Standard Textbook for Safety in Laboratory

Safety Before and After the Experiment I

KIRD | Korea Institute of Human Resources Development in Science and Technology

Standard Textbook
for Safety in Laboratory

Safety Before and After the Experiment Ⅰ

실험 전·후 안전 Ⅰ

Safety Before and After the Experiment Ⅱ

실험 전·후 안전 Ⅱ

Safety for Electricity & Electronics

전기·전자 안전

Safety for Chemistry & Gas

화학·가스 안전

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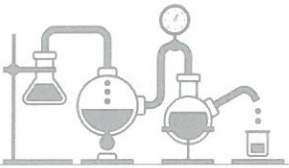

CHAPTER 3 Classification and storage of chemical substances

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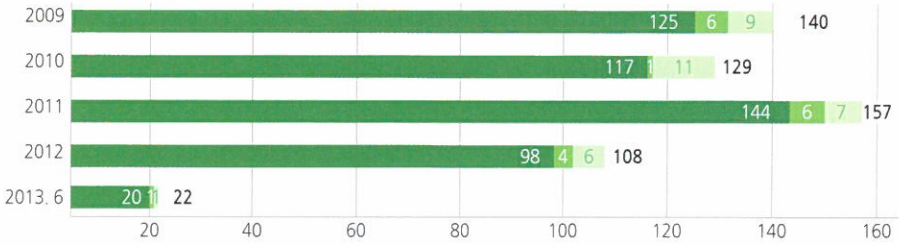
References

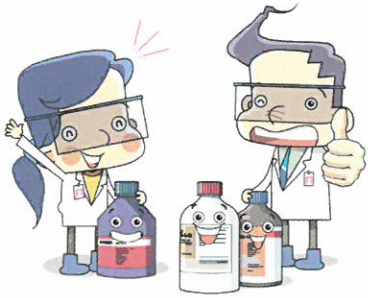
Introduction

With the recent disclosure that chemical substances are the key cause of a diverse range of accidents at industrial sites and laboratories, the "Chemical Substance Management Act" and the "Chemical Substance Registration and Assessment Act" were enacted and came into effect on January 1, 2015 as part of the fundamental countermeasures. In addition, the government is pursuing the establishment of the safety control tower and cooperation system at a national level in order to lay down the fundamental safety measures for disasters and accidents. At the same time, the government is focusing on setting a diverse range of policies that can supplement them at each of the government departments.

As the result of these efforts, "Law on Establishment of Safe Environment for Laboratories (hereinafter referred to as the Research Safety Law)" was enacted in March 2005 and effectuated in April 2006 after after a year of grace period/after one year of grace period. The Research Safety Law, as indicated in its Article 1, is aimed at "securing the safety of laboratories in the areas of science and technology" and "appropriate compensation of the casualties and material losses arising from accidents in the laboratories" at the same time. Moreover, the government has been implementing an extensive range of projects over the last eight years with the research environment safety team playing the central role in order to accomplish such goals. The key contents of the Research Safety Law include enactment of safety management regulations, operation of safety management committee, appropriation of budget for safety management, execution of safety inspection (annually) and precision safety

2009 ~ 2013
Current status of occurrence of laboratory accidents

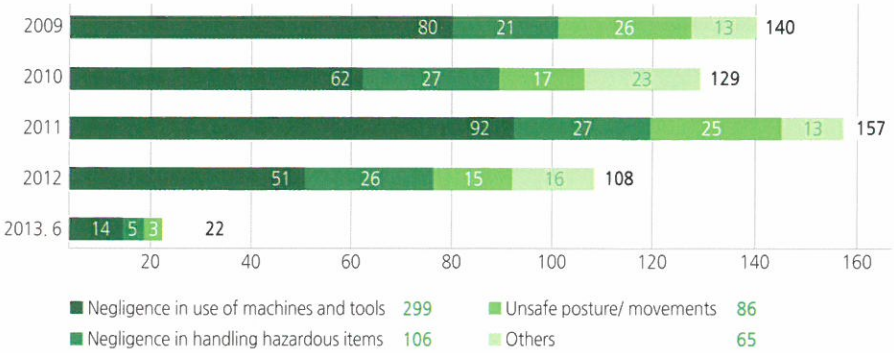




diagnosis (once in two years), subscription to insurance policy (minimum of 100 million Won for death and maximum of 10 million Won for injuries), execution of health check-up, and execution of education and training (regularly scheduled: 1 hour per month, every year; new: 8 hours, research modification: 2 hours), and etc.

