance with the extent of the relative hazardousness of the chemical substances
- Key harmfulness and hazardousness predicted at the time of use
- Equipment for protection of the user from the corresponding risks
- Emergency measures to be taken to prevent and alleviate even more serious injury prior to receiving medical assistance
- Guideline at the time of fire and emergency
- Solution at the time of spilling or leakage
- Special precautions or guidelines on storage of corresponding substances
- Name, contact number and location of the manufacturer or supplier

With the exception of the disposable containers, all the containers for the chemical substances must have labels that provide sufficient information on the contents attached to them. It must be ensured that the label attached to the container does not become damaged in anyway, and it must be confirmed that label has been appropriately arranged on the container of the substance newly received. In addition, add the date of reception, date of breaking the seal and the personnel responsible for the substance to the information contained on the label in order to assist with the determination of the useful shelf-life and whether

to dispose of the substance. For the chemical substances synthesized for special purpose, information including the identification name, date and hazardousness must be indicated on the container.

The following is an example of a label for 'sodium perchlorate'. If it is difficult to search MSDS, it is possible to obtain urgent information including the important material properties, toxicity and emergency measures for the chemical substances from the label attached to the container.



- |   |   |
|---|---|
| A. Product Name                         | I. Lot Number   |
| B. Catalog Number                       | J. Chemical Formula and Formula Weight                                  |
| C. Assay                                | K. Chemical Abstracts Service(CAS) Registry Number                      |
| D. Package Weight or Fluid Content      | L. European Inventory of Existing Commercial Substances (EINECS) Number |
| E. Product Bar Code                     | M. Hazard Pictogram   |
| F. Hazard Statement                     | N. First Aid Measures   |
| G. Storage and Handling Recommendations |   |
| H. Risk and Safety Codes                |   |

**Fig. 1-2** Actual label information on sodium perchloride

### (3) Indication of risk rating

Indication of risk rating allows prompt measures to be taken by those engaged in research activities against the hazardous substances by enabling them to identify the extent of the risks of the chemical substances at a glance. Therefore, it provides assistance in determining the equipment necessary for prevention of and procedures for dealing with and coping with occurrence of emergency situations association with safety accidents.

#### ① Sign System of the National Fire Protection Association, USA (NFPA 704 System, NFPA Diamond)

Until now, the indices that categorized the health hazard, fire hazardousness and stability or the reactivity with other substances into 5 stages, 0~4, for each of the chemical substances by the National Fire Protection Association(NFPA) had been used widely as one of the indices of harmfulness and hazardousness of chemical substances. Currently, the NFPA 704 System, amended in 2012 is being used and the following new system is scheduled to be newly applied from 2017.

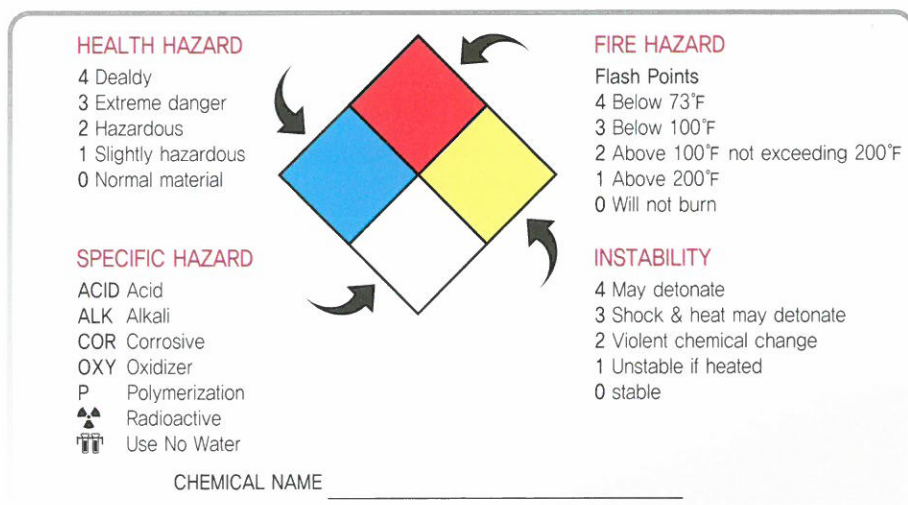


Fig. 1-3 Sign system of the NFPA

This sign system uses 4-color system, namely, blue for information on the “extent of harmfulness to health”, red for “flammability”, yellow for “(chemical) reactivity” and white for “other hazards”. Each of the area is divided into 5 states ranging from 0 (not dangerous) to 4 (very dangerous).

#### Blue – Health related information

- 4 Substance that can induce death or serious injury only with a very short period of exposure (example: hydrogen cyanide)
- 3 Substance that can induce temporary or chronic injury only with a very short period of exposure (example: gaseous chlorine)
- 2 Substance that can induce temporary disability or injury through continuous/ temporary exposure rather than chronic exposure (example: chloroform)
- 1 Substance that can induce light injuries when exposed (example: pine resin/ turpentine)
- 0 Substance that is not a health risk and does not require particular precaution (example: lanoline)


#### Red - Flammability

- 4 Substance is spontaneously or completely evaporated under normal atmospheric environment or has ignition point of less than 23°C at which it proliferates in the air and ignites (example: propane gas)
- 3 Substance among the liquids/solids that can be combusted under ordinary atmospheric environment with ignition point in the range of 23°C~38°C (example: gasoline)
- 2 Substance that needs to be situated in a relatively hot environment or continuously heated with ignition point in the range of 38°C~93°C (example: diesel)
- 1 Substance that ignites when heated sufficiently with ignition point of higher than 93°C (example: soybean oil)
- 0 Substance that does not burn (example: water)

 **Yellow - Instability/reactivity**

- 4 Substance that can explode under ordinary atmospheric environment (temperature/atmospheric pressure) (example: nitroglycerine, RDX)
- 3 Substance that need direct cause of reaction, substance that explodes when sufficient heating and impact is exerted or substance with high reactivity with water (example: fluorine)
- 2 Substance for which chemical changes can be accompanied when the temperature/atmospheric pressure increases, easily react with water or can explode when mixed with water (example: sodium)
- 1 Substance that can become instable when the temperature/atmospheric pressure increases although it is stable under ordinary atmospheric environment (temperature/atmospheric pressure) (example: acetylene)
- 0 Substance that is generally stable when exposed to fire and does not react with water (example: helium)

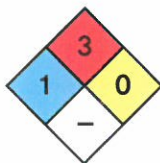
 **White - Others**

- W** Substance that can react with water and can be accompanied by serious risks if reacted (example: cesium, sodium)
- OX or OXY** Oxidant (example: ammonium nitrite)
- COR** Acidic/alkaline substance with strong corrosiveness and can be expressed as ACID (acidic) or ALK (alkaline) (example: sodium hydroxide)
- BIO** Biological hazard (example: smallpox virus)
- POI** Poisonous (example: snake venom)
- Radiation sign** () Radioactive substances (example: uranium, plutonium)
- CRY or CRYO** Cryogenic substances

※ Example of the NFPA sign for acetone and benzene is as follows.

**Acetone**

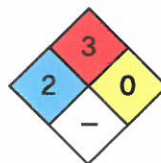
Colorless, highly volatile liquid; sweet odor. Irritating. Also causes: muscle weakness, mental confusion, coma (high concentrations). Ingestion: GI irritation, kidney and liver damage, metabolic changes, coma. Chronic: dermatitis. Highly flammable.



CAS No. 67-64-1

**Benzene**

Colorless liquid; sweet odor. Irritating to eyes/skin/respiratory tract. Toxic. Also causes: headache, dizziness, drowsiness. Absorbed through the skin. Chronic: dermatitis, leukemia, bone marrow damage. Carcinogen. Reproductive effects. Flammable.



CAS No. 71-43-2

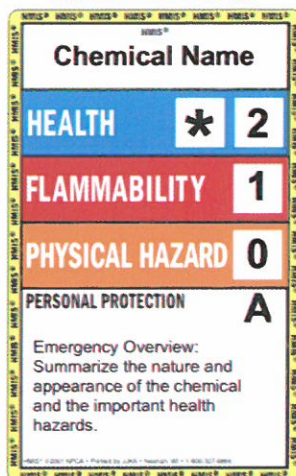
## ② Hazardous Materials Identification System (HMIS)

Hazardous Materials Identification System (hereinafter referred to as HMIS) is a method of easily conveying visual information on the product and was developed by the American Coating Association in order to comply with the regulations of the Occupational Safety and Health Administration (OSHA). Color signs of HMIS are similar to those of the NFPA 704 System.

Each of the areas is divided into 5-stages ranging from 0 (not dangerous) to 4 (very dangerous) with Blue indicating the “extent of health hazard” and Red the “flammability”. However, Yellow, which indicates the “(chemical) reactivity”, has been replaced with Orange in contrast to the color used for NFPA 704 System since April 2002 and this color was referred to as the “Physical hazard”. In addition, White focuses more on the protection of the individual’s body of the workers by enabling the code that indicates the information on the “personal protection devices” necessary in handling the substance to be listed.

- **Blue** – Health related information (same as the NFPA 704 System)
- **Red** – Flammability (same as the NFPA 704 System)
- **Orange** – Hazards to human body (same as the Yellow sign, ‘Instability/ reactivity’ of the NFPA 704 System)
- **White** – Personal protection

### HMIS Label Example



### PERSONAL PROTECTION INDEX

<b>A</b>	<b>G</b>
<b>B</b>	<b>H</b>
<b>C</b>	<b>I</b>
<b>D</b>	<b>J</b>
<b>E</b>	<b>K</b>
<b>F</b>	<b>X</b> Consult your supervisor or S.O.P. for "SPECIAL" handling directions

<b>A</b> Safety glasses	<b>n</b> Optical goggle	<b>o</b> Safety shield & safety glasses	<b>p</b> Gloves	<b>q</b> Boots	<b>r</b> Protective cloths	<b>s</b> Integral protective cloths
<b>t</b> Dust mask	<b>u</b> Gas mask	<b>w</b> Dust & gas mask	<b>y</b> Full-face gas mask	<b>z</b> Airline hood/mask		

Fig. 1-4

Example of HIMS labeling system

## 2. Protection from harmful chemical substances

### (1) Methods protection from the generally harmful chemical substances

There is a diverse range of hazards with substantial differences in the extent of the risks in accordance with the types of the substances. Therefore, researches must be preceded in the direction of minimizing the damages arising from the chemical substances that are harmful to the human body by assessing them. In the laboratory, those engaged in research activities must be protected from the harmful chemical substances by minimizing the quantities of harmful chemical substances introduced to the human body, and, in general, comply with the following rules.

#### ① Changes in the procedures

Replace the procedures with substantial discharging of harmful chemical substances to the health with the procedure that has lower level of discharging of harmful chemical substances or no discharging of harmful chemical substances at all by using harmless chemical substances.

#### ② Isolation of the workers (those engaged in research activities)

If it is not possible to eliminate the discharging of harmful chemical substances, execute the works with full range of safety equipment and personal protection devices, and execute the works in an isolated location in order to protect others engaged in research activities.

### ③ Exhaust from harmful chemicals

Remove as much harmful chemical substances discharged as possible within the laboratory in order to minimize the effects of the harmful chemical substances.

### ④ Wear personal protection devices

Wear a diverse range of appropriate personal protection devices in order to ensure that harmful chemical substances does not infiltrate into the body of those engaged in research activities.

### ⑤ Substitute with less harmful chemical substances

Either minimize the quantities of the harmful chemical substances used in the research or, if substitution is possible, use less harmful chemical substances.

### ⑥ Administrative management

In order to minimize the exposure of those engaged in research activities to the harmful chemical substances, they should be allowed to work only for an appropriate duration of time in shifts not to induce harm to their health and take sufficient rest after the works. Moreover, execute measurement of the concentration and limit the quantity of harmful chemical substances to be stored in the laboratory in regular basis.

### ⑦ Provision of medical monitoring

Continuously monitor and manage the health hazard subjected to those engaged in research activities through regularly scheduled health check-ups.

## ⑧ Provision of education and guidelines for safety in work

Continuously provide education on the precautions in handling harmful chemical substances, method of using personal protection devices and coping with leakage, and train them to work only within the guidelines in order to ensure safety in their works.

## ⑨ Tidying up and cleaning the laboratory

Clean and tidy up the laboratory in order to minimize exposure to the harmful chemical substances.

# (2) Personal protection devices

It is efficient to analyze the channel of introduction of harmful chemical substances and utilize appropriate personal protection devices to block such introduction in order to minimize the quantity harmful chemical substances that infiltrate into the human body. Key channels of infiltration into the human body include inhalation through the respiratory system, contact with eyes or skin, swallowing through the mouth, etc., and, although rare, they may enter the body through injection. Therefore, personal protection devices must be made of the materials and equipped with the functions to effectively block the infiltration channels of harmful chemical substances.

## ① Protection against infiltration through breathing

### a. Types of respiratory protection devices

Respiratory protection devices are divided largely into 'air purification type' and 'air supply type' respiratory protection devices. 'Air purification type' is the format of removing the contaminating substances prior to inhalation through the respiratory system by passing the contaminated air to pass through filtration agent or purification canister, while the 'air

supply type' is the format of supplying only the fresh respiratory air by separating harmful air from the respiratory protection devices with air supply pipe, air hose or self-supplied source of air.

**Table 1-1** Categorization of the respiratory protection devices in accordance with the types and forms

Classification	Air-purifying *		Air supplied type	
Types	Non-powered type	Powered type	Air infusion type	Self-supply type
Configuration of facial part	Full-facial Face-piece Quarter-facial type	Full-facial Face-piece type	Full-facial Face-piece Face shield Hood	Full-facial type
Name of the protective equipment	Dust respirator Gas respirator Dual function respirator (dust and gas)	Powered fan attached dust respirator Gas respirator Dual function respirator (dust and gas)	Air infusion respirator Hose respirator	Air respirator (open type) Oxygen respirator (closed type)

\* Air-purifying includes facial filtration dust respirator

#### • Air purification type

The air purification type respiratory protection devices are divided into non-motorized and motorized types in accordance with the format employed for breathing. Although the manual type accounts for most of the dust mask and gas mask in use at the moment due to its low cost, it has the disadvantages of inconvenience in wearing and difficulties in breathing since the force of the lung is used. On the other hand, the motorized type has the advantage of excellent wearability and ability to the mask under the condition of contaminated air at higher concentration than the manual type although it is more expensive. However, if the oxygen concentration is less than 18% or if the 'harmfulness rating' is high, then, air supply type respiratory protection devices must be used instead of air purification type.



## Harmfulness rating

- In order to make decision on the respiratory protection devices needed, it is necessary to assess the contaminated substances quantitatively and qualitatively. Appropriateness of the protection devices should be decided in accordance with the physical and chemical properties of the harmful chemical substances and the concentration of the contaminated substances. To determine the concentration of the contaminated substances, execute the 'measurement of the work environment' and compute the harmfulness rating in the air as follows :

$$\text{Harmfulness rating} = \frac{\text{Current concentration}}{\text{Allowed concentration}}$$

- If the harmfulness rating is high, engineering management must be executed and appropriate respiratory protection devices must be selected in order to ensure the safety of those engaged in research activities.



## Work environment measurement method

(as announced by the Ministry of Labor)

- Personal collection of the specimen (the worker takes the measurements by wearing the measurement device at the location of the respiratory system) in principle.
  - If personal collection of the specimen is not possible, execute regional specimen collection method (take measurement by fixating the measurement device at a prescribed location).
- Either take measurement continuously for more than 6 hours during the daily work period or take measurement in continuous segments for more than 6 hours in total by dividing the work hours into equal intervals.
  - Measurement is possible only for less than 6 hours: If the duration of generation of the harmful substances is less than 6 hours or if occurrence is intermittent, and in the event of the substances for which the short-term exposure standard has been set and exposure is to high concentration for a short period of time.



**Fig. 1-5** Advantages and disadvantages of manual type and motorized air purification type respiratory protection devices

#### • Air supply type

The air supply type respiratory protection devices are used in locations with oxygen concentrations of less than 18% or very high concentration of harmful substances or toxicity. In addition, it can be used in the event of needing to personally control the air supply by those engaged in research activities at the time of working in cold or high temperature environment. Special full-facial self-supply type respiratory protection devices must be worn in the work place with insufficient oxygen concentration or if the types and concentrations of the harmful substances are not known.



**Fig. 1-6** Examples of respiratory protection devices

## b. Selection of the respiratory protection devices

Familiarizing with the efficiency of respiratory protection devices is helpful in selecting the appropriate protection devices. The efficiency differs from each of the types of the devices and the number in the parenthesis below refers to the general relative efficiency of the respiratory protection devices.

- **Negative pressure type:** Semi-full facial type (10), full-facial type (100)
- **Positive pressure type:** Loose facial part (25), semi-full facial type (50), full-facial type (1000) and helmet/hood (1000)

Although this type is simple and easy to use, the respiratory protection devices that have been verified for the use is highly practical and effective. Therefore, make selection by considering the efficiency of the corresponding protection devices prior to wearing them. Selection criteria for each of the types of respiratory protection devices are examined below.

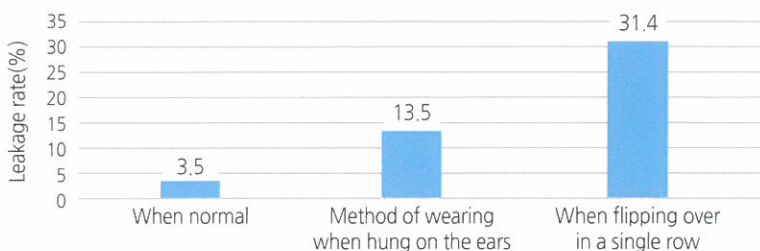
- **Dust mask**
  - Those with high efficiency of dust collection efficiency and low resistance against inhalation and discharging of exhaust
  - Those that maintains excellent air tightness with outstanding adherence to the face
  - Select those that do not generate moisture inside the mask due to breathing
- **Gas mask**
  - Select the purification canister that can detoxify the subject harmful substances
  - Select those with long break-through period indicated on the purification canister

- Air-supplied ask

- If there is contaminated air in the vicinity, those that induce inhalation with force of the lung or manual type is inappropriate
- Select the electrical device explosion-proof type for use in the regions with concerns for fire or explosion

### c. Method of wearing respiratory protection devices

In the case of the filtration type respiratory protection devices, the leakage rate increases to more than 10 times if the method of wearing is not proper. Therefore, it is important to familiarize and comply with the correct method of wearing them.



**Fig. 1-7**

Difference in the leakage rate in accordance with the method of wearing filtration type respiratory protection devices

The respiratory protection devices used most frequently in the laboratory are divided largely into folded type and cup-shaped masks, and must be used by familiarizing the following method of wearing the mask.

### • Folding type mask



- 1 After having spread the wings with both hands, retract by holding the end of the wings



- 4 With fingers on both hands, press down on the fixation clip to enable the nose section of the mask to adhere tightly to the nose.



- 2 Put the section with built-in fixation clip to be situated above the nose and wear the mask to completely cover the nose and mouth by wearing the mask from the chin towards the nose.



- 5 Wrap the entire mask with both hands and adjust it to tightly adhere to the face by checking leakage of air.



- 3 Hook the strap on the ears to fix the position of the mask or extend the strap to the back of the head and join the both straps by using connecting hook.

### • Cup-shaped mask



- 1 Let the head straps of the mask to fall downwards and grab them lightly.



- 4 Fix the lower strap at the back of the neck. Hook the strap on the hook provided and fix the position.



- 2 Align the mask to the face to warp around the nose and chin with the nose-adhesion section to be situated on the top.



- 5 With fingers on both hands, press down on the fixation clip to enable the nose section of the mask to adhere tightly to the nose.



- 3 Hold the mask with one hand and fix the upper strap at the upper portion of the back of the head.



- 6 Wrap the entire mask with both hands and adjust it to tightly adhere to the face by checking leakage of air.

Fig. 1-8

Correct method of wearing masks (folding/cup shaped types)

## ② Protection against infiltration through the skin

The primary goal of protecting the skin is to protect the whole or portion of the body from the diverse range of harmful substances and such harmful substances included chemically harmful substances (toxicity, burn (corrosiveness), irritation, and etc.), physically harmful substances (scattered residues, laser, substances with high temperature, and etc.) and biologically harmful substances (germs, viruses, and etc.). Types of protective clothing include gloves, wristlets, apron, shoe cover and, laboratory gowns and etc., as illustrated.

### a. Materials for the protective clothing

Protective clothing is made of a diverse range of materials depending on its purpose. However, no material can provide protection against all chemical substances and after the passage of prescribed period of time, chemical substances can infiltrate into the protective clothing. In particular, in the case of gloves, a wide range of materials including butyl rubber, natural rubber, neoprene, nitrile rubber, polyethylene, polyvinyl alcohol, polyvinyl chloride, Teflon, viton, 4H, barricade, tychem and etc. are used with equally wide range of applications depending on the materials used. Among these, the neoprene has particularly strong resistance against chemicals such as acid and alkaline, and, as such, it is used mostly in handling powerful chemical substances.

### b. Reactions between Protective cloths and chemical substances

There is a need to note that protective cloths cannot provide perfect protection against the chemical substances due to the following actions.

- **Permeation:** Even though there is no damaged section in the protective cloths, the chemical substances still permeates through
- **Degradation:** Chemical substance dissolves the protective cloths to make the structure loosened or swollen and cracked or hardened.

- **Penetration:** Movement of the chemical substances through the holes in the protective cloths (zipper, needle holes and holes in the fabric, etc.)