However, according to the parliamentary inspection of the Ministry of Science, ICT and Future Planning in 2013, a total of 556 laboratory accidents occurred from 2009 to the first half of 2013, with 94% of the accidents occurring in university research institutes. In addition, without any decrease in the accidents at university laboratories, a total of 177 laboratory accidents occurred in 2014. The major causes of these accidents included negligence of the researchers such as negligence in using machines and devices, handling

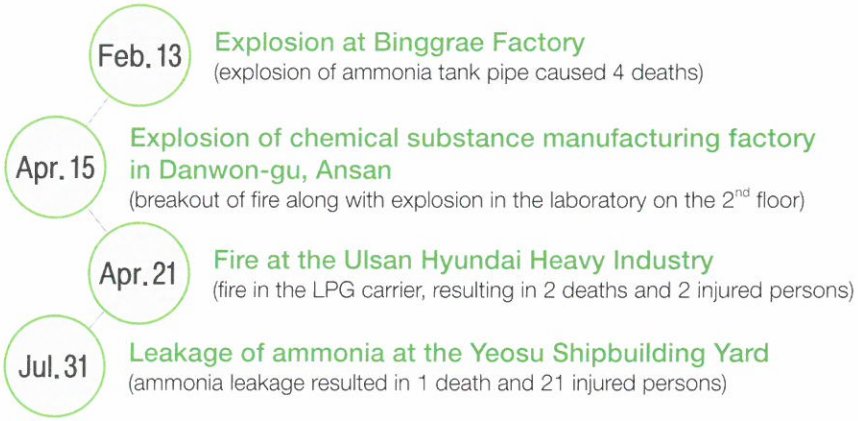
2009 ~ 2013
Causes of laboratory accidents



hazardous items and unsafe posture. In particular, 88% of the safety accidents in the laboratories due to carelessness. Moreover, although it is regulated that personnel involved in research activities must complete 12 hours of regularly scheduled education stipulated by law only 49.3% completed such education in universities and 43.9% in research institutions. This clearly indicated that the awareness of the need for education and training for safety in the laboratory is yet to be settled in the field of science and technology.

Along with the need for firm settlement of education and training, the issue on diversity of the educational contents in accordance with the academic level and areas of major engaged in research activities has been brought up continuously. Therefore, there is a need to confirm the necessity of standardized safety text book at this time considering the efforts that had been put in to establish safe environment thus far.

2014
Example of laboratory accident



This lesson plan aims to build up the foundation of safe research environment by describing the methods of selecting and using appropriate protective devices to secure the safety of individuals those engaged in research activities, and the MSDS utilization methods and chemical substance storage methods as well as safe and appropriate methods of handling waste matters generated from experiments that need to be familiarized prior to the experiment. In addition, the lesson will enable the relevant personnel to familiarize with themselves and prevent a diverse range of safety accidents that can occur prior to experiments and quickly and accurately respond to actual emergencies by. Through these, it is hoped that awareness of the safety issues will be propagated and the improved laboratory safety is guaranteed by advancing the level of the existing laboratory safety lesson plan a step further. Not only that, it is desired that standardized safety text book will ensure appropriate measures under hazardous circumstances.

Basic Safety Rules in Laboratories

○ Protection of those engaged in research activities

- All students must wear shoes that cover the toes during practicum. Shoes made of leather straps, shoes that reveal the toes and sandals are not appropriate as protective shoes.
- Long hair must be tied at the back of the head to prevent injuries.
- Clean lab coat must be worn at all times throughout the experiment and be taken off when leaving the laboratory. (Take precaution since the contaminated lab coat can be a potential cause of infection.)
- It is required to wear eye protection equipment in all laboratories and designated locations, protective eye glasses must be worn at all times during the experiment.

○ Prevention of safety accidents in laboratory

- All students must comply with the terms and conditions required for the safe handling of the substances and microbiological specimen being handled. All microbiological specimens must be deemed to be contagious.
- The source of generation of radiation (laser, UV ray radiation substance or arc lamp, etc.) must be used under the instruction and supervision of teaching assistant or supervisor.

○ General rules at the time of experiment and practicum

- Students are not allowed to enter any pre-treatment laboratory without permission of professor or teaching assistant in charge of the laboratory.
- Experiments not approved for the laboratory is strictly prohibited. Undergraduate students wishing to use the laboratory outside the scheduled hours must acquire written approval by their respective professor or teaching assistant.
- Sitting on the laboratory benches is prohibited and you must not run in corridors of the laboratory.
- You must not drink food & beverages (including bottled beverages) in the laboratory.
- For the correct and safe use of the burner, follow the instruction of teaching assistant.
- Pipetting by using mouth is prohibited.

Basic Safety Rules in Laboratories

○ General rules after the experiment and practicum

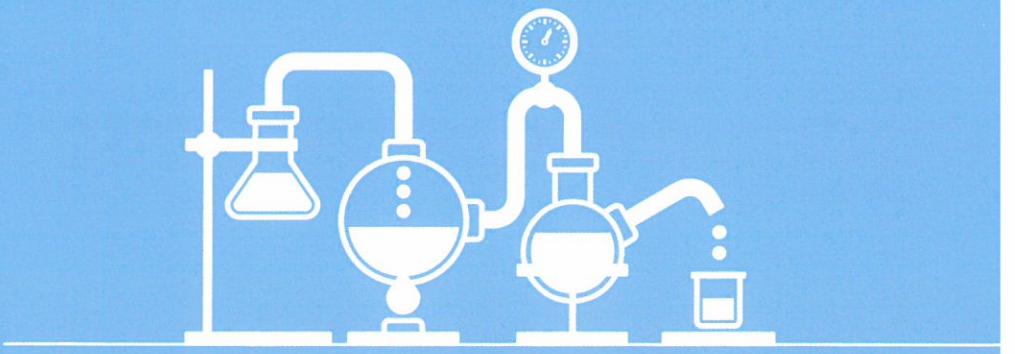
- Notify the teaching assistant about broken equipment or glass devices.
- Keep the areas for experiment and practicum clean. Discard broken glasses, sharp objects and laboratory wastes into the designated waste bin in the laboratory. Do not leave wastes in the sink or unattended. In addition, do not discard wastes into the sink without permission of teaching assistant.
- All leaked substances must be wiped off immediately. Reagents, liquids or experimental devices must not be taken out of the laboratory without the approval of teaching assistant.
- Gloves that came in contact with bio specimen must be thrown out into the specially marked waste bin for bio wastes.
- Make sure to wash your hands all the time before leaving the laboratory.

○ Measures to be taken in emergency situations

- You must become familiarized with procedures to be followed case of emergencies and escape procedures.
- Familiarize with location of all the emergency exits of all the work zones in the floors of the building with laboratory for experiment and practicum.
- You must familiarize with all the safety facilities of the laboratory (locations of safety shower, eye washing equipment, fire extinguisher, and etc.).
- Do not place any obstructions (containers and sacs) to ensure that they do not interfere with the pedestrian path or fire exit.
- Report and record all accidents and even minor mistakes in a form for reporting of injuries, diseases and incidents in the laboratory.
- When executing training for emergencies and emergency escape, move to external stairs or nearest emergency exit quickly and carefully. Move to the designated location (as instructed by teaching assistant) and wait until re-entry into the building is permitted.

Standard Textbook for Safety in Laboratory

Safety Before the Experiment



CHAPTER

1

Personal protective equipment and safety facilities in laboratory

1. Personal protective equipment
2. Safety facilities in laboratory

CHAPTER 1 Safety Before the Experiment

Personal protective equipment and safety facilities in laboratory

1. Personal protective equipment

Personal protective equipment is those worn by personnel engaged in research activities for the purpose of protecting themselves from particular hazardous substances. Although the personal protective equipment cannot reduce or eliminate hazards, it can ensure the personal safety of those engaged in research activities from safety accidents if worn properly. Personal protective equipment include safety glasses, protective gloves, protective clothing, protective respiratory devices, and etc. It is possible to choose personal protective equipment that are appropriate in accordance with the nature of the research as well as the quantity and characteristics of the substances used. The user must be aware of the functions, application methods and limitations of the personal protective equipment being used.

(1) Safety glasses and safety shield

Safety glasses and safety shield can be worn to protect the eyes and face from the hazards of injuries at the time of research activities. The safety glasses and the safety shield can prevent the following safety accidents.

- In the event of unintended spattering of hazardous and harmful substances
- Unexpected flight of objects, particles (fragments, splinters, and etc.) or tools being used at the time of manipulation or operation of equipment in the vicinity
- When using non-ionizing radiation (UV and IR, etc.)

Contact lens must not be worn at the time of research activities. Contact lens is incapable of offering any protection against the contact with chemical substances, and, at times, may even be more hazardous that the ordinary protective glasses under decompression environment and when chemical substances are spattered and come into contact. If it is unavoidable to wear contact lenses, make sure to wear protective goggles and discard immediately if they are contaminated by harmful chemical substances.

In addition, assessment of the hazardousness must be carried out in advance in order to select the safety glasses and safety shield that are appropriate for ensuring of the safe research environment for those engaged in research activities. However, if it is difficult to execute evaluation of hazard, safety administrator needs to be contacted for advice.

※ Assessment of hazard: It is a method of presenting the means of elimination of hazardousness by assessing the hazards in the 4 areas of equipment, substances and environment, personnel, and administration in accordance with the "4M Hazardousness Assessment Manual" (2010) of the Korea Occupational Safety & Health Agency (KOSHA).

① Safety glasses

Diversified range of safety glasses must fit well and be comfortable to everyone when wearing. However, if the gap between the eyes and the safety glasses is too wide or if the glasses slip, it is advisable to select the ones that fit the research environment and individual well by testing various types.

a. Clear Safety Glasses and Goggles

Although they appear to be similar to the ordinary protective eye glasses, they are equipped with strong lens and durable structure against impact. They are used when there is a need to protect the eyes from objects such as particles, glass, metal fragments, and etc. However, they do not provide protection for the entire face and has gap at both sides, up and bottom. Therefore, user must be aware that it is not appropriate in conditions with splattering of hazardous and harmful chemical substances, and can only be used for the minimum protection.

Fig. 1-1 Example of ordinary clear protective eye glasses (left) and clear protective eye goggle that can be worn on top of an ordinary protective eye glasses (right)

b. Clear Safety Goggles

In order to protect the eyes from dust and powder, wearing safety goggles is more appropriate than the safety glasses. However, even the safety shield (cloth) or goggles with wide safety surface and high adhesiveness due to rubber finishing cannot sufficiently protect those engaged in research activities when hazardous and harmful chemical substances are splattered. The following are the representative types of goggles.