Chemical resistance rating is determined through considerations for the permeation rate, breakthrough time and degradation resistance, etc., and the recommendation rating is granted only if more than 8 hours of breakthrough time is possible. If the breakthrough time is in the range of 1~4 hours, rating of caution is given with no recommendation rating given if it is below 1 hour.

### c. Types and selection of the protective cloths

In order to select the appropriate chemical protection clothing, the following issues on the subjects that can impart hazard to the human body must be considered first.

- Hazardousness of the chemical substances
- Extent of exposure to the anticipated hazard
- Duration and environment under which those engaged in research activities will have to perform

One must avoid having the thought that well known materials manufactured by reputable company will have the protection level required, and that the weight or thickness of the fabric will have direct correlation with the protective capabilities. In addition, the manufacturer must provide appropriate data on the materials used for the protection clothing to the administrator or users in order for them to make appropriate selection of chemical protection cloths. There are 4 major levels of laboratory gown to protect the skin against the chemical substances.

**Table 1-2** Types of protective laboratory gown

Protection rating	Level of protection	Application range
Level A	Highest level of protection for the respiratory system, skin and eyes	When one will be exposed to the high concentration chemical gas and vapor at the level of IDLH
Level B	Although it has the level of protection for the respiratory system at same level as the Level A, it has slightly lower level of protection for the skin.	When one will be exposed to the high concentration chemical gas and vapor at the level of IDLH for the respiratory system although there is no major hazard to the skin
Level C	Low level of protection for the respiratory system and skin	When one will be exposed to the chemical gas and vapor at the level below IDLH
Level D	Level of protection that needs only the minimum protection of the skin	When there is no known harmful factors in the atmosphere

### ③ Protection against infiltration through the face and eyes

#### a. Safety glasses

In principle, all those who enter the laboratory including the visitors must wear personal protection devices for eyes even though they do not handle chemical substances. Goggle or safety glasses are protection devices for the eyes against chemical substances or glass fragments, and must be utilized as much as possible since safety glasses or goggle that satisfy the appropriate overseas and domestic standards and equipped with the safety shield on the side can be purchased easily. Selection and safe application method of the safety glasses are as follow.

- Since ordinary safety glasses cannot block UV ray and laser, special safety glasses must be worn during the experiment that uses UV ray or laser.

- If you have to wear normal eyeglasses, choose safety glasses that can be worn over the normal eyeglasses.
- In the event of needing protection of the entire face, wear full-face protection devices (face-shield)
- Never use contact lens in the laboratory (chemical substances will permeate through the gap between the lens and retina)

### b. Safety shield

If those engaged in research activities are working under environment in which there is a possibility of being splattered by chemical substances or exposed to the vapor of harmful chemical substances, protection devices (face shield) that can protect the face including the neck and ears must be used. However, safety glasses must be worn additionally since only the facial protection device alone cannot protect the eyes. In addition, if experimental equipment that uses vacuum or if there is a possibility of explosion and splattering of the chemical substances, it is possible to prevent the damages arising from unexpected accidents by using the standing safety shield placed in front of the experimental equipment.



**Fig. 1-9** Example of safety shield

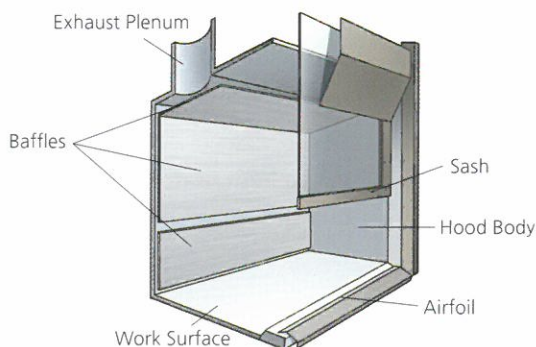
### 3. Occurrence and preventive measures for chemical accidents

#### (1) Safety facilities

##### ① Fume hood

Hood is used to collect, store and eliminate the vapor and gas generated from hazardous chemical substances. In general, it is advisable to perform all experiments on chemical substances within the laboratory within the effective range of the hood. Although it is possible to anticipate the discharging or efflux of hazardous substances, there could also be occurrence of unexpected accidents. Representative safety facilities that can protect those engaged in research activities from gaseous harmful substances include fume hood, spray hood and arm hood.

Fume hood is a facility installed for the purpose of capturing both the harmful gas and vapor. Normally, the minimum face velocity of 0.5m/sec (when the sash is opened maximally) is recommended. Spray hood is a facility installed for the purpose of collecting the harmful substances in particle phase that are generated within the hood, with the recommendation of minimum face velocity of 0.8-1m/sec in general and has filter attached to the hood. Fume hood controls toxic or unpleasant combustible vapor, gas and dust, etc. with sash made of transparent material protects the workers from the scattering or spraying of chemical substances, spray, fire and small scale explosion. Experiment should be carried out within the effective range of the hood as much as possible, and the window must not be opened more than 46cm at the time of experimental works. The structure of the fume hood is illustrated below.



**Fig. 1-10** Structure and examples of ordinary fume hood

The functions of each of the components of fume hood are as follows.

- **Exhaust plenum**

It assists the flow of the air to be uniformly distributed throughout the entire hood and if the quantity of substances accumulated on this device increases, then turbulence is generated and the efficiency of harmful substances collection drops.

- **Baffles**

It is a mobile partition used in forming linear type holes along the rear aspect of the hood. It assists with the maintenance of uniform flow of air on the frontal portion of the hood and increases the efficiency of collection.

- **Work surface**

Area below the hood on which the works are carried out

- **Sash**

It is a transparent door-type mobile plate at the front that can be closed to the optimal height in order to increase the efficiency during work. It is closed completely when not using in order to conserve energy. It provides additional measures to protect the workers from the contamination by providing physical protective barrier.

- **Airfoil**

It is located on both sides of the front portion and along the floor of the hood and functions to induce the air to flow in streamline and to prevent generation of turbulent. The small space below the airfoil functions to discharge the air of the hood in the laboratory when the sash is completely closed.

In order to maintain hood that functions normally, it is necessary to pay close attention to the following.

- Attach gauge to the hood for conformation of the face velocity in order to check that the minimum functions are maintained frequently.
- Identification number and inspection confirmation certificate of the hood must be furnished.
- Inside of the hood must be maintained clean all the time.
- Sash should be used minimally opening it to the extent of allowing convenience in working.
- Objects in the hood must be distanced from the entrance by about 15cm at the minimum and organized so that they do not interfere with complete closure of the sash.
- Those engaged in research activities must wear personal protective equipment when using the hood.

In addition, the following actions must be prohibited when using the fume hood.

- Do not store chemical substances for prolonged period of time in the fume hood.
- Do not use the fume hood as the disposal location for the chemical substances.
- Avoid putting head into the hood as much as possible.
- Do not remove the sash or panel arbitrarily.
- Do not situate sources of generation of sparks such as power outlet in the hood.
- When using the fume hood, close the sash maximally (less than 1/3) and carry out the experiment.
- Prohibit spray works in the fume hood since there are risks of fire and explosion.
  - ※ Precautions must be made when doing spray works in the fume hood since it may become the cause of fire and explosion due to the spray substances that adheres to the exhaust pipe.

## ② Arm hood

Movable arm hood, which is a multi-jointed type device, is used in discharging the harmful substances generated locally since the hood can be rotated and moved up and down freely. Arm hood can quickly discharge small quantity of contaminated air at a particular location along with the advantage of the ease of maintenance due to convenience in transportation and replacement of filters. The configuration of the arm hood is as follows.



**Fig. 1-11** Example of arm hood

## (2) Facility for storage of chemical substances

Chemical substances can be handled safely when storage facilities appropriate for their characteristics are used. In particular, it is safe to store the chemical substances with high volatility and corrosiveness substances such as acidic and alkaline substances in the cabinet specifically manufactured for their characteristics. In addition, many organic compounds generate vapor if stored for prolonged period of time since they have certain level of volatility and this vapor is not only severely hazardous to the health of those engaged in research activities in the laboratory, but also increases the risk of accidents arising from the reactions among the chemical substances. Therefore, there is a need to store them in a location with good ventilation or install ventilation fan to prevent such accidents. However, appropriate safety equipment and facilities to remove the risk factors in the laboratory should be used since it is not easy to find location that fulfil above conditions. The precautions to be exercised when applying and using these safety equipment and facilities are as follows.

## ① Closed type reagent cabinet

### a. Application

Closed type reagent cabinet forcefully discharges the vapor of chemical substances by means of ventilation fan built into the reagent cabinet while chemical substances are stored. Therefore, it lowers the risk of fire or explosion that may occur due to accumulation of flammability vapor while the chemical substances are stored and prevents the hazard that arise due to the reactions amongst the vapor of the chemical substances.

### b. Precautions

- Chemical substances must not be stored in the order of the alphabets of their name but, rather, in accordance with their states by assessing the hazardous substances at the time of storing them together.
- Minimize the chemical substances to be left outside the reagent cabinet.
- Place the glass bottles that are easily broken on the bottom shelf of the reagent cabinet as much as possible.

## ② Cabinet for storage of volatile organic substances

### a. Application

Since the volatile organic substances (organic solvent) have the possibility of spreading fire by acting as fuel, the possibility of explosion due to expansion of the combustible vapor due to the increase in temperature must be reduced by blocking the high temperature of outside. Cabinet for storing of volatile organic substances is normally made of steel with structure that contains air layer for thermal insulation. Accordingly, it functions to prevent spreading of explosion and fire for a prescribed period of time when fire breaks out.

### b. Precautions

- It can be used only if it is equipped with the function to maintain the temperature of less than fire 162°C for more than 10 minutes in the event of fire (on the basis of passing the fire testing of the USA).
- Regularly check that vaporized substances are discharged well through the exhaust duct connected to the hole on the both sides.
- Prevent the risk of ignition due to unexpected discharge by attaching fire protection equipment to the cabinet.

## ③ Cabinet for storage of corrosiveness (acidic and alkaline) substances

### a. Application

This cabinet for storage of corrosive substances such as acid and alkaline with materials and structures similar to the cabinet for storage of volatile organic substances, it is made of corrosive resistant materials such as plastic coated shelves that can withstand acid and alkaline.

### b. Precautions

- Store acid and alkaline separately.
- In particular, situate the cabinet in a location that enables easy transportation of strong acid and alkaline.
- Use the cabinet with plastic epoxy coating, which is a corrosiveness resistant material

## ④ Reagent cabinet with refrigeration or freezer function

### a. Application

Refrigerator for use in the laboratory must be selected carefully to enable storage of special chemical substances. In order to lower the

level of the risk, the storage period for the substances should be as short as possible. It is used in the laboratory to store the small quantity of chemical substances with relatively high instability or high volatility in room temperature with ventilation fan attached at time in order to discharge vapor. The following precautions must be taken in using and maintaining refrigerator.

### b. Precautions

- Label must be attached to the harmful substances that can be stored in the refrigerator.
- Storage label must be attached when storing radioactive substances.
- Place the containers stored in the refrigerator stably and ensure that they are completely sealed and capped.
- Avoid storing of containers with caps made of aluminum foil, cork stopper and glass stopper.
- Use the refrigerator that does not produce frost to prevent water drops from forming in the refrigerator.

## ⑤ Container for storage of flammable waste solution

### a. Application

For the storage of waste solution, use container that is safe for storage of the waste flammability and organic solvent, which normally has strong HDPE structure with thickness of more than 5mm. It must be designed to block the discharging of volatile gas through the application of automatic closing cap and to prevent explosion by discharging the gas through the automatic discharging outlet at the atmospheric pressure in the range of 2~5psi. In addition, container for storage of flammability waste solution must be designed to enable filling in of waste solution easy by equipping it with fire prevention device, convenient handle structure and wide opening.

### b. Precautions

- When selecting a container for storing of specific substances, check that the chemical substances do not react with each other.
- Limit the capacity of the container to less than 20 liters.
- The container must have cap and outlet cover that can be closed tightly and stored in cool location to prevent increase in the internal pressure of the container.
- Choose the ones with outlet cover to minimize the risk of explosion.

## ⑥ Cabinet for toxic substances

### a. Application

Have a spate cabinet for the storage of toxic substances that needs special management. Since these substances are highly hazardous as they are deadly poisons or have strong toxicity, they must be stored separately from the ordinary reagents and prevent access to unauthorized personnel by using locking device all the time.

### b. Precautions

- Furnish ledger for recording of warehousing and use of reagent including the time of warehousing and use, quantity and user of the substances.
- Regularly check the stock of the toxic reagent within the cabinet.



Fig. 1-12

Example of safety cabinet for exclusive use for flammability solution



Fig. 1-13

Example of safety cabinet for exclusive use for corrosiveness solution



Fig. 1-14

Example of pressurized tank for storing of volatile organic substances



Fig. 1-15

Closed type ventilated cabinet for harmful reagents

### (3) Cleaning facilities

#### ① Emergency shower

##### a. Application

When chemical substances are splattered on or have come in contact with the skin or clothing, wash them off with shower facility. Shower facility must be installed at a location with chemical substances (acid, alkaline and other corrosive substances) and accessible by all those working in such location, and must be used and maintained as follows. Install shower facility at a location that is easily accessible from all the laboratories that handle harmful substances, and manage them to be used at all times. The methods of using and maintaining shower facility are as follows.

##### b. Precautions

- Shower facility must be installed at a location that is readily accessible and has clear sign that is easily visible.
- Those engaged in research activities must be able to reach the shower facility with their eyes closed.
- Shower facility must be designed to be operated by chain or triangular handle that can be easily grabbed and pulled.
- The height of pulling device must be adjusted appropriate for the height of the workers and the operation must be checked at least once every quarter in order to ensure they are operational at all times.
- Water sprayed by the shower facility must be able to cover the entire body.
- While the shower facility is being operated, worker must be able to take the clothes, shoes and accessories off by oneself.
- The shower facility must be situated at a distance from electrical distribution panel.
- Shower facility must be installed in close vicinity of drainage hole.

## ② Emergency eye washer

### a. Application

Emergency eye washer is a facility to promptly wash off the chemical substances that have been splattered on the eyes. Therefore, it must be installed in all laboratories that deal with harmful substances and must be installed and managed to enable all the workers in the laboratory to have easy access and use. That is, it must be installed at a location that is within 15m from all locations within the laboratory or reachable within 10 seconds along with sign that can be seen clearly and definitively. Injuries to the eyes are generally accompanied by the skin injuries. Accordingly, it would be desirable to have it next to the shower facility. It can be used in the following manner.

### b. Precautions

- It is advisable to direct water or eye cleansing agent to the lower portion of the nose rather than directly to the eyes.
- The back of the eyelid should also be cleansed by forcefully flipping the eyelids.
- Prevent the washed off chemical substances to flow back into the eyes by beginning from the outside of the nose and moving towards the ears.
- Wash the eyes and eyelids for more than 15 minutes with water or eye cleansing agent.
- When washing the eyes contaminated with harmful chemical substances, make sure to take off the contact lens.
- After having washed the eyes, call hospital or 119 Rescue Center
- Inspect the eye washing device at least once a quarter on regular basis and, in particular, ensure that there is no harmful substances such as rust.

- Install protective cover on the vertical type eye washing device to protect the nozzle from the contaminated substances in the air.



Fig. 1-16

Example of emergency eye cleaner



Fig. 1-17

Example of emergency cleaner  
with eye cleaning function

## 4. Occurrence of and preventive measures for chemical accidents

Majority of the accidents occurring in science and engineering laboratory are related to chemical substances, and it is possible to confirm that checking the information on chemical substances is very important when considering that these accidents result from failure to fully and accurately understand the properties of the chemical substances. Heinrich's Law is the most well-known law associated with accidents. This is the law introduced by Herbert William Heinrich in the book he published in 1931. This Law empirically disclosed that major accidents occur in the midst of the process of repetition of minor accidents

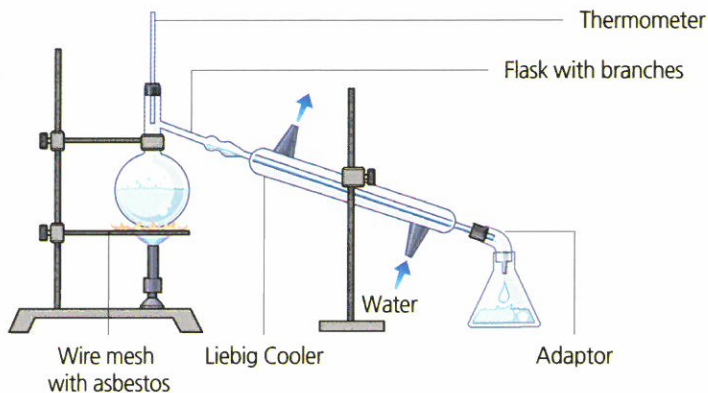
in advance rather than accidentally or suddenly and spontaneously at a given moment. That is, there always are numerous warning signs and preludes over a prescribed period of time prior to the occurrence of major accidents, and that major accidents always occur when the minor issues are overlooked. It warns that although it is possible to prevent major accidents or failures by closely examining and assessing the causes of the minor problems that occur, ignoring and leaving such signs unattended can result in irrevocably serious and major accidents. Therefore, although it is important to handle all safety accidents including those due to chemical substances accidents following the occurrence of the accidents, it is even more important to ensure that similar and same accidents do not occur again by assessing the causes of accidents and concurrently executing education for preventive measures and propagation of the facts.

Therefore, anticipated causes of and precautions to be exercised for prevention of accidents will be examined by categorizing accidents related to a diverse range of chemical substances on the basis of an extensive range of criteria.

## (1) Causes of and preventive measures for accidents for each of the manipulation of chemical experiment

### ① Distillation

Distillation is a process of purifying the substances mixed in the solution by using the differences in boiling point or by vaporizing the organic solvent that contains moisture under the presence of water and moisture scavenger such as sodium potassium or metallic hydrides, and by liquefying the generated vapor. Distillation technology has been used mostly for purification and separation of petroleum, manufacturing of alcoholic beverages and purification of chemical substances.



**Fig. 1-18** Example of distillation

### a. Causes of accidents

- There exists explosion hazard in the distiller due to the increase in the pressure of vapor generated.
- There are risks of fire since flammable substances are used in general and heating is essential to evaporate the chemical substances.
- There is a possibility of occurrence of work environment contamination due to leakage of the heated chemical substances.
- Distillation device may shoot off due to the overheating of the devices.
- The organic solvent may disappear from the system due to the cessation of the supply of cooling water for liquefaction, and gas generated by the reaction of the water reactive substances with the moisture in the air due to the breaking of the glass flask because of the overheated system, thereby inducing explosion accident.
- There exists the possibility of burns for those engaged in research activities due to heated vapor or liquids.

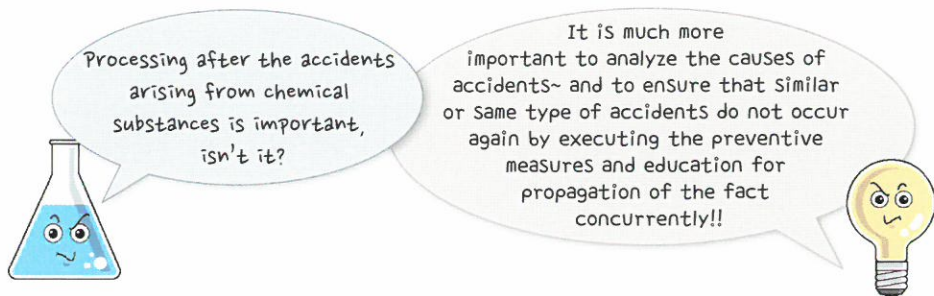
## b. Methods of preventing accidents

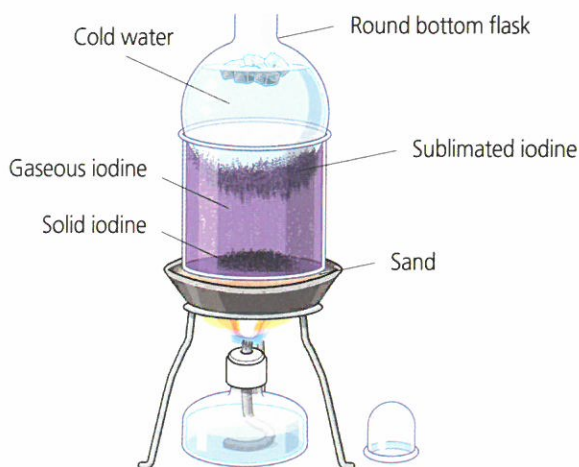
- Utilize a diverse range of substitute distillation design that uses inert gas (example: nitrogen) and low pressure and vapor.
- Use agitator or boiling tips to prevent the phenomenon of spattering due to overheating.
- The most important factor in the prevention of accidents during distillation is to ensure that there is no problem in the supply of cooling water.
- Make sure to ensure that there is no problem in the status of connection of the tube that connects the cooling device with the tap water.
  - ※ Normally, it is important to tightly join the connection by using metallic wire to ensure that the tube will not come off, and it is necessary to confirm prior to commencement of the experiment that measures to cope with cutting off of water supply has been made in preparation for the cessation of supply of cooling water.
- Sublate supply of excessive heat and adjust the heating device to ensure that only sufficient heat to just exceed the reflux temperature.
- In the event of breakage of the glass devices being used, the hazardousness of the accidents increases. Therefore, use only sound experimental devices and avoid using devices with damages.
- When using water scavenging substances to obtain anhydrous organic solvent, take precaution not to use excessive quantity of such substances.
- When removing the residues and refilling again, it is advisable to remove the organic solvent by leaving only the quantity of residues (remaining sodium or potassium, etc.) that is submerged slightly in the hood, and to handle the water scavenging substance that reacts with the water by gradually adding t-butanol, etc. by cooling the flask that contains residue with ice, etc.