- **Direct vented goggles**: Air within the laboratory flows through the goggle. Therefore, although it is suitable for protection of the eyes from small flying fragment, it is not capable of protecting the eyes from the splattering of chemical substances and harmful gases.
- **Indirect vented goggles**: Although the covered vents allow the atmospheric air to pass through, it has the structure that stops liquid from entering the goggle. Therefore, it can protect the eyes from the flying fragment and splattering of chemical substances.
- **Non-vented goggles**: Neither the liquid nor the gas can enter the internal aspect of the goggle. Therefore, it is capable of protecting the eyes from dust, spray, liquid and other harmful gases.

Fig. 1-2 Examples of direct vented goggles (left), indirect vented goggles (middle) and non-vented goggles (right)

② Safety shield

Safety shield or standing shield that protects the neck, ears and face must be used if there is any risk of safety accident due to explosion, implosion and splattering, or during works under vacuum condition. It is recommended that safety shield be always used along with the safety glasses and goggles rather than considering it as the only facial protection equipment. When using the safety shield, wear the safety glasses or safety goggles first and put the shield on the top. Safety shield is needed under the following situations.

- If safety accident due to splattering of large quantity of hazardous and harmful substances and other fragments occurs
- When removing heated liquid from the autoclave
- When handling liquid nitrogen
- When handling highly reactive or high concentration of corrosive chemical substances
- When using glass devices that utilizes vacuum and compression

Fig. 1-3 Examples of various types of safety shield

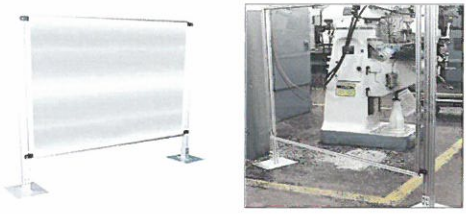


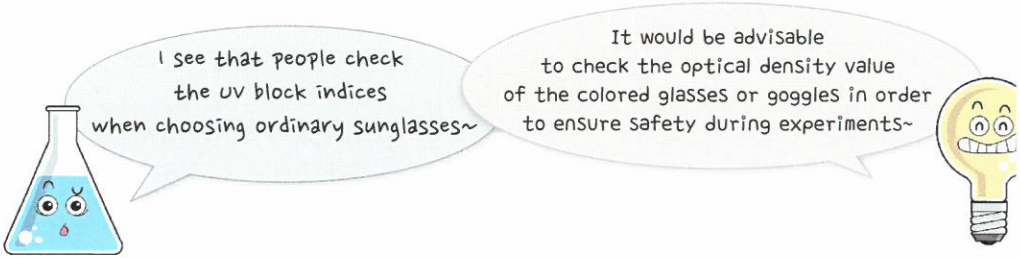
Fig. 1-4 Examples of protective shield and utilization of protective shield

③ Tinted glasses/goggles

Tinted glasses, goggles and safety shield can protect the eyes and the face from the radiation energy generated and leaked at the time of handling or welding equipment that uses laser. Protection equipment with colors appropriate for the types of radiation energy and wavelength of the laser must be used. Therefore, the level of optical density of the safety glasses and goggles to be used must be determined in order to ensure that protection equipment with appropriate color is used.

Optical density refers to the log value of the ratio (I_0/I_1) of the initial radiance (I_1) that passes through against the total radiance being irradiated after the light with particular wavelength passes through the medium (I_0). That is, the higher the optical density, the lower the transmittance of the light.

Fig. 1-5 Examples of various types of tinted glasses



(2) Respiratory protection equipment

Influx of hazardous and harmful substance into the body through the respiratory system is the most common route through which those engaged in research activities are injured. If excessive chemical substances have been spread in the air for prolonged period of time, it can induce long and short-term health injuries. Therefore, exposure to the contaminated air due to harmful dust, vapor, smoke, spray ,gas, and etc., must be prevented through use of appropriate respiratory protection equipment. Appropriateness test must be executed for all respiratory protection equipment including disposable respirator, air-purifying and air supply type respiratory protection equipment on annual basis and application methods must be familiarized prior to use. It should be kept at clean and dry location during storage, and do not share the same respiratory protection equipment with others as much as possible.

① Types of respiratory protection equipment

Table 1-1 Classification in accordance with the types and formats of respiratory protection equipment

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

Respiratory protection equipment can be divided largely into the air-purifying and the air supply type, and their application can differ depending on operation format and configuration of the facial part. The following are the types of respiratory protection equipment commonly used in the laboratory.

a. Filtering face-piece respirator (disposable type)

It is used to filter out harmful particle substances such as asbestos and biological aerosol, and etc. However, it is not capable of protecting those engaged in research activities from harmful non-particles substance such as gas or vapor. Filtering face-piece respirator is a disposable respirator with a highly diversified range of types. Respirator with aerobic valve is frequently used because it enables easier breathing.