- Water must not be used to expediently induce reaction and process the reaction slowly with sufficient time. In addition, secure personal safety in emergency situations by using the appropriate personal protection devices such as shield, safety glasses, rubber gloves, laboratory gowns, and etc.
- When handling liquid substances with high volatile and toxicity, make sure to execute such works in a location with good ventilation, that is, inside the fume hood.
- Adjust the experimental schedule to ensure that personnel will be present until the distillation is completed.
  - ※ In the event of leaving the laboratory in the middle of the experiment, make sure to notify other researcher in the laboratory to enable measures to be taken in the event of emergency situations. To aid this purpose, put up a sign that indicates the name of the chemical substances inside the distillation device, time of commencement of the experiment and time of anticipated conclusion of the experiment, and etc.

## ② Sublimation

Sublimation is a procedure for purification of the vapor of substance that directly converts from solid phase to gas by condensing it to produce pure substance. Sublimation, unlike distillation, separates substances with low sublimation point in the mixture of solids. Therefore, there is no need to additionally input water reactive substances. However, low pressure is utilized by using mechanical vacuum pump in general to lower the sublimation temperature.





**Fig. 1-19** Example of sublimation equipment

### a. Causes of accidents

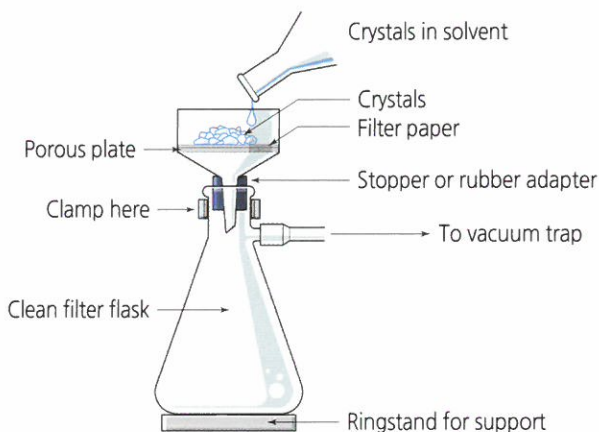
- Use of container (ordinarily glass devices) with crack will induce breakage and explosion accident in the process of pressure reduction. Breakage and explosion accidents can occur in the process of decompression.

### b. Methods of preventing accidents

- Check whether cracks, etc. exists in the container.
- Control the quantity of sublimation to ensure that not too much quantity is sublimated too quickly.
- Similar to distillation, it is advisable to perform the experiment in a location with good ventilation, that is, within the fume hood, in order to prevent a diverse range of risks arising from vapor.

### ③ Recrystallization

Recrystallization is a process of purifying substance into pure substance by using the difference in the solubility of the mixture in particular solvent while the process of separating and obtaining a particular substance from the mixture by using the difference in the solubility is referred to as extraction. This procedure frequently includes repetition of addition and removal, heating and cooling of a diverse range of organic solvents.



**Fig. 1-20** Example of filtration equipment

#### a. Causes of accidents

- Many of the organic solvents used in recrystallization usually have high volatility along with certain extent of toxicity. Accordingly, they have risk of inhalation of fire and harmful substances.

#### b. Methods of preventing accidents

- Check the toxicity and volatility of organic solvents in advance by using MSDS.
- Make sure to use appropriate personal protection devices (safety glasses, rubber gloves, mask, laboratory gown, apron and etc.).

- Do not use glass devices with cracks.
- Do not engage in mischievous activities while the repetitive manipulation is being carried out.
- When handling organic solvents with high volatility, prevent the possibility of occurrence of fire by inspecting whether source of ignition exists in the vicinity all the time.
- Carry out the experiment in a location with good ventilation, that is, in the fume hood.

#### ④ Removal of organic solvent

In the event of removing relatively large quantities of organic solvent from the reactor, Rota-evaporator is used normally and, when the quantity is relatively small, it is removed by using vacuum pump. When using vacuum pump, low-temperature trap (liquid nitrogen or low-temperature slush water tank) is installed commonly in the middle to protect the pump. At this time, there are instances in which the trap is blocked due to removal of too much solvent, thereby lowering the efficiency. In such case, remove the trap container from the low-temperature trap and melt the solidified solvent by increasing the temperature.



**Fig. 1-21** Example of experimental equipment for removal of organic solvent

### a. Causes of accidents

- There is a risk of inhalation of harmful substances due to fire and breathing because a relatively large quantity of solvent has been used.
- In the event of using vacuum pump, refrigerant is put into the refrigerant preservation container (Dewar bottle) in the low-temperature trap and there is a possibility of frostbite due to splattering of the refrigerant.
- If liquid nitrogen is used as the refrigerant, there is a risk of explosion if closed reaction system is used when the oxygen evaporates again after having been liquefied.
- If liquid nitrogen is used as the refrigerant, there is a risk of frostbite due to extremely low temperature. Make sure to wear thermally insulated gloves.

### b. Methods of preventing accidents

- It is desirable to carry out the experiments in a location with good ventilation or in the fume hood. Although refrigerant or low-temperature trap is used, some of the substances can be discharged to outside in vapor form. Therefore, perform the tasks in the fume hood as much as possible.
- Take precautions such as wearing thermally insulated gloves since there is possibility of frostbite.
- When increasing the temperature of the trap container to the room temperature, the reaction system must always be left in open state.

## ⑤ Extraction

Extraction is a method of separating the more than two substances contained in a mixture by using the solvent that can dissolve particular substances. Extraction works in the laboratory are used in separation, purification, analysis, and etc. Soxhlet extraction device is used when extracting substances from solid and liquid separation funnel when extracting substances from liquid. Liquids such as water, alcohol, ether, petroleum ether, benzene, ethyl acetate and chloroform are used frequently as the solvent.



**Fig. 1-22** Example of experimental devices used in extraction

### a. Causes of accidents

- There is a risk of potential pressure expansion due to the generation of gas from volatile and non-mixed liquid.
- Glass separation funnel has greater risk since the stopcock can drop out at the time of manipulation, thereby spilling the contents.

### b. Methods of preventing accidents

- Do not perform extraction unless the temperature falls below the boiling point of the extracted substances.

- When using volatile substances, open the stopcock and rotate the separation funnel to evaporate the gas for discharge into the air. In addition, put the cap on the funnel and flip over to discharge remaining gas by opening the stopcock.
- Lubricate the glass stopcock with oil to make controlling easier. In the event of having to use volatile solvent, avoid using glass stopcock due to the possibility of breakage.
- Do not discharge the separation funnel near flammable substances or source of ignition.
- If there is a need to use separation funnel with capacity of more than 1L by using volatile solvent, there is a risk of the stopcock popping out due to the high pressure exerted on the stopcock. Therefore, manipulated several times by dividing the contents into smaller funnel

## ⑥ Other reactions for which precautions must be exercised

- Gas has approximately 1,000 times greater volume in comparison to the same quantity of solid or liquid. Therefore use the equipment with safety valve when performing experiment that generate gas or involved reaction with gas.
- Design open reaction system by considering the explosion risks at the time of designing experiment.
- If gas liquefies or solidifies, on the other hand, there may be added burden placed on the reaction system due to the reduction in the pressure. Accordingly, there is a need to prepare for such phenomenon.
- In the case of exothermic reaction, there is a need to take precautions since there may be increase in the temperature of the experimental devices due to reaction heat. If explosive exothermic reaction is carried out, there is a danger of incurring burns since control becomes difficult.
- Experimental equipment or device that has exceeded the range of appropriate operational hours has high probability of occurrence of

accident due to overheating. Therefore, it must be maintained under the state for which immediate measures can be taken at the side. Experiments that are too long must be scheduled to divide them into parts in advance.

## (2) Causes of accidents and prevention method for each of the chemical experiment devices

### ① Glass devices

Glass is the most frequently used material for the devices used in the chemical laboratory because of its excellent chemical resistance and transparency. However, it breaks easily due to its vulnerability to impact and numerous accidents occur due to such property.

#### a. Causes of accidents

- When excessive force is exerted to replace the pipet/glass tube in the laboratory, the pipet/glass tube may be shattered.
- Glass tube can be shattered in the process of inserting the glass tube by making a hole in rubber stopper.
- When washing experimental glass devices (beaker, cylinder, flask, and etc.), there is a possibility of incurring cuts by sharp edges.
- In the event of transporting glass bottles containing reagent, workers may slip and fall due to the foreign matters on the floor and get injured by the fragment of the glass bottle as well as induce major accident such as fire and explosion due to the leakage or spilling of the contents.

## b. Methods of preventing accidents

- Prior to using the glass devices, check that there is no crack or broken portions.
- Check whether the compound to be used in the experiment reacts with glass prior to commencing the experiment.
  - ※ Example) Hydrogen fluoride (HF) reacts with glass.
- Glass devices dried in oven is hot and need to be handled while wearing protective gloves such as oven mitt.
- Check for cracks or broken parts of the glass devices prior to cleaning and use appropriate brush and do not exert excessive force when cleaning.
- For glass devices put under vacuum, use thick safety glass that are different from ordinary glass.
- When opening the tightly closed pipe or cap, take precaution as the contents put under internal pressure by explode or erupt out of the container.
- If it is heated at high temperature and then placed on cold experiment counter, glass may shatter.
- Do not handle broken glass with bare hand but after having put gloves on.
- Take the following precautions when inserting the glass tube into hose or rubber stopper.
  - Check whether the diameter of the rubber stop and rubber pipe and glass tube matches with each other
  - Lubricate the glass with water or grease.
  - Wear thick gloves and insert carefully by rotating it slowly.
  - Do not exert excessive force.

## ② Highly pressurized device

With recent increase in the number of experiments dealing with gas, experiments carried out under high pressure are also executed in large numbers. In such cases, experiment device made of high strength materials such as steel is used in general to withstand the high pressure. However, since they have prescribed threshold, precautions are necessary since exerting of pressure in excess of this threshold can lead to major accidents such as explosion, etc. Pressurized sterilizer and reactor that use high pressure are used in many experiments and there is continuous news of relevant accidents, thereby needing particular precautions.

### a. Causes of accidents

- Each of the materials with high strength such as steel, aluminum, and etc. has prescribed threshold pressure. Exerting pressures in excess of the threshold pressure can induce explosion.
- According to the types of gases or solvents used in the pressurized reactor, corrosion and deformation of the reactor may be induced. Weakened reactor due to corrosion can induce explosion.

### b. Methods of preventing accidents

- If high pressure is exerted, safety valve that opens at pressure above the prescribed pressure must be attached.
- If the valve is used for prolonged period of time, it may become blocked and fails to function properly. Therefore, always check whether it operates normally prior to commencement of use.
- Take precaution to ensure that there is no situation in which no one is available to always observe that the prescribed pressure is not exceeded.
- Pressure increases if heated and there is a need to observe that the prescribed pressure is not exceeded.

- Even when experiment is terminated, there still exists pressure inside. Therefore, remove the container cap after having made the internal pressure same as the atmosphere by cooling slowly and discharging internal pressure.
- Always install sensor to confirm the experiment temperature and pressure, and pay close attention. Although electronic temperature and pressure sensor is convenient to use, it cannot be used at the time of power shortage. Pay close attention to check preparations have been made for temperature and pressure sensor that can be used in the event of power shortage.

### ③ Low pressure (vacuum) device

The recent cutting-edge research facilities are using low pressure or vacuum more frequently in order to minimize the effect of substances. Desiccator, depressurized condenser and depressurized filtration devices are examples of such devices.

#### a. Causes of accidents

- There is a high risk of breakage of devices and explosion with the atmospheric pressure exerting high pressure on the low pressure facilities.

#### b. Methods of preventing accidents

- Devices should be made of the materials with sufficient strength to withstand the high pressure the atmospheric pressure is exerting on the facilities.
- Always inspect and check for the presence of cracks or broken parts in the low pressure (vacuum) devices made of glasses prior to and following usage.
- In the event of having constructed the device by joining various components, there is a high possibility of breakage or difference

in the strength of the components. Therefore use the components made with material of same or similar strength if possible, and check presence of damages in the joints at the time of inspection since the possibility of damages is highest at these section.

- If heating or cooling process is included in the experiment, the areas being heated or cooled can easily become damaged. Therefore, it is advisable to give sufficient time to have the device to return to room temperature before moving onto the next procedure.
- Upon completion of the experiment, put away the experimental equipment after having made sure that the internal pressure has returned to the atmospheric pressure by introducing air or inert gas.

#### ④ High temperature device

Hotplate, oven and etc., belongs to the category of high temperature device and have become the key cause of laboratory accidents related to fire since experiments are conducted by heating experimental equipment and maintaining high temperature with a diverse range of methods.



**Fig. 1-23** Examples of high temperature device(heated agitator and heating mantle)

### a. Causes of accidents

- Burns can be induced due to high heat.
- There is high risk of fire, explosion and inhaling of harmful substances at high temperature due to generation of large quantity of vapor of chemical substances.

### b. Methods of preventing accidents

- Commence experiment after having worn personal protection devices such as protective gloves, etc.
- Always observe the devices to ensure that it is not heated above the prescribed temperature.
- Make preparations for possible increase in the pressure.
- In the event of handling flammable substances, it is advisable to have appropriate fire extinguisher at hand.

## ⑤ Low-temperature device

Low-temperature sterilizer and low-temperature freezer trap, etc. belong to the category of low-temperature device and are used in the experiments that need to decrease the activity of microorganisms or freezing process in particular.

### a. Causes of accidents

- In the case of low-temperature, a diverse range of refrigerants such as liquid nitrogen and dry ice, etc. is used. If refrigerant comes into contact with skin, there is possibility of frostbite.
- In the case of liquid nitrogen, it is used by storing it in the refrigerant preservation container (Dewar bottle). This container is vulnerable to impact, which can induce breakage.
- Liquid nitrogen is easily vaporized at room temperature, thereby inducing the risk of suffocation in close space.

### b. Methods of preventing accidents

- Take precaution to ensure there is no set back in wearing personal protection devices such as appropriate protective gloves.
- This container is vulnerable to impact. Therefore, precautions must be taken to prevent leakage of liquid nitrogen in the event of breakage due to impact.
- It is safe to use liquid nitrogen under the environment with good ventilation and open space.

## (3) Causes of accidents and preventive method for each of the chemical experiment equipment

A wide range of experimental equipment and devices are used in chemical experiments and it is impossible to examine all the equipment since their characteristics are highly diverse. However, it is possible to minimize accidents from occurring by considering the precautions under the diverse conditions mentioned above. For devices and equipment, manual for each of the products provided by the manufacturer that contains the means of coping with a diverse range of situation is available. Therefore, make sure to thoroughly understand the manual prior to the use of the device and it is most important to conduct experiment in accordance with the orders presented in the manual. Remember that executing the experiments by ignoring the orders given with the belief that you have become sufficiently familiar with the device can become the cause of the accidents. In this Standard Lesson Plan, causes of accidents that can occur for 4 representative chemical experimental equipment and their respective preventive method will be introduced.

## ① HPLC

Chromatography is a method of separating the ingredient substances of mixture by using the mobile phase and static phase. Among these, HPLC (High Performance Liquid Chromatography, liquid chromatography) has the characteristic of using the liquid as the mobile phase. HPLC is composed of the mobile liquid phase, static column phase, highly functional pump and detector, key compositional components of the injection section and column heater, and section that displays signal and data.

### a. Causes of accidents

- There are very few direct causes of accidents through the use of HPLC. Majority of the causes of safety accidents is the inexperience in using the equipment.
- Accidents can occur due to the breakage of glass bottle that contains the solvent used in the HPLC column.
- High pressure pump is used for the use of HPLC. There exists the possibility of safety accidents at this time.

### b. Methods of preventing accidents

- Take precautions to ensure that there is no setback in wearing of personal protection devices such as appropriate protective gloves.
- In the case of glass container, take precaution in handling since it can be broken easily. If it is broken, take particular care since the solvent can leak into the air.
- Prevent safety accidents by familiarizing the method of using not only HPLC but also high pressure pump.



Fig. 1-24 Example of HPLC

## ② Gas Chromatography (GC)

Gas chromatography (GC) is similar to HPLC in terms of the basic purpose of application but differs in that GC uses gas as the mobile phase in most cases. After having adsorbed the specimen to be analyzed into the column tube, separate and analyze the specimen by having carrier gases such as hydrogen and helium through the column. GC is used widely in a diverse range of areas including natural science, agricultural engineering, engineering, medicine and pharmacology due to its wide application range.

### a. Causes of accidents

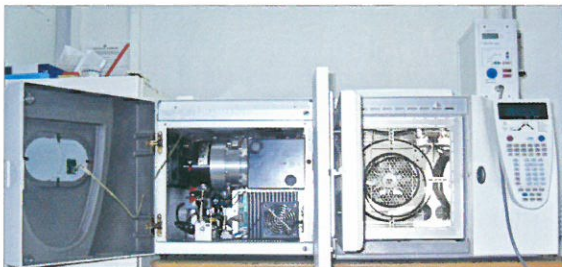
- When using GC, gas is used as the mobile phase. Therefore, be aware of the precautions to be taken in using gas.
- Depending on the analysis conditions, the equipment operates at a very high temperature. Normally, the portion of the equipment operated at high temperature is protected, there still is concern for burns and precautions need to be taken.
- At the time of use of the vacuum pump and gas, there are concerns for the safety accidents.

## b. Methods of preventing accidents

- Familiarize and comply with the precautions of using gas. In particular, when using hydrogen as the mobile phase gas, take precaution as it is a flammable gas and in discharging of the mobile phase.
- The oven and the column are heated to high temperature in accordance with the analysis conditions. Take precaution not to open the protective equipment of the oven and column at the time of experimental analysis and, if they have to be touched unavoidably, make sure to wear protective gloves.
- Prepare for safety accidents by familiarizing the method of using the vacuum pump.



**Fig. 1-25** Example of GC



**Fig. 1-26** Image of the oven and column inside the GC

## ③ Centrifuge

Centrifuge is a machine that separates the solid and liquid or liquid and liquid that are difficult to be separated on the basis of the differences in the density by using centrifugal force rather than gravitational separation force. Centrifuge is divided into centrifugal settler and centrifugal filter according to the centrifugal effect. It includes Sharples type centrifuge, De Laval type Centrifuge, decanter, basket type centrifugal filter and extrusion type centrifuge. In addition, it is used in a wide range of areas for industrial, commercial and research purposes.

### a. Causes of accidents

- Centrifuge uses centrifugal force generated from extremely high rotation speed. If the balance is not achieved, the machine will lose its balance and shooting off may occur. If hit by objects that are shoot off from the centrifuge, the impact may be quite substantial.
- Centrifuge is used widely in the uranium concentration facility in nuclear power generation. Major accident occurred in Iran in which centrifuge for development of nuclear power development was destroyed by hacker.

### b. Methods of preventing accidents

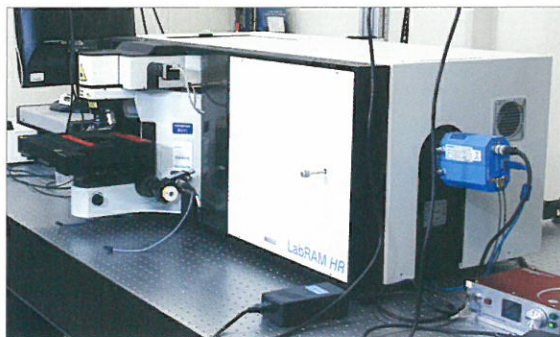
- Prior to using the centrifuge, accurately align the weight of the specimen to be placed inside to align the balance properly.
- Definitely tighten and manage with wrench or nuts to prevent the accident of displacement of rotor during rotation.
- If the internal aspect of the centrifuge chamber is contaminated by specimen (pathogenic, toxic, radioactive substances, and etc.), clean thoroughly to make sure that the internal aspect of the equipment or rotor does not become damaged.
- When the centrifuge is not being used, detach the rotor to always maintain dry state in the chamber.



**Fig. 1-27** Photograph of centrifuge

## ④ Raman

Raman is a type of spectroscopic equipment and uses laser. Raman has established independent domain in the academic area of vibrational spectroscopy and is being used in an extremely wide range of areas for research purposes.



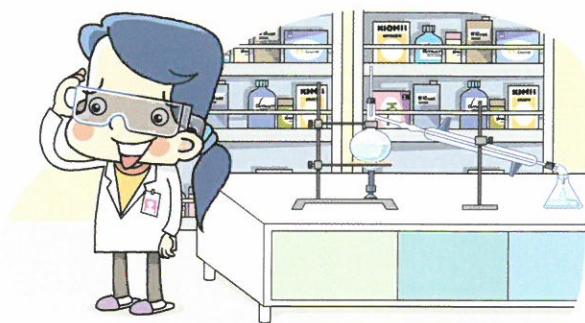
**Fig. 1-28** Photograph of Raman equipment

### a. Causes of accidents

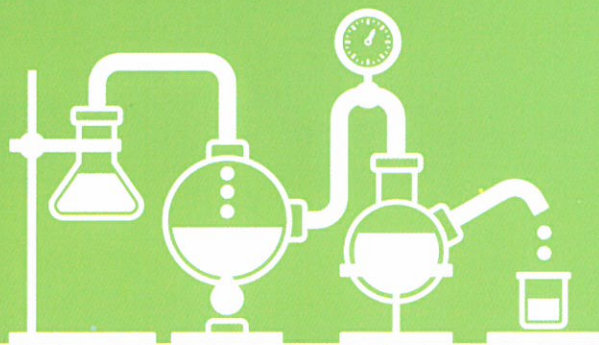
- Raman is a representative equipment of vibrational spectroscopy that uses laser and there exists possibility of safety accidents arising from the use of laser.
- The most direct hazard in general is damages to the eyes. If the eyes are directly exposed to the laser wave, eyesight may be damaged.
- Skin burns can occur due to the laser system. In addition, laser can burn cloth or paper, and ignite solvents and other combustible substances. Moreover, high output laser can even melt the substances due to high heat contained.

## b. Methods of preventing accidents

- Make sure to wear safety glasses all the time to protect the eyes.
- When using the equipment, take particular precautions to ensure that eyes are not directly exposed and notify to those in the surroundings that experiment is in progress in order for them to take precaution as well.
- Prolonged period of use of laser can induce a diverse range of problems and leaving the laboratory during the experiment must be prohibited strictly. In addition, take precautions since there is a possibility of increased temperature due to the laser if it is used for prolonged period of time.



Standard Textbook for Safety in Laboratory  
Safety for Chemistry & Gas





CHAPTER

# 2

## Gas Safety

1. Characteristics and classification of gases
2. Causes and damages of gas accidents
3. Handling and storage of gases
4. How to cope with gas accidents



## 2

## CHAPTER

## Safety for Chemistry &amp; Gas



## Gas Safety

### 1. Characteristics and classification of gases

#### (1) Characteristics of gases

Volume of the gas is about 1,000 times larger than the same quantity of liquid or solid substances. Therefore, it has relatively very low density. If it is used in natural state, it is inconvenient and uneconomical to use due to its large volume. Therefore, it is usually used by reducing the volume through compression, making the majority of gas substances to be used by compressing them in a special container that can withstand high pressure. However, some of the gases such as acetylene has the property of exploding, thereby necessitating the application of other methods.

In addition, majority of the gases, with the exception of a few, have neither the color nor odor, making it very difficult to detect their presence only on the basis of human senses. Accordingly, if the gaseous substances are leaked, it is not easy

to cope with them, and, in particular, careful precautions must be exercised when handling toxic gas. Although it is necessary to use gas detector in order to check such leakage of gaseous substances, it is also important to decide the location of installation of the detector with the warning alarm when leakage occurs given the characteristic of gas with a widely ranging density. In order to prevent a diverse range of accidents arising due to such characteristics of the gases, Korea is inducing the safety use of the gases through the implementation of Law on Safety of Highly Pressurized Gases.

## (2) Classification of gases

Gases can be classified diversely in accordance with their diversified properties (state/flammability/toxicity). They are categorized into compressed gas, liquefied gas and dissolved gas depending on the physical state, and into flammable and nonflammable gases and oxidizing gas according to the flammability of the gases. In addition, they can be categorized into toxic, non-toxic and corrosiveness gases according to the toxicity of the gases.

**Table 2-1** Classification of gases in accordance with their physiochemical characteristics

Classification of gases		Types of gases
Classification according to the state	Compressed gas	Oxygen, Hydrogen, Methane, Nitrogen, Argon, etc.
	Liquefied gas	Propane, Butane, Ammonia, Carbon Dioxide, Liquefied Oxygen And Liquefied Nitrogen, etc.
	Dissolved gas	Acetylene
Classification according to the combustibility	Flammable gas	Hydrogen, Ammonia, Propane, Butane, Acetylene, etc.
	Oxidizing gas	Oxygen, Air And Chlorine, etc.
	Flammable gas	Nitrogen, Carbon Dioxide, Argon And Helium, etc.
Classification according to the toxicity	Toxic gas	Chlorine, Carbon Monoxide, Sulfurous Acid Gas, Ammonia, Ethylene Oxide, etc.
	Non-toxic gas	Nitrogen, Oxygen, Butane And Methane, etc.

## ① Classification in accordance with the phases of gas

### a. Compressed gas

Compressed gas refers to those with the gauge pressure of more than 1 MPa (approximately 10 atmospheric pressure) at the room temperature or 35°C. These gases have critical temperature that is lower than the room temperature, do not liquefy even if compressed and exist in gaseous state.

Example) Oxygen, Nitrogen and hydrogen, etc.

※ Critical temperature: Temperature at which liquefaction does not occur regardless of how much pressure is exerted.

### b. Refrigerated liquefied gas

Refrigerated liquefied gas refers to those that are under the pressure of 0.2 MPa (approximately 2 atmospheric pressure) at room temperature or 0.2 MPa (approximately 2 atmospheric pressure) at 35°C with the critical temperature that is higher than the room temperature. It is liquefied within a highly pressurized container and has vapor pressure that corresponds to that temperature. Highly pressurized gas has the possibility of inducing accidents such as rupturing of container and eruption of the gases, etc. Occasionally, they are subjected to the Law on control of highly pressurized gas as they can be the cause of disasters such as gas explosion, ignition, intoxication and suffocation, etc.

Example) Carbon dioxide, ammonia, chlorine and LPG (liquefied petroleum gas), etc.

### c. Dissolved gas

Dissolved gas refers to those that can explode when compressed or liquefied and is used by dissolving the gas in solvent that can dissolve the gas well.

Example) Acetylene (acetylene displays slight positive pressure at the temperature of 15°C.)

## ② Classification in accordance with the flammability of the gases

### a. Flammable gas

Flammable gas refers to that discharge light and heat when ignited after having been mixed with oxygen or air. There is an extensively wide range of their types with representative flammable gas including methane, ethane, propane and hydrogen, etc. Although flammable gases are in gaseous state at room temperature and pressure, there are some that become liquefied when compressed (example: ethane and propane, etc.) or has the lower limit of explosion of less than 10% or the difference in the lower and upper limits of explosion is more than 20%.

Example) Methane, ethane, propane, hydrogen, and etc.

### b. Nonflammable gas

Nonflammable gas refers to that does not combust on its own and does not assist in burning of other substances. That is, it refers to the gases that is irrelevant with combustion.

Example) Argon, helium, nitrogen, etc.

### c. Oxidizing gas

Oxidizing gas refers to those necessary for combustion of fuel including flammability gas.

Example) Air, oxygen and chlorine, etc.

## ③ Classification in accordance with toxicity

### a. Toxic gas

Toxic gas refers to that imparts harm to the human body if exists in concentration above the particular concentration in the air.

Example) chlorine (1 ppm), ammonia (25 ppm), sulfurous acid gas (5 ppm), carbon monoxide (50 ppm), etc.

### b. Non-toxic gas

Non-toxic gas refers to those that do not impart harm to the human body even if they exist in concentration above the particular concentration in the air.

Example) Oxygen and hydrogen, etc.

### c. Corrosive gas

Corrosive gas has the property of corroding the substances it comes in contact with.

Example) Chlorine, fluorine, sulfurous gas, hydrogen sulfide, ammonia, hydrogen chloride and ethylene oxide, etc.

**Table 2-2** Terminologies related to toxicity

Abbreviation	Terminologies	Meaning
TLV-TWA (allowable concentration)	Threshold Limit Value - Time Weighted Average (allowable concentration)	harmful substances concentration at which no side effect is felt when a person works an average of 8 hours at the work place per day
LD50	Lethal Dose fifty	Orally admitted half of the lethal substance dose
TDLO	Toxic Dose Low	Orally admitted minimum substance toxicity dose
LDLO	Lethal Dose Low	Orally admitted minimum lethal substance dose
LC50	Lethal Concentration fifty	4-hour inhalation half of the lethal substance dose
TCL0	Toxic Concentration Low	Air influx minimum substance toxicity dose
LCL0	Lethal Concentration Low	Air influx minimum lethal substance dose

**Table 2-3** Flammable and toxic gas regulated by the Law on the safety management of highly pressurized gas

Inflammable Gas			
Acrylonitrile	Carbon Monoxide	Ethylene	Butylene
Acrylaldehyde	Carbon Bisulfide	Ethylene Oxide	Methyl Ether
Acetaldehyde	Methane	Propane	Mono-Methylamine
Acetylene	Chloromethane	Cyclopropane	Dimethylamine
Ammonia	Methyl Bromide	Propylene	Trimethylamine
Hydrogen	Ethane	Propylene Oxide	Ethylamine
Sulfide	Chloroethane	Butane	Benzene
Hydrogen Cyanide	Vinyl Chloride	Butadiene	Ethylbenzene

Toxic Gas			
Acrylonitrile	Chloromethane	Benzene	Monosilane
Acrylaldehyde	Chloroprene	Phosgene	Diborane
Sulfurous Acid Gas	Ethylene Oxide	Hydrogen Iodide	Hydrogen Selenide
Ammonia	Hydrogen Cyanide	Hydrogen Bromide	Phosphine
Carbon Monoxide	Hydrogen Sulfide	Hydrogen Chloride	Mono Germane
Carbon Bisulfide	Monomethyl Amine	Hydrogen Fluoride	
Fluorine, Chlorine	Dimethylamine	Mustard Gas	
Methyl Bromide	Trimethylamine	Algin	

※ Allowable concentration

It refers to the concentration of gas that can kill more than half of the adult white rats within 14 days when the rats are exposed over a period of 1 hour every day or the concentration of gas that does not impart any harm to the human body when the person is exposed to the gas for a period of 8 hours every day. The [Table 2-4] below illustrates the allowable concentrations of the key gases.

**Table 2-4** Allowable concentration of key gaseous substances

Less than 0.1 ppm	Less than 1 ppm	Less than 5 ppm	Less than 10 ppm	Less than 100 ppm	More than 100 ppm
Arsine	GeH <sub>4</sub>	CH <sub>2</sub> CHCN	H <sub>2</sub> S	NH <sub>3</sub>	CH <sub>3</sub> CHO
H <sub>2</sub> Se	PH <sub>3</sub>	SO <sub>2</sub>	CS <sub>2</sub>	NO	PhEt
Si <sub>2</sub> H <sub>6</sub>	Cl <sub>2</sub>	NO <sub>2</sub>	C <sub>6</sub> H <sub>6</sub>	CO	CH <sub>4</sub>
B <sub>2</sub> H <sub>6</sub>	CH <sub>2</sub> CH <sub>2</sub> O	SiH <sub>4</sub>	HCN	CH <sub>3</sub> Cl	CCl <sub>2</sub> CCl <sub>2</sub>
F <sub>2</sub>	CH <sub>2</sub> CHCl	CBr <sub>4</sub>	CH <sub>3</sub> NH <sub>2</sub>		MeCHCH <sub>2</sub>
O <sub>3</sub>		HF	Me <sub>2</sub> NH <sub>2</sub>		CO <sub>2</sub>
COCl <sub>2</sub>		HBr	Me <sub>3</sub> NH <sub>2</sub>		
		HCl	EtNH <sub>2</sub>		
			Et <sub>2</sub> NH <sub>2</sub>		
			Et <sub>3</sub> NH <sub>2</sub>		

## 2. Causes and damages induced by gas accidents

### (1) Causes of gas accidents

Majority of the gas accidents are induced mostly due to the aging, breakage and defective state of installation of gas piping and valves with the negligence of the user as the foremost major cause. In particular, key causes of the occurrence of gas accidents in the laboratory are as follows.

- Inadequate safety education and supervision
- Inadequate installation of gas cylinder
- Problems in management and storage
- Problem in using
- Work in a location with poor ventilation

## (2) Damages arising from gas accidents

Damages arising from gas can be divided into physical damages and chemical damages and the formats of these damages can be described as follows.

Types of the damages incurring from gas related accidents are as follows:

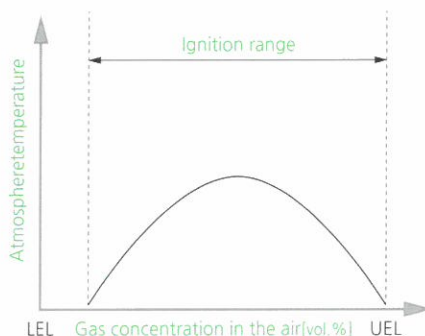
- Explosion: Occurs when explosive gases (acetylene, hydrogen, LPG, LNG and ammonia, etc.) are leaked or ignited.
- Gas poisoning: Occurs due to the leakage of toxic gases (chlorine, hydrogen chloride, carbon monoxide, sulfurous acid gas, ammonia and phosgene, etc.).
- Suffocation: Breathing becomes difficult due to the lack of oxygen in the blood because of the leakage of suffocating gas (carbon monoxide, etc.).

### ① Physical damages

- Primary impact induced by the explosion of highly pressurized gas
- Injuries to the body by the fragments generated through shattering of the highly pressurized gas tank
- Secondary fire by the source of ignition following explosion

### ② Chemical damages

- Suffocation and paralysis due to toxic gas
- Combustion/explosion limit



**Fig. 2-1** Combustion range and threshold concentration

Combustion and explosion of flammable gas can occur only when it is appropriately mixed with oxidizing gas and this range of mixing is referred to as the combustion range or explosion range. That is, it refers to the highest (upper limit) and lowest (lower limit) of concentration that can induce combustion when the flammable gas is mixed with air, and is based on the maximum value (maximum explosion limit) and the minimum value (minimum explosion limit) of the concentration necessary for a particular chemical substances to explode. Since combustion and explosion occur in such domain of the maximum and minimum limit, the explosion limit is also referred to as the “explosive range”. This limit is indicated by the % of the volume of flammable gas in the mixture of air and flammable gas, and the highest concentration limit for combustion to occur is referred to as the upper limit and the minimum concentration the lower limit.

**Table 2-5** Combustion/explosion limit of the representative gaseous substances

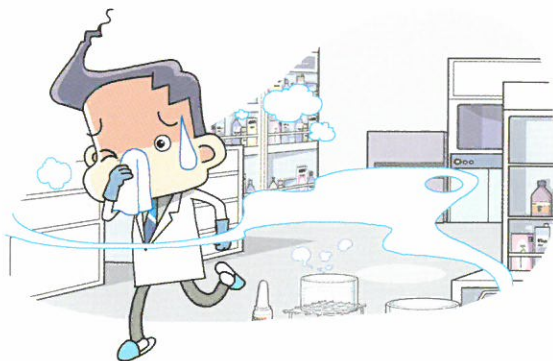
Gas	Combustion range	Gas	Combustion range
Hydrogen	4~75	Acetylene	2.5~81
Carbon monoxide	12.5~74	Propane	2.1~9.5
Methane	5~15	Butane	1.8~8.4
Ethane	3~12.5	Ammonia	15~28
Ethylene	2.7~36	Hydrogen cyanide	6~41

## conditions of explosion

For explosion to occur, 3 conditions, namely, fuel, ignition source and oxidizing agent, are essential. In other word, controlling of these conditions are deemed to be very important in preventing explosion accidents since lack of anyone of these conditions will prevent occurrence of explosion. Air (oxidizing agent) exists even at the minimum limit in the majority of the environments that handles gaseous substances.

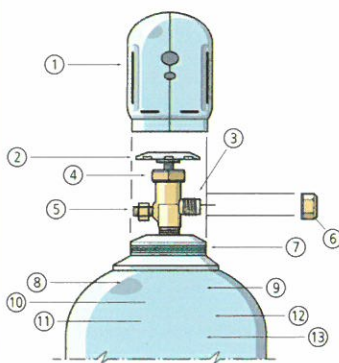
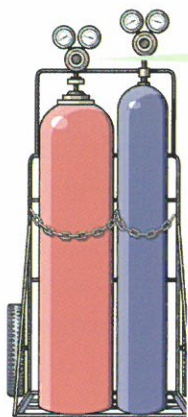
Therefore, it is essential that the fuel substances exist in concentration outside the explosion limit in order to prevent explosion. For this purpose, exhaust or ventilation works are emphasized among the manipulations related to gaseous substances. In addition, even when 2 conditions are satisfied, explosion does not occur unless energy exceeding the minimum ignition temperature is supplied by the source of ignition.

However, the source of ignition can include a diverse range of causes such as electrical spark, surfaces with high temperature and friction heat, etc. Therefore, it is very important that the fuel substances are not situated within the explosion limit.



### 3. Handling and storage of gases

#### (1) Structure of gas tank



1. Cylinder Cap
2. Valve Handwheel
3. Valve Outlet Connection
4. Valve Pack Nut
5. Pressure relief valve
6. Valve Outlet Cap
7. Cylinder Collar
8. DOT/Cylinder type & PSI rating
9. Cylinder serial number
10. Initial hydrostatic test date
11. First 5 year hydrostatic retest
12. "\*" qualifies for 10 year retest
13. Original inspectors insignia

**Fig. 2-2** Structure of the gas tank

The most vulnerable section of the gas tank is the point at which the valve and container is joined, frequently referred to as the neck. The majority of the containers is constructed of steel to withstand the high pressure of the gases, the valves are made of brass with lower strength due to reasons such as ease of processing. Therefore, there is a possibility of breakage when impact is exerted to the valves. Therefore, it must be remembered that the vulnerable section of the container has to be protected by putting on cylinder cap at the time of transportation and storage. In addition, appropriate transportation facility exclusively for gas tanks must be used at the time of transportation of gas tank.



















## (2) Distinction of gas tank

Since the highly pressurized gas tank is made of strong metallic materials to withstand the high pressurized, it is not possible to confirm the contents since it is not possible to look inside the container. Therefore, the contents of the highly pressurized gas tank are distinguished by means of the color of the container as per the agreements made. The colors used to indicate the representative combustible and toxic gases are as follows.

**Table 2-6** Colors of the containers in accordance with the types of gases

Types	Colors	Types	Colors
Oxygen	Green	Oxygen	White
Hydrogen	Orange	Cyclopropane	Orange
Acetylene	Yellow	Nitrous oxide	Blue
Liquid ammonia	White	Liquid carbonated gas	Grey
Liquid chlorine	Brown	Ethylene	Red
Liquid carbonated gas	Blue	Nitrogen	Black
Fire extinguishing container	Coloring according to Fire Service Act	Helium	Brown
Other gases	Grey	Other gases	Grey

However, the colors of the container for the gases are yet to be unified throughout the world and some of the regions continue to choose colors in accordance with the prevailing tradition in the region. Therefore, the types of the gases indicated in the label must be confirmed prior to use. As a reference, the table of comparison of colors of the gases by the USA and International Standard Organization (ISO) is presented below.

	USA		ISO	
Carbon Dioxide		Grey		Grey
He-O <sub>2</sub>		Brown & Green		Brown & White
Medical Air		Yellow		Black & White
Nitrogen		Black		Black
Nitrous Oxide		Blue		Blue
O <sub>2</sub> -He		Green & Brown		White & Brown
Oxygen		Green		White
Vacuum (Suction)		White		Yellow
WAGD (EVAC)		Purple		Purple

**Fig. 2-3**

The colors of gas container in USA and ISO



Aren't all the gas tanks the same??

No! It is not possible to look inside the highly pressurized gas tanks since they are made of strong metallic materials to withstand the high pressure! Make sure to check the colors of the tanks since the contents of the pressurized gas tanks are distinguished by their colors!



Even if it is the same gas, the color used to identify the gas may differ, making the distinction of the gases on the basis of the color of the gas tank dangerous. In addition, it must be remembered that some of the accidents occurred due to the actions of refilling and using the gas contained in the tank based on the color of the tank that is different from the gas indicated on the label. Therefore, if the name of the gas on the label does not match with the gas based on the color of the tank, do not use the gas under no circumstances and receive accurate information from or request replacement by the manufacturer or supplier by contacting the safety administrator immediately. In addition, if the type of the gas in the gas tank is not clear (if there is no label), indicate it as unknown container, and contact the safety administrator to take appropriate measures. Moreover, it must be remembered that the characteristics of gas must be confirmed through MSDS prior to use. Additionally, colors are indicated differently depending on the application. As an example, medical oxygen is indicated with white also.

### (3) Precautions to be taken when using gases

Following precautions must be taken when using highly pressurized gas.

- Familiarize with the issues necessary at the time of leakage by confirming the types of gas by checking the label on the highly pressurized gas tank and the characteristics of the gas by reading GHS/MSDS.
- Store the containers by distinguishing those that are not used, those currently being used and the empty containers.
- Highly pressurized gas tank must be firmly fixed to the wall or post by using fixation device or steel chain.
- Make sure to put the cap on the container to protect the valve neck at the time of storage since the damages can be increased due to the leakage of the contents if the valve neck is damaged when it falls.
- Highly pressurized gas tank must be stored at temperatures below 40°C and used in location with good ventilation.

- Take particular care not to store the flammable gas and oxidizing gas in the same cabinet.
- When exchanging gas, make sure to leave some pressure in the container such that air does not enter and confirm that there is no leakage. Make sure to put the cap on after the exchange.
- In the event of using the system of distributing the gas to the end user by connecting to the gas pipe rather than directly to the end user, make sure that the gas pipe is not contaminated by other gas at the time of exchanging of the gas tank.
- When connecting the gas tank, use Teflon tape on the nut to assist with airtightness in order to prevent leakage.
- Check the normal operation of the pressure regulator and perform leakage test prior to using gas.
- Make sure to install flashback arrestor for the highly pressurized flammability gas to prevent explosion accidents by interrupting spark to enter into the fuel or oxygen, an oxidizing gas.
- If the valve of the pressure regulator is opened suddenly, the flow of gas increases rapidly and there is a risk of accidents due to frictional heat or static electricity, thereby needing precaution.