Fig. 1-6 Examples of various types of filtering face-piece respirators

b. Air-purifying respirator (cartridge replacement type)

Air-purifying respirator can prevent influx of a highly diverse range of harmful substances into the respiratory system in accordance with the types of the cartridge. Therefore, it is important to select the appropriate cartridge for the corresponding harmful substance through hazard assessment at the time of use. For storage, detach the cartridge from the respirator. It is desirable to store the cartridge in a clean and dry location. It must be inspected for contamination of, breakage or crack in the aerobic valve. In addition, positive pressure and negative pressure must be checked by subjecting the respirator to appropriateness test while personally wearing it in order to determine the efficiency and ease of breathing of the respirator. Cartridge must be checked and maintained regularly and used within the expiration date.

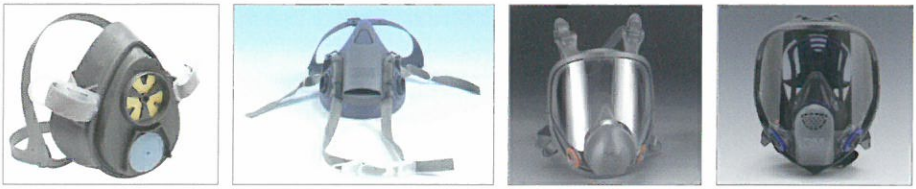


Fig. 1-7 Example of various types of air-purifying respirators

Fig. 1-8 Example of various types cartridges

c. Powered Air Purifying Respirator (PAPR)

Powered air-purifying respirator using battery as the source of the power is composed of face-piece or full-facial safety shield, respiration pipe, fan operated by battery and cartridge filter. Although the fan removes the contaminating substances by passing the contaminated air through the cartridge and sends clean air to the safety shield side, it does not supply oxygen directly. Therefore, it cannot maintain the same oxygen concentration as the initially supplied air. In addition, just like the non-powered air-purifying respirator, appropriate cartridge must be selected in accordance with the corresponding harmful substance. In order to prepare for unexpected accidents, the battery must always be stored at fully charged state.

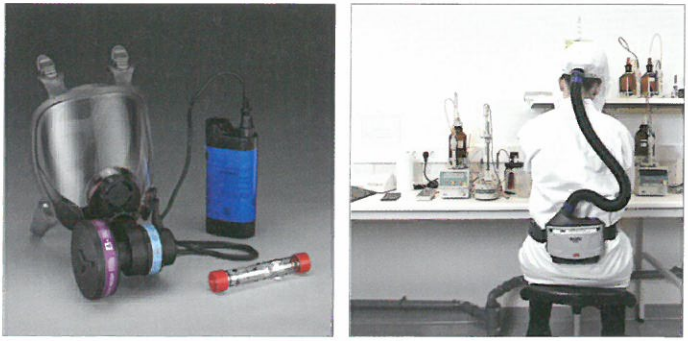


Fig. 1-9 Example of powered air-purifying respirator and image of wearing the respirator

d. Surgical Respirators & Dust Respirators

Surgical respirator and dust respirators cannot be considered as respiratory protection equipment since they do not provide any respiratory protection function. Therefore, it must be recognized that separate respiratory protection equipment is needed when using the corresponding respirator in the laboratory.

Fig. 1-10 Example of surgical respirator

(3) Safety gloves

Selection of appropriate safety gloves is very important to prevent safety accident in the laboratories. Safety gloves must be worn when handling hazardous and harmful chemical substances with unknown toxicity, corrosive substance, rough or sharp substances, hot and cold substancesand, and etc. Although disposable latex, vinyl and nitrile gloves are appropriate for the majority of research environments, other appropriate safety gloves must be selected in accordance with the characteristics of the chemical substances under the following circumstances.

- When immersing in or handling chemical substances for prolonged period of time
- When handling highly concentrated corrosive chemical substances
- When handling chemical substances with highly acute toxicity

Prior to using safety gloves, wear and tear as well as puncture holes must be checked. Blow air into the glove and block the wrist portion to check if there is any leakage of air. You must not use water for this purpose since it would make wearing the gloves inconvenient when wearing it after the inspection and finding puncture holes more difficult due to the surface tension of the water.

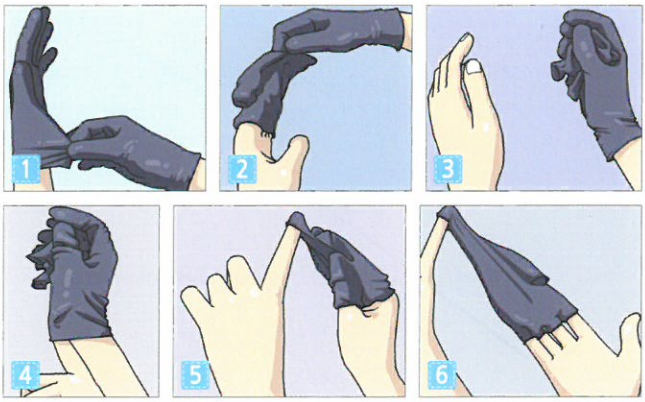


Fig. 1-11 Order of taking disposable glove off

After having touched harmful substance or research equipment, precautions must be taken to avoid inducement of secondary contamination by allowing the contaminating substance on the glove to come into contact with other locations of the body. In addition, take off the gloves by avoiding contact with the outside of the glove as much as possible after the use. For disposable gloves, take off by flipping the glove inside out by pulling the wrist section towards the fingers so that the inside of the glove faces the outside. Dispose of the glove after having taken it off. Reusable gloves must be cleaned and dried for storage.