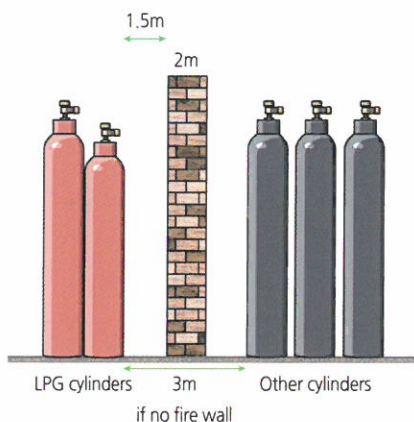


**Fig. 2-4** Good and bad examples of gas usage in laboratory

## (4) Precautions in storing of gas tank

It is possible to reduce the risks of accidents only when precautions are taken for the following issues in storing the highly pressurized gas tank.

- When the gas tank is not being used, close the valve on the gas tank and put cap on.
- Firmly fix the gas tank to prevent it from falling.
- Make sure to always store the gas tank at temperatures under 40°C.
- Store the container that have been used and those not being used by distinguishing them.
- Make sure there is good ventilation in the storage location.
- When storing the gas tank outdoors, it must be at a location that can minimize the effects of heat and climate.
- Always store the combustible, oxidizing and toxic gas separately since there is a possibility of explosion when they are mixed, or store them by having a distance of more than 3m between them after having constructed protective wall.
- Gases with high reactivity must be stored separately.
- Make sure that other substances, in particular, corrosiveness substances, flammable substances such as oil and LPG and source of ignition are not stored in the location for storage of gas.
- Container for pyrophoric toxic substances must be stored at a location with good ventilation by distinguishing them or in gas tank cabinet storage, and allow access only to the authorized personnel.
- Make sure to check the time of refilling along with whether the gas tank has been tested or not. If the refilling time has been lapsed or neared, stop using the gas and have it collected by contacting the manufacturer.



**Fig. 2-5**

Example of installation of protective wall (in principle, it must be separated by more than 3m)

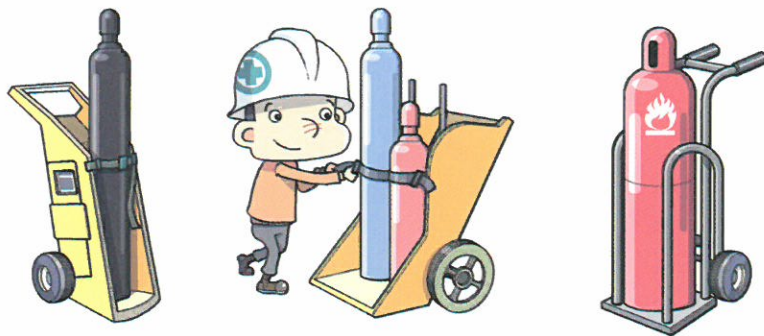
### Standard for accidents prevention facilities

- Safety device must be installed in the highly pressurized gas facilities in order to return the internal pressure to less than the working pressure.
- In the storage facility for flammable gas that is heavier than the toxic gas and air, there is a need to install gas detector in order to effectively cope with the gas leakage by promptly detecting it.
- Electrical facilities among the storage facilities of flammable gas must be equipped with appropriate explosion proof function in accordance with the installation location and the types of the gases.
- It is necessary to install ventilation device in the gas facility and storage facility for flammable gas in order to ensure that the leaked highly pressurized gas does not remain inside the facility.
- There is a need to take necessary measure to prevent the static electricity generated inside the flammable gas storage facilities from becoming the source of ignition.

## (5) Precautions at the time of transportation

Following safety rules must be abided by strictly since there are numerous risks of accidents during transportation of highly pressurized gas tank.

- When transporting highly pressurized gas tank, make sure to always wear protective gloves, safety glasses and safety shoes, and use designated transportation equipment.
- When transporting flammable substances, make sure that fire extinguisher, fire prevention equipment and personal safety equipment, etc. are properly equipped with.
- Make sure to detach the pressure regulator, close the valves and put the cap on prior to the transportation in order to protect the tank from collision with other objects.
- Take precautions not to impart impact to the gas tank through collision with other tanks or falling when lifting and lowering the tanks.
- Do not transport container with gases that can react with each other.
- Make sure to maintain the temperature at below 40°C while transporting the gas tanks.



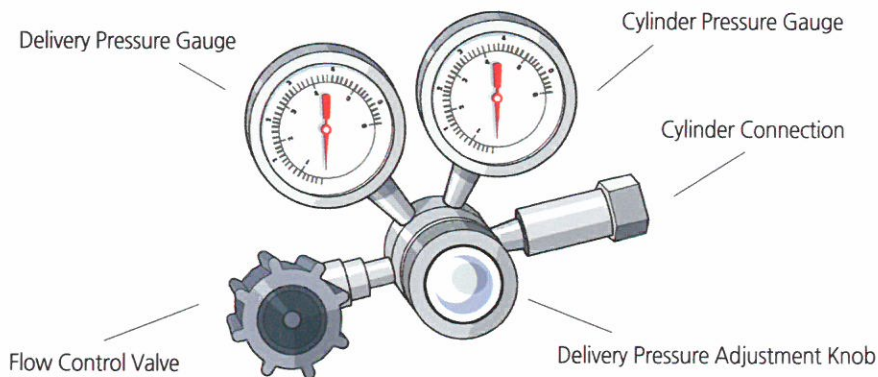
**Fig. 2-6** Example of correct transportation of gas tank

## (6) Pressure regulator

### ① Precautions when using pressure regulator

Pressure regulator is a very important equipment to transfer an accurate quantity of gas when using the gas. Therefore, there is a need to pay close attention to calibration, storage and maintenance of the pressure regulator in order for it to operate appropriately to secure safety.

The following figure illustrates the names of each of the components of the pressure regulator. You must be familiar with the functions and proper use of each of the components prior to commence the use of the pressure regulator. In addition, use proper device when connecting the gas tank and the pressure regulator. The threads on the flammable gas and ordinary gas tank are in opposite directions of each other. This must be familiarized thoroughly and paid close attention at the time of connection.



**Fig. 2-7** Name of the components of pressure regulator

- Pressure regulator must be connected to the outlet of the gas tank.

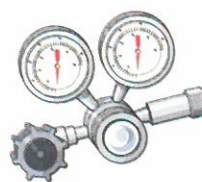
- Completely loosen the discharging pressure control knob of the pressure regulator by turning it in counter clockwise direction.
- In the case of flammable gas, it is made in the opposite direction of those for ordinary gas. Therefore, it must be turned clockwise direction to loosen the control knob.
- Check whether the gas flow control valve of the pressure regulator has been closed completely.
- Gradually open the valve of the gas tank until the pressure gauge of the pressure regulator displays the pressure of the gas tank.
- Turn the discharge pressure control knob of the pressure regulator in the clockwise direction until the desired pressure is reached.

## ② Types of pressure regulator

There are wide range of pressure regulators in accordance with the application purposes and types as illustrated below.



Single-Stage



Two-Stage



Low Pressure



High Pressure

Fig. 2-8

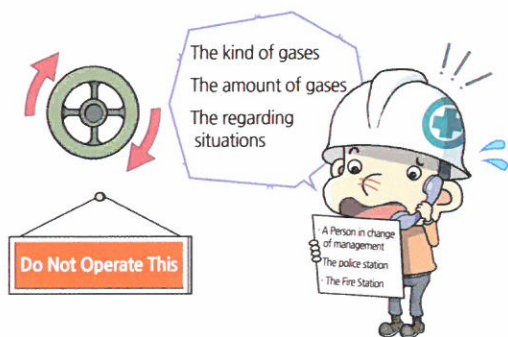
Types of pressure regulators

## 4. How to cope with gas accidents

In preparation for the event of occurrence of accidents related to gas, familiarize with the following means of coping and habituate them by participating in mock training.

### (1) Stopping leakage

- Close the pump and valves.
- Stop operation of all the equipment.
- Indicate the area with occurrence of leakage in order to enable stoppage of operation.
- Check the type and quantity of the gas leaked, and accurately assess the situation prior to contacting the interested party and 119 Rescue Center.



**Fig. 2-9** Proper means of coping with leakage accidents

## (2) Close off and seal off the areas of leakage

- When the leakage is confirmed, this method is very effective.
- It is possible to easily confirm leakage in the closed off section.
- If leakage occurs in the open section, direct sealing off can be applied depending on the extent of leakage.



**Fig. 2-10** Prevention of proliferation of toxic gas by airtight closure

## (3) Fire and evacuation

Following measures are necessary if ignition or explosion occurs along with leakage simultaneously.

- In the event of fire with the leakage of toxic or flammability gas as the cause, prompt evacuation is necessary to avoid the risks of explosion and intoxication.
- It is advisable to leave the location in which fire broke out as they are and, as a preventive measure, remove the combustible substances or prohibit the access by anyone other than the authorized personnel.
- Prepare evacuation center and prevent accidents.

- Take appropriate measure by using emergency treatment kit for those who came in contact with toxic gas.
- Personnel responsible for gas safety must confirm the preventive measures about once a week and replace or regularly refill disposable goods such as gasmask and purification canister.

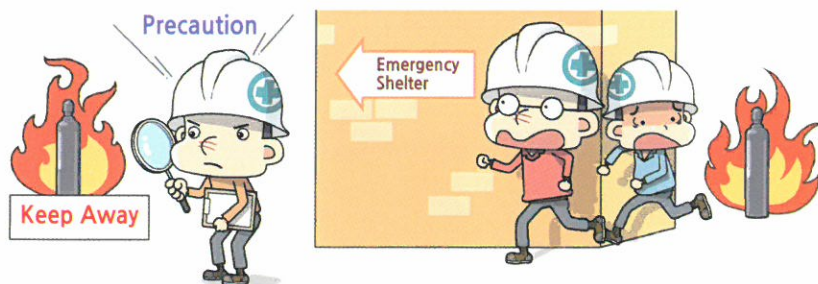


Fig. 2-11 Information on fire and evacuation

## (4) Measures to be taken against leakage of toxic substances

If toxic substance is leaked, there is a possibility of intoxication and the following measures must be considered.

- Warn about the area of leakage of toxic gas to others
- Stop breathing for as long as possible.
- Cover the mouth and nose with mask or towel as much as possible.
- Direct the face towards the direction of the wind.
- Run to higher ground.
- Report the leakage of toxic gas to administrator or responsible personnel.

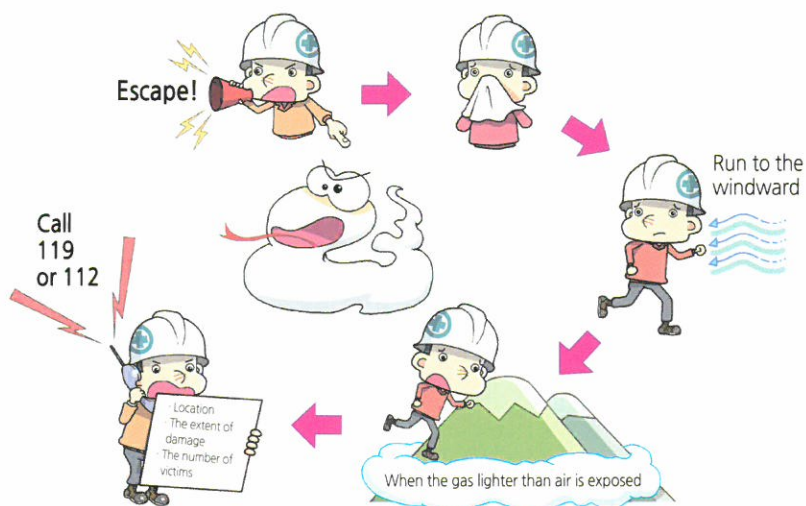


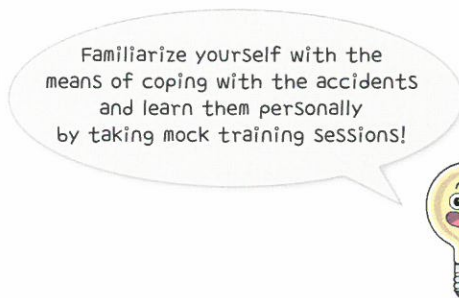
Fig. 2-12 Measures to be taken at the time of leakage of toxic substances

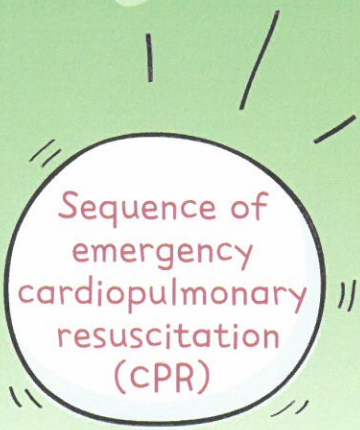
## (5) Maintenance of protective equipment for toxic gas

- Protective equipment necessary in closing the valve or in purifying the contaminated region must be stored in close vicinity of the region that uses the toxic gas.
- Protective equipment must be inspected by personnel responsible at least once a week, and disposable goods such as gasmask and purification canister must be replaced or regularly refilled after use.
- Pressure above the set value in advance must always be applied to the supplementary breathing equipment.
- Training on the use of protective equipment must be provided on regular basis (at least once every 3 months) in order for those engaged in research activities in the laboratory to use them effectively at the time of emergency.

## (6) Method of emergency measures at the time of LPG and urban gas (LNG) accidents

- LPG is heavier than air and will sink down to the floor. Keep composure and sweep it off with broom.
- If you use ventilation fan or cooling fan out of the urgency, gas may be ignited due to the spark generated at the time of turning on the switch. Make sure not to manipulate electrical devices in such event.
- Contact the sales outlet for LPG or the management agent for urban gas to receive instructions on the necessary measure to be taken, and use the gas again after having confirmed that it is safe to do so.
- In the event of fire breaking out, turn off the stopcock on the gas device and if you have time, turn off the valve as well.
- If major fire breaks out, call the urban gas company to cut off the supply of gas to that region.



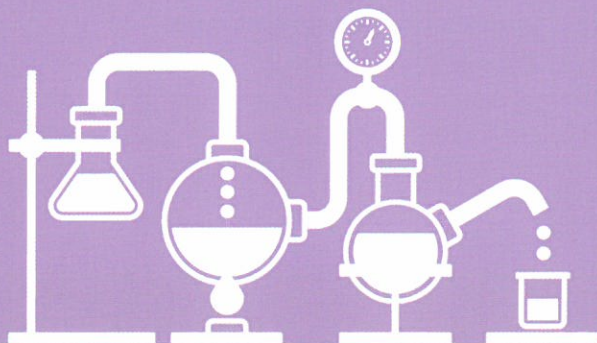


## Sequence of emergency cardiopulmonary resuscitation (CPR)

- ① Check whether the patient is conscious or not by tapping the shoulder
- ② Check breathing by putting ears and cheek to the nose and mouth of the patient
- ③ Ask someone in the surrounding to request assistance by calling 119 (request automatic external defibrillator (AED))
- ④ Chest compression 30 times
  - After having interlocked fingers of the both hands, place the palm of the hand at the center of the chest and compress the chest at vertical angle to the chest with the depth of 5cm at the minimum with the rate of 100~120 times per minute
- ⑤ Artificial respiration
  - While keeping the airway open, block the nose with fingers and blow in air through the mouth of the patient 2 times.
- ⑥ Return to the procedure No. 4 above and recommence compression of the chest within 10 seconds
- ⑦ Repeat the above procedures continuously until the 119 emergency rescue squad arrives.



Standard Textbook for Safety in Laboratory  
**Safety for Chemistry & Gas**





CHAPTER

# 3

## Chemical and Gas Safety Accidents in Laboratories

1. Examples of chemical safety accidents
2. Examples of gas safety accidents



# 3

## CHAPTER Safety for Chemistry & Gas

### Examples of chemical gas safety accidents in laboratory



#### 1. Examples of chemical safety accidents

Many chemical substances are equipped with unique properties and will result in occurrence of accidents or impart hazard to the health of those engaged in research activities in dealing with them unless they are not appropriately handled in accordance with their respective characteristics. Examples of the accidents for which the ignorance on such chemical substances is the cause and the preventive methods for these accidents will be examined in this Chapter.

#### (1) Hazards of mercury

Although mercury is used widely in our daily life including the thermometer or electronic products, it is a substance with highly toxic vapor. Recently, such fact has been propagated extensively and well and cases of being injured directly by mercury have become very rare. However, there still are numerous incidents of not knowing the proper processing method, thereby leaving substantial risks

of long-term damages. Accordingly, brief summary of the examples of relevant accidents and method of dealing with the leaked mercury is given below.



**Fig. 3-1**

Image of exposed mercury and diagram that illustrates the harmfulness to human body



## Mercury leakage accident at a university in the USA

### Overview of the accident

- Date: March 24, 2011 at about 14:35
- Location: Chemical laboratory at the Providence University, USA
- Type: Leakage accident of harmful substance
- Status of damage: Exposure of the professor and 10 students to mercury who were examined and treated at a specialized institution

### Preventive measures

- Mercury must be stored in durable container that is not easily broken and precautions must be made to avoid contact with skin.
- If the mercury is spilt, collect with syringe if the quantity is large and with bandage if the quantity is small.
- Vacuum cleaner must never be used since the powerful suction strength and heat will vaporize the mercury.
- When disposing mercury, put into the container filled with water and close it tightly, and contact the safety administrator for disposal.



## Intoxication by mercury compound

### Overview of the accident

- Date: August 1996
- Location: Darmouth College laboratory
- Type: Intoxication through toxic substance coming in contact with skin
- Status of damage: 1 death (professor)

### Preventive measures

- Since the rubber gloves are not capable of providing protection against all the chemical substances, make sure to wear appropriate personal protection devices.
- Even the insignificant contact with the chemical substances must undergo examination at a hospital.
- Take precaution against negligence arising from habitual actions.

## (2) Hazard of explosion of solid powder

Chemical reaction rate is proportional to the surface area. Therefore, the substances in large lump has low reaction rate while those in minute powder have very high reaction rates. With the recent advancement in the nano-technology, the number of laboratories dealing with nano substances is increasing, thereby increasing not only the health risks but also the possibility of explosion by unintended source of ignition, which requires precaution.



We always have to be very careful in laboratory!

And also, we should keep in mind that good research comes from safe environment





## Explosion accident at the Atomic Nuclear Engineering Department of S University



**Fig. 3-2**

Accident due to exposure of aluminum powder and photograph of Raman equipment

### Overview of the accident

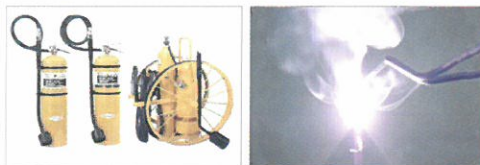
- Date: September 18, 1999
- Location: Atomic Nuclear Engineering Department laboratory
- Type: Explosion due to aluminum powder
- Status of damage: 3 deaths and 1 injured

### Preventive measures

- Metallic powder has high possibility of explosion and source of ignition must be removed from the surrounding area.
- Subscribe to insurance in preparation of the damage compensation following the occurrence of the accident.
  - ※ This incident provided the opportunity to enact the “Law on the establishment of safe environment in the laboratory” as the following measure.



## Magnesium powder fire accidents



**Fig. 3-3**

Images of magnesium combustion reaction and fire extinguisher for metallic fire

### Overview of the accident

- Date: October 7, 2010 at about 09:17
- Location: Material Engineering Department laboratory of Tennessee University, USA
- Type: Fire accidents due to chemical substance
- Status of damage: No damage

### Causes of accidents

- Powder generated in the process of manufacturing of samples by cutting and expanding magnesium is presumed to be the cause of the accident.

### Preventive measures

- Only purchase the minimum quantity needed for the experiment for the substances with high reactivity.
- Prohibit accumulated storage of chemical substances in the laboratory and, if possible, substitution with chemical with lower reactivity is recommended.
- Take particular precautions when handling water reactive metals such as magnesium, aluminum and sodium, etc.
- There is a risk of fire breaking out for water reactive metal when they come in contact with water or moisture.
- There is a risk of explosion for magnesium and aluminum if they exist in powder form.
- In the event of occurrence of fire due to water reactive chemical substances, use dry sand and fire extinguisher for metallic fire.

### (3) Hazards of water reactive substances

Water reactive substances refer to those that violently react with water and are stored in oil in general in order to minimize the contact with water. However, if they come into contact with water in handling, heat is generated due to the violent reaction and explosion also results due to the violent reaction between hydrogen that is normally generated concurrently and air. Occasionally, it refers to the substances that have spontaneous combustibility (risk of ignition in the air) such as yellow phosphorous. It is dangerous to store large quantity at once and must be stored in cold location in small portions. Powder fire extinguishing agent can be used in the event of fire.

Alkaline metal : Li, Na, K

Alkaline earth metal : Ca, Mg

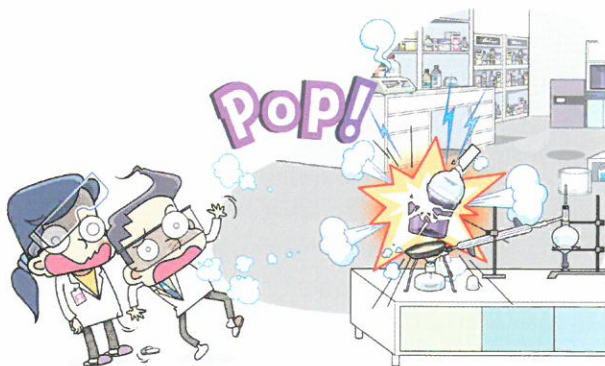
Hydride : KH, NaH,  $\text{LiAlH}_4$ ,  $\text{NaBH}_4$ ,  $\text{CaC}_2$  etc.



Explosive reaction with water, generating  $\text{H}_2$  and heat

**Fig. 3-4**

Types and properties of water reactive substances





## Accident in the laboratory of Southern Methodist University, USA



**Fig. 3-5** Article on sodium hydride accident and properties of water reactive substances

### Overview of the accident

- Date: May 11, 2010 at about 15:20
- Location: Laboratory of Southern Methodist University, USA
- Type: Fire accident due to chemical substances
- Status of damage: 1 human casualty

### Causes of accidents

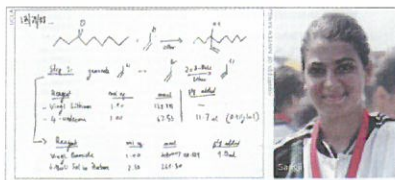
- NaH (sodium hydride) was poured into the ice water while handling NaH, which is a water reactive substance.

### Preventive measures

- Familiarize with the characteristics and safety information of the chemical substances by using MSDS when handling them.
- Water reactive substances must be stored at room temperature under dry conditions within fireproofed facility, and are not stored along with aqueous solution and absorptive substances.
- There is a risk of burn or loss of sight if contact with skin or eyes is made. Accordingly, make sure to wear personal protective equipment such as protective gloves and safety glasses when handling.
- Use dry sand, dried limestone or fire extinguisher for metallic fire in the event of fire breaking out due to water reactive substances.



## Butyl lithium explosion accidents



**Fig. 3-6** Victim of butyl lithium explosion accident

### Overview of the accident

- Date: May 11, 2010 at about 15:20
- Location: Chemical laboratory at UCLA, USA
- Type: Explosion accident due to chemical substances
- Status of damage: 1 death

### Causes of accidents

- Accident occurred during the experiment with the scale increased by 3-fold after having conducted the 1<sup>st</sup> and 2<sup>nd</sup> preliminary experiments on organic synthesis.
- Butyl lithium exploded and was proliferated by the hexane stored in the hood.
- The researcher died due to severe burn when the fire caught the cloths of the researcher.

### Preventive measures

- Inspect the presence of defects in experimental glasses and stoppers in advance.
- Do not store flammable substances such as hexane in the hood.
- Do not conduct hazardous reaction experiment alone.
- Conduct experiment by assessing the hazard of the main experiment by sufficiently analyzing the results of the preliminary experiment.
  - Make sure to wear personal protection devices such as safety glasses, protective gloves and laboratory gown.

## (4) Processing of waste solution



### Accident arising from contamination by the flammable experimental waste solution

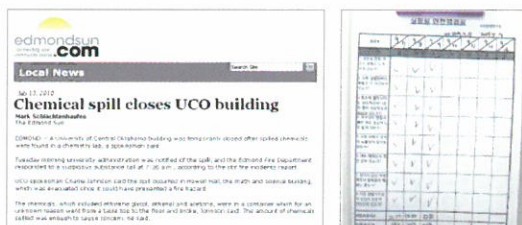


Fig. 3-7

New article on the accident at the Oklahoma University USA and laboratory safety inspection checklist



Fig. 3-8

Safety transportation cart dedicated for experimental waste solution

#### Overview of the accident

- Date: July 13, 2010 at about 07:30
- Location: Howell Hall of the Oklahoma University, USA
- Type: Contamination accident by harmful substance
- Status of damage: No damage

#### Causes of accidents

- Waste matters from the chemical experiment such as ethanol and acetone conducted on the previous day is presumed to be the cause.

## Preventive measures

- When leaving the laboratory after the conclusion of the experiment, execute safety inspections including whether harmful substances such as experimental waste solution have been left unattended and operation of devices, and fill in the inspection checklist.
- In the event of transporting the collected experimental waste solution to the collection station, use safety transportation cart by more than 2 persons while wearing personal protection equipment.



## Burn accidents due to explosion of chemical substance



Methods of using eye washer and emergency shower

Fig. 3-9

News report on the accident at the Maryland University, USA, and method of using eye washer and emergency shower

## Overview of the accident

- Date: September 26, 2011 at about 12:30
- Location: Organic chemistry laboratory at the Maryland University, USA
- Type: Accident due to explosion of chemical substance
- Status of damage: Burn and stabbing wound in 2 persons (1<sup>st</sup>~2<sup>nd</sup> degree burns in face and arm), damage to 1 fume hood

## Causes of accidents

- Explosion is presumed to have occurred by disposing the mixture of nitric acid with sulfuric acid while the substances that rapidly react when mixed with nitric acid with sulfuric acid (organic solvent and water, etc.) was included in the collection container for disposed chemical substance.

## Preventive measures

- Experimental waste solution generated in the process of chemical experiments must be collected in the storage container distributed by the relevant institution.
- Familiarize with the emergency treatment to be executed in the event of burns arising from acidic and alkaline substance.
- Sufficiently wash with flowing water(for 15 minutes) by using shower or eye washer promptly.
- If they come in contact with laboratory gown and shoes, take them off promptly before they come in contact with the chemical substance.
- Institutions that deal with chemical substance must install shower and eye washer in the vicinity of the corresponding laboratory and regularly manage that they operate normally at the time of emergency.



## Accident due to leakage of waste solution from acid experiment



**Fig. 3-10**

Site of accident due to leakage of waste solution from acid experiment

## Overview of the accident

- Date: September 2, 2011
- Location: Laboratory of OO Institute of S University
- Type: Accident due to leakage of chemical substance
- Status of damage: No damage

## Causes of accidents

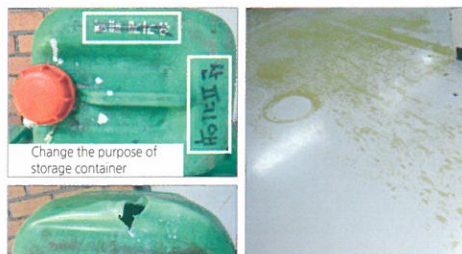
- Hydrogen peroxide of piranha solution (sulfuric acid + hydrogen peroxide) used in cleansing glass devices was collected in the storage container for experimental waste solution and the temperature increased in the process of storage.
- It occurred when the solution with increased reactivity reacted with other contents, thereby inducing crack in the container because of the increased internal pressure and leakage of the acidic waste solution such as nitric acid and hydrochloric acid to outside of the container.

## Preventive measures

- The reactivity of the hydrogen peroxide solution must be lowered sufficiently and collect in the storage container for experimental waste solution.
- Experimental waste solution generated in the process of chemical experiments must be collected in the container distributed by the relevant institution.
- Experimental waste solution must be separated and collected in the designated container by distinguishing them into acid, alkaline, organic and inorganic matters.
- Reactive and explosive substances must be collected in the container after having converted into safe substance.
- Prohibit storage of the substances that cannot be put together in the same container although they are of the same category by reviewing MSDS in advance.



## Accident due to the explosion of storage container for experimental waste solution



**Fig. 3-11** Site of accident due to leakage of experimental waste solution

### Overview of the accident

- Date: April 2010
- Location: Laboratory of OO Institute of S University
- Type: Explosion of experimental waste solution canister
- Status of damage: Contamination of the inside of laboratory

### Causes of accidents

- Sulfuric acid that has the property of exploding when it comes in contact with organic substances and toluene, which is an organic solvent, was collected in the same storage container for experimental waste solution, and the container was exploded.
- At the time of the accident, the storage container purchased arbitrarily was replace and used for organic experimental waste solution in the laboratory.

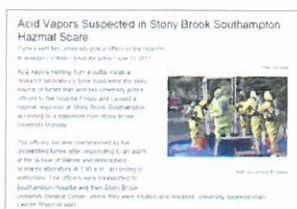
### Preventive measures

- Experimental waste solution generated in the process of chemical experiments must be separated and collected in the storage container provided by relevant institution by classifying them into acid, alkaline, organic and inorganic substances.
- Attach a tag to the container and record the key ingredients at the back of the tag at the time of collection of the experimental waste solution.

## (5) Hazards of highly volatile substances



### Accident due to inhalation of acidic vapor



**Fig. 3-12** News report on the accident and the image of fume hood being used as a reagent cabinet

#### Overview of the accident

- Date: June 10, 2011 at about 03:40
- Location: Maritime Atmospheric Science Research Institute of the New York State University (Stonybrook Campus), USA
- Type: Accident due to leakage of harmful substances
- Status of damage: 2 people inhaled harmful vapor

#### Causes of accidents

- The accident is presumed to be the result of the leakage of harmful acidic vapor from the reagent bottle stored in the fume hood in the laboratory.

#### Preventive measures

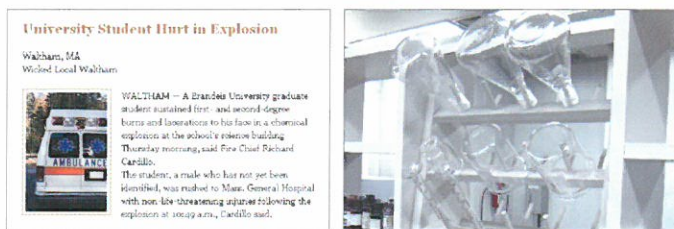
- At the time of leaving the laboratory upon conclusion of the experiment, execute safety inspections including whether harmful substances such as experimental waste solution has been left unattended and operation of the devices, and fill in the daily inspection checklist.
- Refer to the proper method of using the hood.
- Check whether the hood operates normally prior to commencement of use (check the suction after having put tissue to the hood).

## Preventive measures

- Do not use the hood as a storage location for reagents.
- Experimental equipment should be installed inside the area that is at least 15cm from the edge of the hood.



## Chemical substance explosion accidents



**Fig. 3-13**

News report on the accident at the Brandeis University, USA, and need to undergo inspection processes for the glass flask prior to use

## Overview of the accident

- Date: September 9, 2010 at about 10:30
- Location: Science Department of the Brandeis University, USA
- Type: Organic solvent explosion accidents
- Status of damage: Burns to 1 person

## Causes of accidents

- While a graduate student was carrying out the experiment for collection of the tetrahydrofuran at low-temperature through decompression distillation, explosion is presumed to have occurred due to the condensation of the oxygen in the air because of defect in the closure section of the glass flask

## Preventive measures

- When handling chemical substances, familiarize with the safety information by using MSDS in advance.

## Preventive measures

- Familiarize with the precautions to be taken at the time of using glass experiment devices.
- Check for the presence of crack or broken part prior to the use. (In particular, equipment that is subjected to high temperature heating or vacuum must be checked.)
- Use round flask rather than triangular flask that is broken more easily at the time of decompression distillation.
- Make sure to use vacuum grease or vacuum connecting device at the joint with the glass device in order to ensure that air does not enter the device.



## Accident due to leakage of fuming sulfuric acid



**Fig. 3-14**

Site of the accident due to leakage of fuming sulfuric acid at the S University

## Overview of the accident

- Date: August 8, 2011
- Location: Laboratory of OO Institute of the S University
- Type: Leakage of chemical substance
- Status of damage: No damage

### Causes of accidents

- Fuming sulfuric acid with strong corrosiveness that had been stored in cryogenic freezer was leaked to area outside the freezer due to the shortage in power supply, thereby inducing the accident.

### Preventive measures

- Institutions and laboratories that have experiment equipment with concerns for accident at the time of power shortage must prepare measures to cope with the power shortage such as installation of emergency power supply equipment (UPS).
- Only purchase the minimum quantity needed for the experiment as much as possible for flammable liquid, reactivity and explosive substances and use them.
- Prohibit accumulated storage of such substances in the laboratory and pay particular attention to the management of chemical substances.



## Explosion accident of oil vapor of organic solvent



Outside of fire accident



Inside of fire accident

**Fig. 3-15**

Site of the explosion accident at the technology research center in Gumi City, Gyeongbuk Province

### Overview of the accident

- Date: August 27, 2011 at about 13:34
- Location: Technology research center of OO Chemical in Gumi City, Gyeongbuk

## Overview of the accident

- Type: Chemical substance (oil vapor) explosion accident
- Status of damage: 5 deaths, 2 severely injured persons and property damages valued at about 10 billion Won

## Causes of accidents

- Combustible oil vapor of heptane generated while drying new material fiber in the textile yarn drier failed to be discharged and remained in the drier. When the static electricity generated in the work place ignited the oil vapor of heptane that reached the explosion limit of 1.1-6.6%, thereby inducing explosion and fire.

## Preventive measures

- Ventilation facilities must be installed at the locations in which oil vapor can stay in order to prevent explosion and gas intoxication accidents.
- In the locations with the risks of fire and explosion due to static discharge sparks, prohibit the use of earthing and explosion proof electrical device, and the personnel with access to the location must wear anti-static clothing, shoes and gloves, etc.
- Experiments that are accompanied by hazards such as explosion and fire, etc. must be executed in accordance with the standard safety procedures after having had sufficient discussions with responsible personnel for research in advance.



Wouldn't it be unfair and frustrating to be injured due to the mistakes of others?

Damages can be avoided and prevented if everyone takes precautions in the laboratory!  
Make sure to abide by the basic safety rules for the sake of others and you!





## Thionyl chloride explosion accidents



**Fig. 3-16**

Harmfulness of thionyl chloride and image of the site of the explosion accidents

### Overview of the accident

- Date: June 25, 2011 at about 10:47
- Location: Merkert Chemistry Center of the Boston University, USA
- Type: Chemical substance explosion accidents
- Status of damage: Stabbing wound/burn to 1 person

### Causes of accidents

- Although the accurate cause of the accident is still unknown, it is presumed to have occurred due to the procedural problems in the experiment.
- Beaker containing thionyl chloride exploded due to the occurrence of unexpected reaction while a researcher was conducting the experiment using a small quantity of thionyl chloride in the laboratory alone.

### Preventive measures

- Do not execute experiment alone in the laboratory. If it is unavoidable that the experiment be conducted alone, notify the responsible personnel for research and colleague in order to have them aware of the situations.

## Preventive measures

- For the experiment, check the safety of each of the stages of the experiment in advance and execute them in accordance with the prescribed procedures. Make sure to wear appropriate personal protective equipment including safety glasses, facial protection shield and protective gloves, etc.
- When handling chemical substances, do so after having sufficiently familiarized with the safety information including harmfulness to human body, toxicity and the methods of handling by using MSDS.

## (6) Contamination accident due to the leakage of substance harmful to human body



### Leakage of pyridine in a laboratory of university



#### Students hospitalized after chemical spill

Firefighters evacuated the Phillips-Wangensteen Building after a spill in a seventh-floor lab.

By Lauren Hart

Minneapolis firefighters contained a 10-gallon (two 5-gallon) spill of hazardous chemical (pyridine) following a leak in a 400-sq-ft lab on the seventh floor of the Phillips-Wangensteen Building.

Two students suffered burns, one and four lines of the hazardous chemical pyridine in a seventh-floor lab at the building. Minneapolis Fire Department spokesman Chad Miller said.

All four night firefighters and a HAZMAT crew responded.

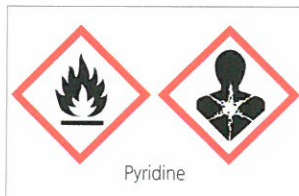


Fig. 3-17

Photograph of transportation container for chemical substance, new report on the accident and the harmfulness of pyridine

## Overview of the accident

- Date: September 29, 2010 at about 18:00
- Location: Phillips-Wangensteen Building at the Minnesota University, USA
- Type: Harmful substances contamination accident
- Status of damage: Pyridine exposure by 2 persons

## Causes of accidents

- Contamination was proliferated into the internal aspect of the building when a researcher spilt pyridine 2-4L in the area near the entrance of the building due to the negligence in transportation outside of the laboratory while conducting the experiment.

## Preventive measures

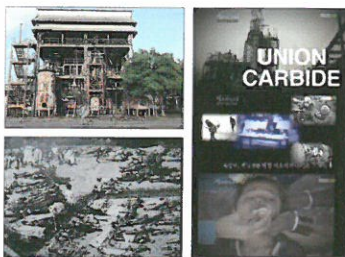
- Chemical substances contained in glass container must be transported by placing the contents in container dedicated for transportation without leakage and breakage or by placing them in a secondary container.
- Familiarize the precautions to be taken at the time of handling and storing flammable substances storage in the laboratory.
  - Purchase only the minimum quantity needed for the experiment for use and prohibit accumulated storage in the laboratory.
  - It must be handled in the fume hood or under ventilation equipment as much as possible.
  - Avoid source of ignition such as heat, flame and spark, etc.



## 2. Examples of gas safety accidents



### Methyisocynate (MeNCO) leakage accident in the Union Carbide Agricultural Chemical Factory in Bopal, India



**Fig. 3-18** Accident due to leakage of chemical substances in Bopal, India

#### Overview of the accident

- Date: December 2, 1984
- Location: Union Carbide Agricultural Chemical Factory in Bopal City, India
- Type: Leakage of 40~45 tons of toxic gas, MeNCO
- Status of damage: More than 3,500 people died (more than 6,900 death according to some report) and injuries in more than half a million people

#### Causes of accidents

- 40~45 tons of MeNCO stored in the Union Carbide Agricultural Chemical Factory was leaked.

#### Preventive measures

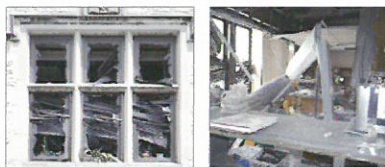
- Secure a diverse range of facilities and execute training for coping with emergency situations in preparations for the leakage of toxic gas.

## Preventive measures

- Notify the residents in the surrounding areas of the existence of toxic gas and provide information necessary in evacuation at the time of emergency.
- Development of new processes that can avoid use of toxic gas is needed.
- Measures for appropriate damage compensation need to be prepared.



## Gas explosion accidents at the Missouri University, USA



**Fig. 3-19**

Gas explosion accidents at the Missouri University, USA

## Overview of the accident

- Date: June 28, 2010 at about 14:20
- Location: Biochemistry laboratory of Columbia Campus of the Missouri University, USA
- Type: Gas explosion
- Status of damage: 1 severely injured person and light injuries to 3 persons

### Causes of accidents

- Explosion limit was reached due to excessive supply of hydrogen gas at the time of supplying of the mixed gas (95% hydrogen + 5% nitrogen) with the total volume of 2m<sup>3</sup> necessary for the growth of bacteria for reduction of sulfate into the anaerobic chamber, and explosion occurred due to the contact with the source of ignition within the culture chamber.

### Preventive measures

- Safely secure highly pressurized gas tank and put on the cap at the time of transportation and storage.
- Gas tank that exceeded the refilling time need to be refilled with gas since there is a risk of breakage of valves or check the refilling time if it is used for prolonged period of time.
- Gas leakage warning system must be installed in the laboratory that uses flammable and toxic gas in order to enable the workers to quickly take appropriate measures at the time of gas leakage.



## Explosion accident at a subsidiary research center of a company in Daejeon due to gas leakage



**Fig. 3-20**

Explosion accident in a subsidiary research center of a company in Daejeon due to gas leakage

### Overview of the accident

- Date: January 8, 2009 at about 14:40
- Location: Polymer laboratory
- Type: Gas explosion and fire
- Status of damage: 1 death and injuries to 1 person

## Causes of accidents

- While executing polymerization experiment, explosion accident occurred due to the leakage of large quantity of reactive chemical substances such as water, 1,3-butadiene and flammable liquid, which are solvents filled in the batch reactor (10L) in the initial stage of the reaction.
- After having collected the specimen by opening the discharging valve at the bottom of the reactor, the valves was not closed completely, thereby inducing leakage of reactive substances. The leaked polymerization substances and liquids at this time became the cause of the primary fire. The secondary explosion occurred due to the vapor lump formed due to the discharging or remaining in the discharging section of the vaporized liquid through the air supply equipment situated below the work hood and the exhaust equipment situated at the top.

## Preventive measures

- Make sure to confirm whether the valve is opened or closed at the time of opening and closing the valve.
- Promptly close the valve when leakage is confirmed.
- Check whether the exhaust system is working properly in order to harmoniously discharge vapor.
- Use personal protection devices and safety shield in preparations for explosion.
- Check the operation of safety valve when using highly pressurized reactor.
- Execute regularly scheduled training in preparation to cope with emergency situations.



## Explosion accident in a university laboratory due to gas leakage



**Fig. 3-21** Explosion accidents due to gas leakage in a university laboratory

### Overview of the accident

- Date: July 4, 2009 at about 16:00
- Location: University laboratory in Daejeon
- Type: Gas explosion
- Status of damage: Damages to the glass window, ceiling and experimental equipment and materials

### Causes of accidents

- Small quantity of hydrogen gas was leaked from the hydrogen storage device with small capacity(10ml) and became the direct cause of the explosion.
- The accident of erroneous operation and stoppage of the equipment occurred because the experimental equipment was operated for prolonged period of time without the presence of researcher and safety inspection on the abnormal operation of the experimental equipment had not been conducted.

### Preventive measures

- If experimental equipment is operated for prolonged period of time, researcher must be present to observe normal operation of the experiment and, in the event of erroneous operation, there is a need to take appropriate measures immediately.
- When handling flammable substances (hydrogen etc.), always inspect and confirm the presence of leakage and source of ignition regardless of the minute quantity being used.



## Reactor explosion accidents



**Fig. 3-22**

Glass reactor explosion accidents in a research center in Daejeon

### Overview of the accident

- Date: January 21, 2002 at about 17:45
- Location: Research laboratory in Daejeon
- Type: Reactor explosion
- Status of damage: Abrasion to leg in 1 person and damage to glass reactor (200L)

### Causes of accidents

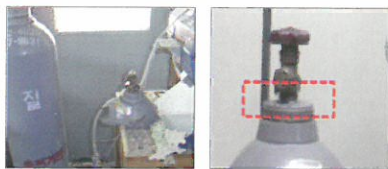
- It is presumed to have occurred in the process of hasty transportation of intermediate product of antibiotics as the post processing in the synthesis reaction while there is residual hydrogen gas.