① Selection of appropriate safety gloves

The following must be considered when selecting safety gloves.

- **Extend of degradation in protective function**: Gloves' reduced extent of protective functions due to expansion, contraction, hardening, and decomposition through contact with chemical substances.
- **Infiltration rate**: Time taken for the chemical substances that initially came in contact with the surface of the gloves to be detected inside the gloves.
- **Penetration time**: Time taken for the chemical substances to test infiltration into the internal aspect of the glove.

When handling mixture, safety gloves must be selected based upon the length of penetration time. This can be found by making reference to the Chemical compatibility chart or Chemical resistance chart as well as GHS/MSDS provided by the manufacturer.

Following issues are supplementary selections that can be made.

- **Sizes**: There are various sizes including S, M, L and XL Those engaged those engaged in research activities should choose the one that is the most comfortable when wearing.

- Length: The length of the gloves must be chosen in considerations for the situations in which the hands are immersed into or be splattered with chemical substances. Normally those with the length of approximately 35cm can protect the user from most of the situations.
- Thickness: Although thick gloves would be ideal in preventing the exposure of the skin, unnecessarily thick safety gloves may present difficulties and discomfort in manipulating the experiment.
- Presence of internal powder: Corn powder is used mostly for the internal aspect of the gloves. It must be remembered that it can induce skin allergic reaction although it makes putting on and taking off the gloves easier.

② Utilization in accordance with the material used for the safety gloves

- Butyl rubber: It is the most appropriate type when handling ether and ketone range of substances with high volatility. In addition, although it has highest resistance against majority of gas and water vapor infiltration, it is vulnerable to gasoline, aromatic aliphatic series and halogenated hydrocarbon series.
- Neoprene: It can be used when handling acidic corrosive substances and oils since it has outstanding tensile strength and thermal resistance. However, it is vulnerable to halogenated and aromatic hydrocarbon series. They come in disposable and reusable types.
- Latex, natural rubber: It can be used in handling a diverse range of chemical substances including acids, corrosive substance, bases, detergents and alcohols due to its outstanding resilience and resistance. However, it is vulnerable to organic solutions and puncture holes are difficult to find. In addition, the protein in the latex can induce allergic reaction. Precautions are needed since such reaction can be accompanied by symptoms including skin rash, inflammation, respiratory disorder, coughing and shock.

- Nitrile: It is the most commonly used disposable gloves in the laboratories and is made of synthetic rubber that does not contain latex protein. It has resistance against a wide range of chemical substances and is appropriate for those engaged in research activities with allergic reactions to latex. It can be used when handling solvents, oils, some acids and bases, and the rip and puncture holes are easy to find. Select appropriate nitrile gloves by referring to the information or GHS/MSDS provided by the manufacturers prior to ordering since there are ones with widely varying thicknesses. Nitrile gloves with thickness of less than 6mm are disposable ones, and those with greater thickness can be reused or for broader range of applications depending on the situations.
- PVC: It can be used when handling majority of peroxides, amines, lipids, acids and petroleum hydrocarbons due to its excellent durability and resistance. However, majority of PVC gloves are vulnerable to organic solvents.
- PVA: Gas cannot infiltrate. It provides outstanding protection against aromatic and chlorine solvents. However, it cannot be used when handling water and aqueous solutions since it absorbs water well.

How to use glove correctly for safe experiment

- If sufficient protection cannot be achieved with a single type of glove, it is possible to wear 2 different types of glove or 2 layers of the same type of glove. It makes manipulation of hands during experiment easier than using thicker gloves due to the concerns for the infiltration of harmful substances. Moreover, it is possible to secure greater safety when contaminating substance comes into contact with the glove by taking off the outer layer immediately.

In addition, it is possible to make the movements of hands easier by wearing tightly fitting glove on top of loosely fitting glove if needed.

(4) Protective clothing

Wearing ripped and poorly fitted clothing with severe exposure in the laboratory may subject those engaged in research activities to hazardous situations. Therefore, wear clothing that fits well without exposure during the research activities, and wear protective clothing that can protect the body physically and chemically on top of daily wear if there is a possibility of being contaminated by hazardous and harmful substances. When selecting protective clothing, appropriate choice must be made in accordance with the location and application. For example, although knee length long sleeve laboratory gown is appropriate for ordinary chemical experiment, there is a possibility of the long sleeve being caught when manipulating machines. Therefore, it would be advisable to wear short sleeve protective clothing. Following are the types of protective clothing commonly used in the laboratories.

① Disposable laboratory gown

Disposable laboratory gown can be used when handling hazardous substances in animal and plant experiments. Normally, the materials used for disposable laboratory gown have undergone sterilization treatment. There are a wide range of types including those that can prevent absorption of liquid including those made of thin plastic material. Although it can be disposed of along with ordinary waste if only a small quantity of contaminating chemical substance contacted the gown, those contaminated by hazardous, biological and radiation substance must be separated and disposed of in accordance with the properties of the contaminants.