### Preventive measures

- Avoid hastily manipulating the experiment without confirming that the risk factors are completely removed.
- There is a need to maintain the experimental environment with sufficient removal of the risk factors or development of new process such as the utilization of detector that can detect the hazardousness such as explosion.



## Explosion accident in a combustion engineering laboratory within a research center



**Fig. 3-23** Explosion accident in Combustion Engineering laboratory

### Overview of the accident

- Date: May 14, 2003 at about 14:54
- Location: Combustion engineering laboratory of K University in Daejeon
- Type: Explosion
- Status of damage: 1 death and 1 serious injury

### Causes of accidents

- Explosion accident occurred in the process of exerting pressure by using nitrogen gas rather than compressed air due to the amendment in the experiment plan (experiment for dissolving hydrogen peroxide by using lanthanum-cobalt oxide as the catalyst).
- Explosion of the gas tank due to the gas leakage due to the breakage of the valve neck in the process of using nitrogen gas in the transportation of approximately 10L of mixed gas (27% hydrogen + 73% air) and unconfirmed source of ignition.
- Broken valve because of lack of use for prolonged period of time was used without being inspected.

### Preventive measures

- Always maintain the laboratory in clean and tidy condition.
- Always check the presence of damages to the highly pressurized gas tank prior to use and refrain from using tanks that are too old.

## Preventive measures

- Make sure to check the refilling time and do not use the tank if the refilling time has lapsed or is near. (Sudden opening of the valve needs to be avoided as much as possible.)
- If there is change in the experiment plan, assess the risk factors and remove them through the assessment of hazardousness in advance.



## Explosion accident of gas for manufacturing of semiconductor within Shihwa Industrial Complex



**Fig. 3-24**

Explosion accident of gas for manufacturing of semiconductor within Shihwa Industrial Complex

## Overview of the accident

- Date: October 27, 2001 at about 08:30
- Location: Company D in the Shihwa Industrial Complex in Shiheung City, Gyeonggi-do
- Type: Gas explosion
- Status of damage: Building damage

## Causes of accidents

- Diborane gas (100% 1.3kg) was leaked and exploded as the valve of the smaller tank that did not align with the size of the roller in the rolling process was opened and broken.

### Causes of accidents

- Risk of occurrence of a major secondary accident existed as there was no standard for detoxification facility following the gas leakage and explosion accident (for the standards for the facilities and handling of deadly toxic gas for semiconductors (about 7 types including diborane, silane and phosphine), apply the standard for ordinary gas refilling facility in accordance with the Law of safety management of highly pressurized gas).

### Preventive measures

- Set new standard for facilities for highly toxic and flammable gas.
- Thoroughly supervise the use of equipment and containers that coincide with the specifications.
- Pay close attention to and exhaustively supervise the possibility of damages to the valves arising from collision between the containers during manipulation.



## Chlorine gas leakage accident

### Overview of the accident

- Date: December 1995
- Location: Laboratory in a university in the USA
- Type: Gas leakage
- Status of damage: Injury suffered by 1 person

### Causes of accidents

- Leakage occurred when the main gas valve was opened after having connected the gas pipe to the chlorine gas tank.
- Human casualties incurred due to the discharging of the chlorine gas towards the workers because of the breakage of the valve while closing the valve by those engaged in research activities by using spanner.

## Preventive measures

- Make sure not to close the valve with excessive force (possibility of damages to the valves)
- Maintain the airtightness of the joint by using Teflon tape.
- Safety glasses must be worn in the laboratory and do not perform experiment alone. In particular, gas tank should be manipulated in the presence of those engaged in research activities who are highly experienced.
- Transport the worker to the hospital immediately in the event of inhalation of toxic gas.



## Explosion accident in a laboratory of the Precision Chemical Support Center in Ulsan



**Fig. 3-25**

Explosion accident in a laboratory in the Precision Chemical Support Center in Ulsan

## Overview of the accident

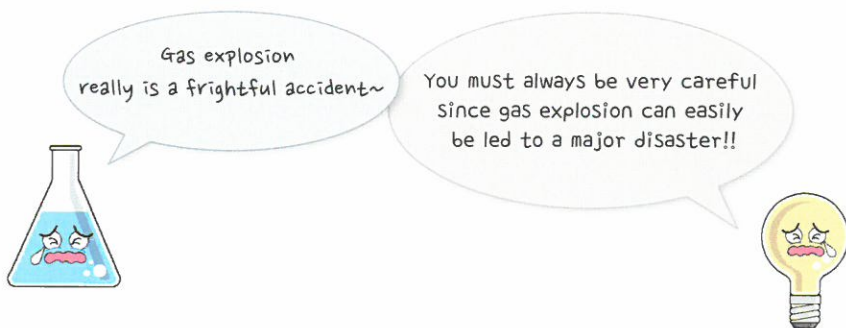
- Date: July 29, 2008 at about 17:00
- Location: Chemical ingredient analysis center on the 2<sup>nd</sup> floor of the Precision Chemical Support Center in Ulsan
- Type: Explosion due to leakage
- Status of damage: 1 death, 2 severely injured persons and property damages to the facility and analyzing equipment valued at 780 million Won

## Causes of accidents

- Hydrogen gas injected into the element analyzer exploded due to the electrical spark generated during the electrical works for installation of experimental table.

## Preventive measures

- Exhaustive management must be executed to prevent leakage of combustible and oxidizing gases such as hydrogen and oxygen, etc.
- Thoroughly conduct the inspection of leakage at the gas connection section (soap bubble test, etc.).
- Prior to and following the use of gas, inspections and installation of facility for prevention of conduction need to be executed.
- Minimize the quantity of gas kept in the laboratory.
- Allows the gas tank whose use has completed to be store in outdoors.





## Explosion accident in an explosion proof laboratory in Korea



Destroyed experimental equipment



Oxygen gas container

**Fig. 3-26** Explosion of LPG and oxygen gas within experimental equipment

### Overview of the accident

- Date: December 21, 2010 at about 14:35
- Location: Explosion proof laboratory at the H University in Asan, Chungnam
- Type: Explosion accidents
- Status of damage: 1 death, 1 severely injured person and 1 slightly injured person

### Causes of accidents

- It is presumed that gas explosion occurred inside the container due to the unknown source of ignition in the process of mixedly injecting oxygen (compressing) after having injected LPG into the container by inserting cylindrical pipe (50x80cm) into the explosion pressure absorption equipment that the laboratory developed independently

### Preventive measures

- Since it is not the extensive range of experiences and knowledge that prevent accidents, there is a need to execute exhaustive safety inspections prior to and following the experiment all the time.

## Preventive measures

- When handling flammable gas under the condition that allows accumulation of static electricity, precautions such as explosion proof electrical facility, earthing and prevention of electrification of the workers in order to prevent ignition and explosion due to discharging sparks.
- Use and store the gas tank in a location with good ventilation, and, in particular, install gas leakage warning device to enable the workers to make prompt measures against gas leakage when using combustible toxic gas.





## Ammonia leakage accidents



**Fig. 3-27** Ammonia leakage accident in Namyangju City, Gyeonggi-do

### Overview of the accident

- Date: February 13, 2014 at about 13:00
- Location: Factory No. 2 of the company B in Namyangju City, Gyeonggi-do
- Type: Ammonia leakage and explosion
- Status of damage: 1 death, 3 injured persons and facility damages

### Causes of accidents

- It is presumed that the pipeline exploded in the process of spraying water by the staffs to the ammonia storage tank when ammonia odor was sensed around the tank.

### Preventive measures

- Check the presence of gas leakage and make repairs if necessary by making regularly scheduled inspection of the corrosion of the pipelines.
- Familiarize the measures to be taken at the time of emergency by checking the MSDA of ammonia gas.



## Overtuning accident of highly pressurized gas transportation vehicle in the school



**Fig. 3-28**

Overtuning accident of highly pressurized gas transportation vehicle inside the S University

### Overview of the accident

- Date: August 27, 2010 at about 16:30
- Location: Entry road of the Natural Science College of the S University
- Type: Leakage of gas from the gas tank loaded due to overturning of the vehicle
- Status of damage: 2 slightly injured persons and destruction of highly pressurized gas tank

### Causes of accidents

- Vehicle that had gas tanks loaded mostly in the rear portion of the vehicle slipped backwards while moving backwards on a rain soaked inclined road and was overturned due to inexperienced driving skill.

### Preventive measures

- The supplier of highly pressurized gas must comply with the standards for operation of transportation vehicles for highly pressurized gas.
- Make sure to put cap on the container for highly pressurized gas being transported.
- Prohibit loading combustible and oxidizing gas tanks in the same transportation vehicle.
- Transportation vehicles for highly pressurized gas should use safer detours rather than inclined roads.



## Explosion accident in a photochemistry lab in France

### Overview of the accident

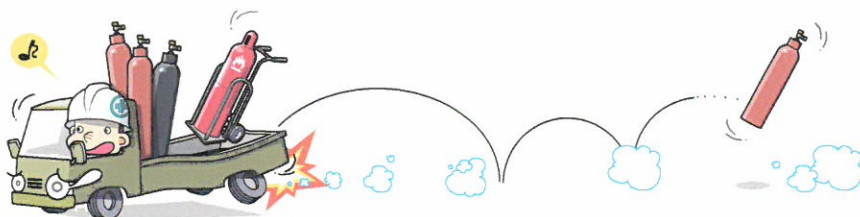
- Date: 2006
- Location: Optical Chemistry laboratory of the Ecole Nationale Supérieure de Chimie de Mulhouse in France
- Type: Explosion accidents
- Status of damage: 1 death

### Causes of accidents

- Ethylene, a flammable gas, left in the highly pressurized reactor exploded.

### Preventive measures

- In the event of conducting experiments that use highly pressurized reactor, combustible or toxic gas residues after the reaction must be removed by using inert gas and the container cover must also be removed (eliminate the source of ignition).
- Check normal operation and airtightness of the pressure safety valve of highly pressurized reactor prior to and following the use.
- Check presence of leakage due to foreign matters at the joint.





## MOCVD (Metalloorganic Chemical Vapor Deposition) reactor explosion accident



**Fig. 3-29** Inside the MOCVD reactor prior to and following gas explosion

### Overview of the accident

- Date: November 16, 2011 at about 17:00
- Location: OO Research Center of S University
- Type: Gas explosion
- Status of damage: Damages to the facility valued at more than 8 million Won

### Causes of accidents

- Air entered the internal aspect of the reactor due to the crack in the connecting section between the reactor and hydrogen tube or crack in the aged quartz reactor in the process of deposition procedure, and was mixed with hydrogen and ignited by SiC heated to the temperature of 350°C in the mixture state, thereby inducing explosion.

### Preventive measures

- In the event of using flammable gas, always inspect the possibility of the entry of oxidizing gas into the experimental equipment, normal operation of and presence of abnormality in the equipment prior to and following the experiment.
- Mixed gas of hydrogen with air or oxygen can explode even with weak source of ignition.

## Preventive measures

- In the laboratory that deals with combustible, toxic and suffocating gas, gas leakage detector must be installed to enable the workers to take appropriate measures quickly at the time of leakage.
- Draft instruction and educational text, and execute education in advance for those engaged in research activities of experiment that entails risk factors.





## Chamber rupture accident due to breakdown of the gas pressure gauge



**Fig. 3-30** Rupturing of the chamber due to excessive supply of gas

### Overview of the accident

- Date: August 2010
- Location: Laboratory at the OO Institute of S University
- Type: Rupturing of the experimental equipment due to the excessively supplied gas due to defective gas pressure gauge
- Status of damage: 1 slightly injured person

### Causes of accidents

- Researcher over supplied nitrogen due to the failure to check the normal pressure because of the faulty gas pressure gauge and the chamber cover (Quartz, 1cm) was ruptured in the process of supplying nitrogen to the chamber to conduct UV irradiation experiment.

### Preventive measures

- At the time of using highly pressurized gas, check the normal operation of gas facilities including the pressure gauge, thermometer and regulators, etc. in advance, and regularly make inspections for breakage and faults.
- Devices connected to the highly pressurized gas such as regulator, pressure gauge and hose, etc. must not be used with other gases concurrently, and must be used exclusively for the corresponding gas.



## Accident that caused loss of eyesight of the Nobel Laureate in Chemistry in 2001

### Overview of the accident

- Date: 1970
- Location: Chemical laboratory at MIT in the USA
- Type: Generation of glass fragment and loss of eyesight due to the explosion of liquid oxygen
- Status of damage: 1 severely injured person

### Causes of accidents

- A professor entered the laboratory without wearing safety glasses to observe the progress of the NMR tube sealing works that a graduate student was conducting.
- Sealing works were carried out without removing the air sufficient at the time and, accordingly, oxygen in the air was condensed by liquid nitrogen and vaporized with the increase in the temperature in the room, thereby causing shattering of the NMR tube.
- Shattered glass fragment pierced the eye and caused the accident in which the professor lost the eyesight.

### Preventive measures

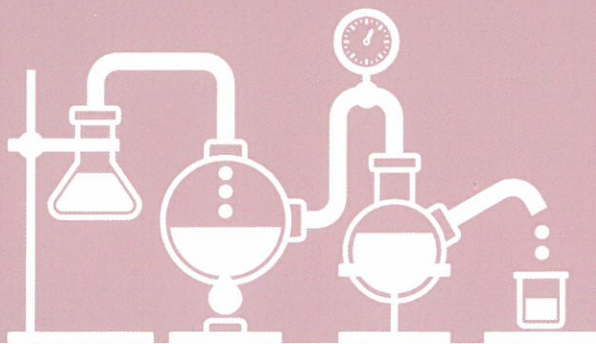
- Always wear safety glasses in the laboratory.
- When carrying of airtight sealing works on the glass device by subjecting it to vacuum, seal the device after having confirmed that the air has been removed sufficiently.
- Definitely realize that damages can be incurred by the mistakes of others.

## Methods of evacuation at the time of fire breaking out

- When you detect fire, shout "Fire!" loudly to alert others.
- Sound the emergency fire alarm.
- Never use elevator. Use the stairs instead.
- Once you get out of the site of fire, never get back in.
- If your clothes catch fire, cover your eyes and mouth with both of your hands and roll on the floor.
- When you have evacuated from the site of the fire, wait for the rescue squad in the direction from which wind is blowing.



Standard Textbook for Safety in Laboratory  
Safety for Chemistry & Gas





# Appendix

1. Content composition of GHS/MSDS
2. Actual Examples of GHS/MSDS





## Appendix 1 **Content Composition of GHS/MSDS**

Source: Clause 1 of the Article 10 of the Announcement No. 2013-37 by the Ministry of Employment and Labor

### ■ Information on the chemical products and companies

- A. Product name (same name or categorization code used in the warning sign):
- B. Recommended use and limitations in the use of the product:
- C. Supplier information (although the information of the company responsible for the supply and drafting of MSDS for the corresponding product need to be entered regardless of whether the companies is a manufacturer, importer or distributor, in the case of imported products, enter the information on the domestic supplier for contact in the event of occurrence of inquiries or emergency):
  - Company name
  - Address
  - Emergency phone number

### ■ Harmfulness and hazardousness

- A. Classification of harmfulness and hazardousness
- B. Items of warning signs including the expressions for preventive measures (refer to the separate data)

- Pictorial symbols
- Sign languages
- Harmfulness and hazardousness descriptions
- Description of the preventive measures

C. Other harmfulness and hazardousness that has not been included in the classification criteria for harmfulness and hazardousness (example: hazardousness of dust explosion):

#### ■ **Name and contents of the constituting ingredients**

Usual and nick name of the chemical substances, CAS No. or identification No. and contents (%)

The corresponding information may be omitted in the event of acknowledgement that there is justification for protection as confidential business information in drafting MSDS.

#### ■ **First aid measures**

- A. Enters the eyes:
- B. Comes in contact with the skin:
- C. Inhalation:
- D. Swallowed:
- E. Other precautions of physician:

#### ■ **Measures at the time of explosion and fire**

- A. Appropriate (and inappropriate) fire extinguishing agent:
- B. Particular harmfulness generated by the chemical substances (example: harmful substances generated at the time of combustion):
- C. Protective devise at the time of suppressing fire and preventive measures for fire:

■ **Means of coping with leakage accidents**

- A. Measures to be taken and protective devices to safeguard human body:
- B. Measures to be taken to protect the environment:
- C. Purification or disposal method:

■ **Handling and storage methods**

- A. Safe handling information:
- B. Safe storage method (including the conditions to be avoided):

■ **Exposure prevention and personal protective devices**

- A. Standard for exposure and biological exposure to chemical substances, etc.:
- B. Appropriate engineering management:
- C. Personal protection devices
  - Protection of respiratory system:
  - Protection of eyes:
  - Protection of hands:
  - Protection of the body:

■ **Physical and chemical characteristics**

- A. External appearance (physical state and color, etc.):
- B. Odor:
- C. Odor threshold:
- D. pH:
- E. Melting point/freezing point:
- F. Initial boiling point and the range of the boiling points:
- G. Ignition point:

- H. Evaporation rate
- I. Flammability (solid and gas)
- J. Upper and lower limit of the ignition or explosion range
- K. Vapor pressure:
- L. Solubility:
- P. Vapor density:
- O. Specific gravity:
- R. n-octanol/water distribution coefficient:
- S. Spontaneous combustion temperature:
- T. Decomposition temperature:
- U. Viscosity:
- V. Molecular weight

■ **Stability and reactivity**

- A. Chemical stability and possibility of harmful reaction:
- B. Conditions to be avoided (discharging of static electricity, impact and vibration, etc.):
- C. Substances to be avoided:
- D. Harmful substances generated at the time of decomposition:

■ **Toxicological information**

- A. Information on the exposure channel with high possibilities
- B. Information on health hazard
  - Acute toxicity (list all the possible channels of exposure):
  - Skin corrosiveness or irritation:
  - Severe damages to or irritation of eyes:

- Sensitivity to the respiratory system:
- Skin sensitivity:
- Carcinogenicity:
- Mutagenicity of reproductive cells:
- Reproduction toxicity:
- Particular target organ toxicity (single exposure):
- Particular target organ toxicity (repetitive exposure):
- Inhalation hazard:
  - ※ The channel of exposure and the health hazard information can be listed together by combining A and B above.

#### ■ Effects on the environment

- A. Ecological toxicity:
- B. Residue and decomposition properties:
- C. Biological condensability:
- D. Soil migration:
- E. Other harmful effects:

#### ■ Precautions in disposal

- A. Disposal method:
- B. Precautions to be taken at the time of disposal (including the methods of disposal of contaminated container and packaging):

#### ■ Information necessary for transportation

- A. UN No.:
- B. UN-appropriate shipment name:
- C. Hazardousness rating in transportation:
- D. Container rating (if applicable):

- E. Maritime pollution substances (indicate as applicable or not applicable):
- F. Special safety measures that the user need to know or necessary in relations to the transportation or transportation means:

- **Current status of legal regulations**

- A. Regulations in accordance with the Industrial Safety & Health Law;
- B. Regulations in accordance with the Law on the management of harmful chemical substances:
- C. Regulations in accordance with the Law on the management of hazardous substances safety:
- D. Regulations in accordance with the Law on management of disposed substances:
- E. Regulations in accordance with other domestic and foreign laws:



- **Other reference issues**

- A. Source of the data:
- B. Date of the initial drafting:
- C. No. of amendments and the date of the final amendment:
- D. Others:



## Appendix 2 Actual Example of GHS/MSDS

Source: KOSHA

 Ministry of Employment and Labor	<h3 style="margin: 0;">Material Safety Data Sheet</h3>	 <b>KOSHA</b> <small>Korea Occupational Safety and Health Agency</small>
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Material	CAS No.	KE No.	UN No.	EU No.
Benzene	71-43-2	KE-02150	1114	200-753-7

**1. Information on the chemical product and the company**

A. Product name Benzene

B. Recommended use and limitations on the application of the product

Recommended use	Manufacturing of industrial chemical substances including polymer, detergent, agricultural chemicals, dye and resin, and solvent for wax, resin, oil and natural rubber.
Limitations on the application	Gasoline additive

C. Supplier information (in the case of imported product, enter the information on the domestic supplier that can be contacted in emergency situations)

Company name	No data available
Address	No data available
Emergency Tel. No.	No data available

**2. Harmfulness – danger**

A. Harmfulness – danger classification

Flammable liquid: Category 2
Acute toxicity (orally administered): Category 4
Skin corrosiveness/irritation: Category 2

Severe eye injuries/irritation: Category 2  
 Carcinogenicity: Category 1A  
 Gamete mutagenicity: Category 1B  
 Specific target organ toxicity (single exposure): Category 1  
 Specific target organ toxicity (single exposure): Category 3  
 (anesthetic action)  
 Specific target organ toxicity (repetitive exposure): Category 1  
 Absorption harmfulness: Category 1  
 Chronic aquatic environmental harmfulness: Category 3

#### B. Warning signs including the words for the preventive measures

Pictorial symbols



Signal words

Danger

Harmfulness and danger words

H225 Highly flammable liquid and steam  
 H302 Harmful if swallowed  
 H304 Can be fatal if swallowed and introduced into the  
 respiratory tract  
 H315 Induces irritation of the skin  
 H319 Induces severe irritation of the eyes  
 H336 May induce drowsiness or dizziness  
 H340 May induce genetic defect  
 H350 May induce cancer  
 H370 Induces damages to ( ) in the body  
 H372 Induces damages to ( ) in the body if exposed for  
 prolonged period of time or repetitively  
 H412 Harmful aquatic organisms due to long-term effect

Words for preventive measures

Prevention

P201 Secure instruction manual prior to use  
 P202 Do not handle prior to having read and understood all  
 the words on the safety prevention measures  
 P210 Please keep distance from heat, spark, flame and high  
 temperature – refrain from smoking  
 P233 Tightly close the container  
 P240 Join or ground the container and accommodating facility  
 P241 Use electrical, ventilation, lighting, ( ) devices for  
 prevention of explosion  
 P242 Use only the tools that does not generate spark  
 P243 Take measures to prevent static electricity

Countermeasures

- P260 Do not inhale (dust, fume, gas, mist, steam and spray)
- P261 Avoid inhalation of (dust, fume, gas, mist, steam and spray)
- P264 Thoroughly clean the area being handled following handling
- P270 Do not eat, drink or inhale when using this product
- P271 Handle only in outdoors or in locations with good ventilation
- P273 Do not discharge into the environment
- P280 Wear (protective gloves, clothes, eye glasses and facial mask)
- P281 Wear appropriate personal protective gears
- P301+P310 If swollen, please undergo medical check-up by medical institution (doctor) immediately
- P301+P312 If swollen and experience discomfort, please undergo medical check-up by medical institution (doctor) immediately
- P302+P352 Wash thoroughly with large quantity of soap and water if it comes in contact with skin
- P303+P361+P353 If it comes in contact with skin (or hair), take off or remove all the contaminated clothes, and wash the skin with water/take shower.
- P304+P340 If inhaled, transfer to a location with fresh air and take rest in a posture that makes breathing easier.
- P305+P351+P338 If it comes into contract with eyes, carefully wash with water for several minutes. If possible, remove the contact lens. Continue to wash
- P307+P311 If exposed, please undergo medical check-up by medical institution (doctor)
- P308+P313 If exposed or have concerns for exposure, please seek medical measures and advices
- P312 If you experience discomfort, please undergo medical check-up by medical institution (doctor)
- P314 If you experience discomfort, please seek medical measures or advices
- P321 Take ( ) measures
- P330 Wash the mouth
- P331 Do not cause vomiting
- P332+P313 If there is skin irritation, please seek medical measures and advices.