② Fireproof laboratory gown

Fireproof laboratory gown is made of fabric that does not catch fire. Therefore, it can be used when handling spontaneously igniting substances or highly reactive substances. Nomex, which is a heat resistant synthetic fiber,

provides outstanding protection against fire and is highly rip-proof. In addition, it is used as the material for fireproof laboratory gown due to its outstanding resistances against most of the solvents, acids and bases. However, precautions must be taken since it is decomposed by bleaches containing chlorine. Although fireproof laboratory gowns made of fireproof processed fabric can be used for various applications, care must be taken during washing since their functions can deteriorate.

③ Ordinary laboratory gown

Ordinary laboratory gowns are used when conducting ordinary experiment that does not require particular precautions. Although cotton laboratory gown has certain degree of fireproofing, it can be worn out by acid and does not provide sufficient fireproofing as a fireproof laboratory gown. This must be kept in mind when wearing them. In addition, majority of laboratory gowns made of 100% polyester laboratory gown and cotton/polyester blended fiber has low level of fireproofing, making them inappropriate when handing flaming substances. Ordinary laboratory gown can generally be used for about a year and must be washed regularly for maintenance.

Fig. 1-12 Examples of ordinary laboratory gowns

④ Apron

Apron is not worn instead of the laboratory gown. It is worn on top of the laboratory gown when there is a particular need for supplementary protection against chemical substances. Make appropriate selection in accordance with the purpose of the research activities since the materials and types of the apron are extensive. Make purchase by confirming the resistance against chemical substances by making reference to the information provided by the manufacturers.

Fig. 1-13 Examples of aprons

(5) Safety shoes

In the laboratory and locations that use and store chemical substances, shoes that protect the toes must be worn at all times. Shoes with holes, sandals and sneakers made of fabric are not appropriate due to the possibility of being exposed to the hazardous and harmful substance as well as broken glasses. Therefore, it is possible to avoid safety accidents that can occur due to the spilling of large quantity of solvents and corrosive substance by wearing shoe covers or boots with resistance against chemical substances.

Fig. 1-14 Examples of shoe covers and safety boots

2. Safety facilities in laboratory

(1) Eye washer and safety shower facility

All laboratory that handle hazardous chemical substances that can induce corrosion, serious irritation, permanent damages to tissues and intoxication by toxic substance must be equipped with eye washer and safety shower facility. Eye washer and emergency shower should be installed in close vicinity reachable within 10 seconds of incurring injuries due to harmful substance in order to wash off the harmful substances immediately. Moreover, there must not be any obstacles that can trip feet in the path to the corresponding facility. In addition, those engaged in research activities must familiarize with the location and use of the emergency eye washer and shower each of the buildings and regions of their activities, and must undergo medical examination and treatment after having washed the eyes and taken emergency shower.

① Use of eye washer in emergency situation

Fig. 1-15
Example of emergency eye washer

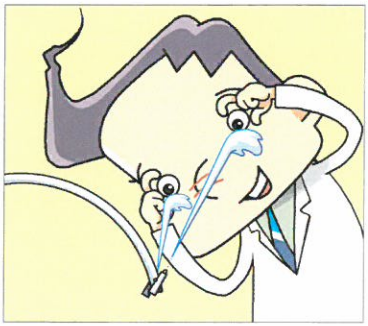


Fig. 1-16
Washing method by using emergency eye washer

- Familiarize how to use eye washer. There is a tendency of tightly closing eyelids when chemical substances come into contact with eyes. Accordingly, put efforts to wash the eyes with the eyes opened widely and, if it is difficult, ask colleague to help keeping the eyelids open while washing the eyes.
- Since it is difficult to reach and use the eye washer when chemical substances comes into contact with eyes, cope with the emergency situation by receiving assistance from colleague.

② Use of shower in emergency situation

- Emergency shower can be used for dousing fire on clothing.
- In the event of having come into contact with hazardous chemical substances and have to remove them, emergency shower must be the type that can be operated by pulling down the shower handle while standing below the shower head. Water spray must be continuous and must be stopped by pushing the handle upward.
- Harmful substances that splattered on the laboratory gown and other types of protective clothing can induce further injury by coming in contact with skin or being absorbed into the protective clothing. In order to prevent such safety accidents at initial stage, they can be removed by using emergency shower as soon as presence of harmful substance on the protective clothing is detected. However, if this does not immediately remove the harmful substances and spread while the clothing is wet, you must take off the shoes and protective clothing as quickly as possible with the assistance of colleagues.
- Fundamentally, washing under the shower for about 15 minutes is recommended. While taking shower after coming in contact with the harmful substance, colleague should contact the emergency center (119 Rescue Center, health clinic and etc.) using the number listed in close vicinity of the emergency shower.

Fig. 1-17 Example of emergency shower equipped with eye washer

(2) Fire extinguisher

All laboratories that handle flammable and combustible chemical substances must be equipped with fire extinguisher for suppression of fire. All the fire extinguisher must be situated on the wall of the location without any miscellaneous articles or in fire extinguisher cabinet. Those engaged in research activities must be familiar with the location and application as well as the types of the fire extinguisher furnished in the laboratory. In addition, if fire extinguisher was used for the dousing of the fire, the circumstances at the time must be reported to the administrator of the laboratory.