	P337+P313 If the irritation of the eyes continues please seek medical measures and advices.
	P362 Take off the contaminated clothes and wash them prior to using again.
	P370+P378 Use ( ) to extinguish fire in the event of fire.
Storage	P403+P233 Tightly close the container and store in a location with good ventilation
	P403+P235 Store in a location with good ventilation and with maintenance of low temperature
	P405 Store in storage space with locking device
Discard	P501 Discard the container for the contents (in accordance with the details stipulated in the relevant laws)
C. Other harmfulness and dangers not included in the standard for classification of harmfulness and dangers (NFPA)	
Health	2
Fire	3
Reactivity	0

### 3. Name and contents of the constituent ingredients

Name of the substance	Benzene
Other name (generally used name)	Benzol
CAS No.	71-43-2
Content (%)	100%

### 4. Guidance on emergency measures

A. Comes in contact with the eyes	<p>If it comes into contact with the eyes, carefully wash with water for several minutes, If possible, remove the contact lens. Continue to wash.</p> <p>If irritation of the eyes continues, please seek medical measures and advices.</p>
B. Comes in contact with the skin	<p>Wash the skin with soap and water.</p> <p>Remove the contaminated clothes and shoes, and quarantine the contaminated area</p> <p>Please seek medical measures and advices if there is skin irritation</p> <p>If it comes in contact with the skin (or hair), take off or remove all the contaminated clothes. Wash the skin with water/take shower.</p> <p>In the event of burns, cool the corresponding area with cold water as long as possible and do not remove the clothes that are stuck to the skin.</p>

C. When inhaled

In the event of having been exposed to a large quantity of dust or fume, remove with clean air and take medical measures if there are symptoms including coughing or others.

Do not induce vomiting.

If breathing is difficult, supply oxygen.

Execute artificial respiration if not breathing.

D. When swollen

If it is swollen, undergo medical examination by medical institution (doctor) immediately.

Wash out the mouth.

Do not induce vomiting.

E. Other precautions of medical doctor

Allow the medical staff to be aware of the corresponding material in order to take protective measures.

Symptoms arising from contact and inhalation may be delayed.

In the event of exposure, contact the medical staffs and take special emergency measures including follow-up examination, etc.

## 5. How to cope in the event of explosion and fire

A. Appropriate (inappropriate) fire extinguishing chemicals

In the event of extinction of fire related to this material, use alcohol foam, CO<sub>2</sub> or water spray.

Use dry sand or soil in the event of extinguishment by smothering

B. Specific harmfulness generated by chemical substance

Container may explode if heated.

Can induce fire and explosion through violent polymerization reaction

Highly flammable liquid and steam

Highly flammable: Easily ignited due to heat, spark and flame

Leakage has the risk of fire/explosion

There is a risk of vapor explosion indoor, outdoor and sewage

Explosive mixture may be formed at ignition point or above

Vapor can form explosive mixture with the air

Vapor can induce dizziness or suffocation without being perceived

Vapor can be ignited by being transferred to the source of ignition

Irritating and highly toxic gas can be generated due to pyrolysis or combustion while burning.

Can irritate or cause burns to the skin and eyes when inhaled and come into contact

It may be toxic if inhaled or absorbed into the skin

C. Protective devices to be worn and preventive measures at the time of extinguishing fire

Rescuer must wear appropriate protective devices

Take precaution since it is lighter than water in most cases

Majority of the vapor is heavier than air, it will proliferate along the floor surface and may be accumulated in low grounds or closed space

Remove the container from the area of fire if it is not dangerous

Extinguish the fire by maintaining safe distance outside the area of fire

In the event of large scale fire with tank on fire, use unmanned fire extinguishing equipment. If this is not possible, back away and let it burn

In the event of the tank fire, cool the container with large quantity of water even after the fire had been extinguished

In the event of the tank fire, back away immediately if there is high pitch sound coming from pressure discharging device or if the tank discolors

In the event of the tank fire, extinguish fire from the maximum possible distance or by using unmanned fire extinction equipment

In the event of the tank fire, back away from the tank engulf in flame

## 6. Means of coping with leakage accident

A. Measures and protective devices necessary to protect the human body

Avoid inhalation of (dust, fume, gas, mist, vapor and spray)

Do not touch or walk on leaked substances

Those who have no need to enter or have no protective devices must not enter

Remove all the sources of ignition since very fine particles can induce fire or explosion.

Remove all the sources of ignition

Make sure to earth all equipment at the time of handling the substances.

Immediately wipe off what has been spilt and following the preventive measures stipulated in the protective device section.

Quarantine the contaminated regions

Stop leakage if it is not dangerous

Foam for inhibition of vapor can be used to reduce the generation of vapor

Take precautions against the substances and conditions to be avoided

B. Measures and protective devices  
necessary to protect the environment

Leakage can induce contamination

Prevent entry into the water channels, sewage, underground floors and closed spaces

Do not discharge into the environment

C. Purification or removal method

Make ditch by keeping sufficient distance from the liquids leaked if large quantity has been leaked

Absorb what has been spilt with inert materials (example, dry sand or soil) and place in container for chemical wastes

Construct embankment for fire extinction and collect water

Absorb the liquid and wash out the contaminated area with detergent and water

Collect the absorbed substances by using clean explosion proof equipment

## 7. Handling and storage method

### A. Safe handling method

Avoid inhalation of (dust, fume, gas, mist, vapor and spray)

Open the cap carefully prior to opening

Do not handle the substance prior to fully reading and understanding the descriptions of all the safety prevention measures

Make sure to earth all the equipment at the time of handling the substance.

Use only the devices that does not generate spark

Do not exert pressure, cut, weld, soldier, connect, puncture, grind or expose to heat, flame, spark

Residue of the product may remain even when the container is emptied. Therefore, comply with all the preventive measures of the MSDS/label

Do not swallow, drink or inhale when using this product

Prevent prolonged or continuous contact with skin

There is a concern for oxygen deficiency when working in low ground or closed surface.

Therefore, measure the oxygen concentration in the air and ventilate at during work

Take measures to prevent static electricity

Thoroughly clean the area of handling after the completion of handling

Use the product by paying close attention to handling/storage

Use electrical, ventilation and lighting ( ) equipment with preventive measures for explosion

Take precaution against materials and conditions to be avoided

**B. Safe storage method**

Completely drain the empty drums and close the opening appropriately and return to the drum regulator or arrange them appropriately immediately

Keep distance from heat, spark, flame and high temperature – no smoking

Tightly seal and store the container in a location with good ventilation

Keep distance from food and drinking water

Take precaution against substances and conditions to be avoided

Store in location with good ventilation and maintain low temperature

**8. Prevention of exposure and personal protective devices****A. Standard for exposure to chemical substances and biological exposure standards, etc.**

Domestic regulations TWA – 1 ppm 3mg/m<sup>3</sup> STEL – 5ppm 16mg/m<sup>3</sup> (allowable standard)

ACGIH regulations TWA 0.5ppm  
STEL 2.5ppm

Biological exposure standard S-phenylmercapturic acid in urine: 2.5ug/g creatinine,  
t,t-Muconic acid in urine: 500ug/g creatinine

**B. Appropriate engineering management**

Either use separation of the processes and localized exhausting or execute other engineering management that control the air level at below the exposure standard.

Facility that stores or uses this substance must be equipped with facial wash facility and safety shower

**C. Personal protection device Protection of respiratory system**

Wear respiratory protection device certified by the KOSHA that is appropriate for the physiochemical characteristics of the gas/liquid exposed to

If the exposure concentration is lower than 10ppm, wear semi-full facial type respiratory protection device equipped with appropriate filter or purification canister

If the exposure concentration is lower than 25ppm, wear loose-fitting hood/helmet type motorized respiratory protection device equipped with appropriate filter or purification canister, or continuous flow type dust mask.

If the exposure concentration is lower than 50ppm, wear full-facial type or motorized semi-full facial type, or air supply type continuous flow type/pressure required semi-full facial type respiratory protection device equipped with appropriate filter or purification canister

If the exposure concentration is lower than 1000ppm, wear full-facial type or helmet/hood type, pressure required type air supplied mask equipped with appropriate filter or purification canister

	If the exposure concentration is lower than 10000ppm, wear self-air supply type (SCBA) or pressure required self-air supply type (SCBA) respiratory protection device equipped with appropriate filter or purification canister
Protection of eyes	No data available
Protection of hands	No data available
Protection of body	No data available

## 9. Physiochemical characteristics

A. Outer appearances	
State	Liquid
Color	Colorless – Yellow
B. Odor	Characteristic odor
C. Odor threshold	4.68ppm
D. pH	No data available
E. Melting/Freezing point	5.50°C
F. Initial boiling point and range of the boiling points	80.10°C
G. Ignition point	-110°C (c.c.)
H. Evaporation rate	No data available
I. Flammability (solid, gas)	No data available
J. Upper and lower limit of ignition or explosion limit	8.0/1.2%
K. Vapor pressure	94.8mmHg (250°C)
L. Solubility	0.18g/100ml (250°C)
M. Vapor density	2.8 (air = 1)
N. Specific gravity	0.88 (water = 1)
O. n-Octanol/Water distribution coefficient	2.13
P. Spontaneous combustion point	4980°C
Q. Degradation temperature	No data available
R. Viscosity	0.604 cP (250°C)
S. Molecular weight	78.11

## 10. Stability and reactivity

A. Chemical stability and possibility of hazardous reaction	Highly flammable liquid and vapor Can induce fire and explosion through fierce polymerization reaction
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	Can be toxic if inhaled or absorbed into the skin
	Irritates or burns the skin and eyes when inhaled or contacted
	Can form explosive compound at ignition point or above
	Container may explode if heated
	Highly flammable: easily ignited by heat, spark and flame
	There is risk of fire/explosion for the leakage
	There is risk of vapor explosion indoor, outdoor and sewage
	Vapor can form explosive mixture with air
	Vapor can flashback by moving to the source of ignition
	Vapor can induce dizziness or suffocation without being perceived
B. Conditions to be avoided	Keep distance from heat, spark, flame and high temperature – no smoking
C. Substances to be avoided	No data available
D. Harmful substances generated at the time of degradation	Irritating and highly toxic gas can be generated due to pyrolysis or combustion when it burns
<b>11. Information on toxicity</b>	
A. Information on highly probable exposure route	No data available
B. Health hazard information	
Acute toxicity	
Oral	LD50 930mg/kg Rat
Percutaneous	LD50 > 8200mg/kg Rabbit
Inhalation	Vapor LC50 44.66mg/L 4hr. Rat
Skin corrosive or irritating	Induces irritation as the result of skin irritation test on rabbits
Severe eye damage or irritating	Induces intermediate level of irritation as the result of eye irritation test on rabbit
Hypersensitivity to respiratory system	No data available
Hypersensitivity to skin Carcinogenicity	No data available
Carcinogenicity	
Industrial Safety & Health Law	Carcinogenic (special management substance)
Notice by Ministry of Employment and Labor	1A
IARC	Group 1
OSHA	No data available
ACGIH	A1

NTP	K
EU CLP	Carc. 1A
Mutagenicity on reproductive cells	<ul style="list-style-type: none"> <li>· Special management substances under the Industrial Safety &amp; Health Law (mutagenicity on reproductive cells)</li> <li>· Notice by the Ministry of Employment and Labor 1B</li> </ul>
Reproductive toxicity	It displays fetal toxicity with the dose that displays animal toxicity in the mother in NTP (1986) and ATSDR (2005), and is categorized as Class 2
Specific target organ toxicity (single exposure)	It can be thought that it has anesthetic action on the respiratory system as the target organ on the basis of the description in (NICNAS (2001)) of irritation of skin, nose, eyes and pharynx, induces bronchitis and laryngitis, serious large bleeding in lung in people, and observation in (EHC150(1993)) of respiratory disorder under anesthetic state in animal experiments. Based on these findings, it is categorized into Category 1 (respiratory system) and Category 3 (anesthetic action).
Specific target organ toxicity (repetitive exposure)	Cases of death due to failure to form bone marrow, hyperplasia or hypocytosis, blood toxicity, aplastic anemia are reported in people. Transverse myelitis, frequent headache, sense of fatigue, sleeping disorder and memory disorder, reduction in the white and red blood cell counts, and increase in the average volume of red blood cells are displayed. Abnormal configuration of the circulating red blood cell and neutrophils, reduction in the numbers of karyocyte of spleen, circulating red blood cell and lymphocyte, reduction in the white blood cells, reduction in the cellular schwannoma of bone marrow, reduction in multipotential hepatic cells, and reduction in the numbers of red blood cells, white blood cells and leukocyte and volume ratio of red blood cell, and increase in the average volume of red blood cells are observed in experimental animals.
Hazard of inhalation	There is risk of inducing chemical pneumonia if the liquid is swallowed
<b>12. Effects on the environment</b>	
<b>A. Ecological features</b>	
Fishes	LC50 5.3mg/L 96hr.
Crustacean	EC50 10mg/L 48hr. (Water flea toxicity: EC50=20, 6ppm, 48hr. (National Institute of Environmental Research))
Birds	EC50 41mg/L 8hr.
<b>B. Residues and degradability</b>	
Residue	log Kow 2.13
Degradability	No data available
<b>C. Bio-concentration</b>	

Concentration	No data available
Bio-degradation	50(%) 28 days
D. Mobility of soil	No data available
E. Other adverse effects	No data available

**13. Precautions in disposal**

A. Methods of disposal	1) Incinerate 2) Process through evaporation and enrichment, then incinerate the residues 3) After having purified through separation, evaporation, extraction and filtration, incinerate the residue 4) After having processed by using reactions of neutralization, oxidation, reduction, polymerization and condensation, either incinerate the residue generated or process again through methods including condensation, sedimentation, filtration and dehydration and incinerate the residue
B. Precautions in disposal	Dispose the container (in accordance with the details specified in relevant laws)

**14. Information required for transport**

A. UN No.	1114
B. Appropriate shipping name	Benzene
C. Hazard rating in transportation	3
D. Container rating	2
E. Maritime contaminants	No data available
F. Special safety measures that the user need to know or need in relations to the transportation or transportation means	
Emergency measures at the time of fire	F-E
Emergency measures at the time of leakage	S-D

**15. Current status of legal regulations**

A. Regulations in accordance with the Industrial Safety & Health Law	Materials to be subjected to work environment measure (interval of measurements: 6 months) Materials to be subjected to special health check-ups (interval of check-up: 6 months) Materials for special management\
	Materials for setting of exposure standards
	Materials for setting of allowable standards

B. Regulations in accordance with the hazardous chemical substance management law	Materials to be prepared for accidents Toxic substances
C. Regulations in accordance with the safe management law for hazardous substances	Class 4, type 1 petroleum (non-water soluble liquid) 200L
D. Regulations in accordance with the law on management of waste matters	Designated waste mater
E. Other regulations in accordance with domestic and overseas laws	
Domestic regulations	
Law on management of residual organic contaminants	Not applicable
Overseas regulations	
US Administration Information (OSHA Regulation)	Not applicable
US Administration Information (CERCLA Regulation)	4.53599kg 10lb
US Administration Information (EPCRA 302 Regulation)	Not applicable
US Administration Information (EPCRA 304 Regulation)	Not applicable
US Administration Information (EPCRA 303 Regulation)	Applicable
US Administration Information (Rotterdam Convention Substance)	Not applicable
US Administration Information (Stockholm Convention Substance)	Not applicable
US Administration Information (Montreal Convention Substance)	Not applicable
EU Classification Information (Confirmed Classification Results)	F: R11Carc. Cat. 1: R45Muta, Cat. 2: R46T: R48/23/24/25Xn: R65Xi: R36/38
EU Classification Information (Hazard Description)	R45, R46, R11, R36/38, R48/23/24/25, R65
EU Classification Information (Safety Description)	S53, S45

## 16. Other references

- A. Source of Data ICSC (Upper and lower limits of the ignition or explosion limit)
- (1) ICSC (2004) (2) Merck (13th, 2001) (3) SRC (2005) (4) Dean (15th Ed.) (5) NLM (6) NICNAS (2001) (7) EHC 150 (1993) (8) Ministry of Labor (2002) (9) NTP (2005) (10) IARC (2005) (11) ACGIH (2006) (12) EPA (2000) (13) EU REACH Law (2006) (14) NTP TR289 (1986) (15) NTP (1986) (16) ATSRD (2005) (17) IRIS (2002) (18) NICNAS (2001) (19) EU-RAR (2003) (20) PHYSPROP Database (2005) (21) Existing chemical substance safety inspection data

B. Date of initial draft February 19, 2008

C. No. of revisions and the date of the final revision

No. of Revisions 16 times

Date of the final revision September 11, 2014

D. Others

2. Harmfulness and hazardousness (additional information): Classification of toxic substances in accordance with the announcement No. 2011-15 by the National Institute of Environmental Research is as follows:

- Flammable liquid: Category 2
- Acute toxicity (oral): Category 4
- Skin corrosive/skin irritation: Category 2
- Sever damage to eyes/eye irritation: Category 2
- Mutagenicity on reproductive cells: Category 1
- Carcinogenicity: Category 1
- Specific target organ toxicity (repetitive exposure): Category 1
- Inhalation hazard: Category 1
- Chronic hazard on aquatic environment: Category 3
- Substances to be subjected to special management in accordance with the Annexed Table 12 of the Regulations on the Industrial Safety & Health Standard
- Results of classification of mutagenicity on reproductive cells and reproductive toxicity provided by the "Standard for exposure to chemical substances and physical factors" of the announcement number 2012-31 by the Ministry of Employment and Labor: Mutagenicity on reproductive cells category 1B

- ◎ This Material Safety Data Sheet (MSDS) is the material provided by the KOSHA for the protection of the health of the workers and 'drafting and furnishing of MSDS by business operator' in accordance with the Article 41 of the Industrial Safety & Health Law, and should be used as reference in drafting MSDS in accordance with the actual situation and status of each of the work sites.
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  - Tel: (042) 869-0300 (trunk line)

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## ○ On-line Sources

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Korea Advanced Institute of Science & Technology: [www.kaist.ac.kr/html/etc/safety/safety\\_01020401.html](http://www.kaist.ac.kr/html/etc/safety/safety_01020401.html) (laboratory safety)

Labor Environment & Health Research Institute, Work and Environment: [safedu.org/pds1/10686](http://safedu.org/pds1/10686) (list of carcinogenic substances)

Cornell University): [sp.ehs.cornell.edu/lab-research-safety/chemical-safety/](http://sp.ehs.cornell.edu/lab-research-safety/chemical-safety/) (laboratory chemical safety)

Princeton University: [web.princeton.edu/sites/ehs/labsafetymanual/TOC.htm](http://web.princeton.edu/sites/ehs/labsafetymanual/TOC.htm) (laboratory safety manual)

The University of Vermont: [www.uvm.edu/safety/lab/\(laboratory safety\)](http://www.uvm.edu/safety/lab/(laboratory%20safety))

Rockford System: [www.rockfordsystems.com/online/safeguarding/freestandshlds.cfm](http://www.rockfordsystems.com/online/safeguarding/freestandshlds.cfm) (protective membrane)

Sercrim Labtech: [sercrim.com](http://sercrim.com) (safety products)

Direct Industry: [trends.directindustry.com/](http://trends.directindustry.com/) (safety facilities)

※ In addition, news articles in Kyunghyang Shinmun, Seoul News, Dong-A Ilbo and Yonhap News were referred to





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