Fig. 1-18 Example of fire extinguisher

Fig. 1-19 Dry chemical extinguisher

All fire extinguishers are required to indicate the types of fire it can be used on in accordance with the Fire Services Act.

- A: For ordinary fire (fibers, timber, paper and etc.)
- B: For oil fire (oil and combustible liquid)
- C: For fire due to short circuit
- D: For fire due to metal

① How to use powder fire extinguisher

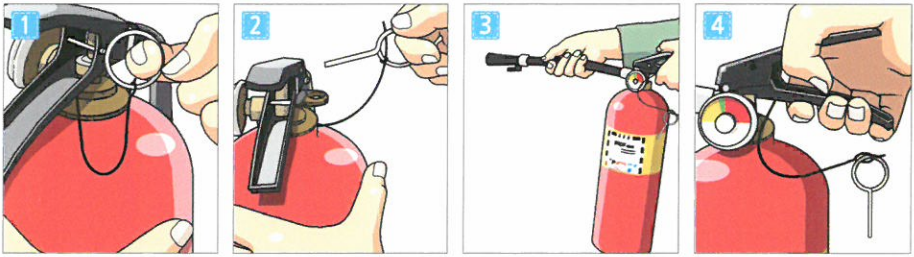


Fig. 1-20 Order of using powder fire extinguisher

1~2 Pull out the safety pin in the handle.
3 Stand with the wind on the back and direct the hose towards the fire.
4 Tightly squeeze the handle and spray the extinguisher towards the fire. Spray as though sweeping with a broom.

Using ordinary powder fire extinguisher is not difficult. If fire breaks out, pull out the safety pin first, direct the nozzle towards the fire and spray the extinguisher as though sweeping with a broom. It must be noted that (in the outdoors) stand with the wind on the back and widely spread all over the area of fire. Powder fire extinguisher utilizes the suffocation extinction format of cutting off oxygen supply. Therefore, it is effective only if spread widely over the area of fire. When pulling the safety pin from the fire extinguisher, do so while firmly holding onto the body of the fire extinguisher. It is difficult to pull out the pin while holding the handle out of confusion.

② How to use fire extinguisher thrown into the fire

When using the fire extinguisher thrown into the fire, take off the protective cover, take the extinguisher canister and throw into the fire. It is a fire extinguisher ideal for children, elderly and disabled persons. The fire extinguisher thrown into the fire is easier to use than the ordinary fire extinguisher since it douses fire by directly throwing the case containing liquid phase fire extinguishing agent into the fire. However, in the case of oily fire, it is advisable to through the extinguisher in the surrounding floor or wall to allow the extinguishing agent to cover the area of fire rather than directly onto the ignition point of the fire.

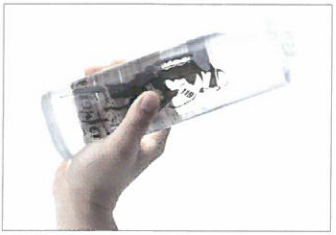


Fig. 1-21

Example of fire extinguisher thrown into the fire

③ How to use indoor fire extinguisher

Drag the long hose of the indoor fire extinguisher, point the nozzle to the ignition point and water is sprayed by opening the valve in the fire extinguisher cabinet. Accordingly, it is advisable for 2 persons to operate the indoor fire extinguisher.

- When fire breaks out, turn on the transmission switch to send an alarm for fire and open the fire extinguisher cabinet to take the hose out.
- Spread out the hose to ensure that there is no folded part of the hose. If the person holding the nozzle is ready to spray water, turn on the water supply by turning the valve on in the fire extinguisher cabinet.
- Hold onto the nozzle tightly since the water pressure is very high and spray water onto the fire.

(3) Fume hoods

Fume hood is a facility installed for the purpose of capturing both the harmful gas and vapor. Normally, the minimum face velocity upper 0.4m/sec (when the sash is opened maximally) is recommended. Experiment should be carried out inside the hood as much as possible and the sash must not be opened by more than 46 cm at the time of conducting the experiment. The structure of the fume hood is illustrated below.

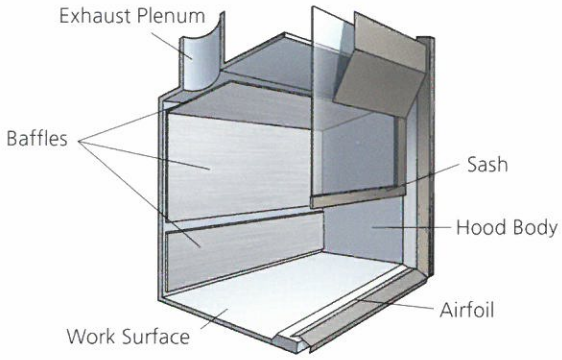


Fig. 1-22 Structure and example of ordinary fume hood

① Functions of the components of the fume hood

a. 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.

b. 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.

c. Work surface

Area below the hood on which the works are carried out

d. 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 used in order to conserve energy. It provides additional measures to protect the workers from the contamination by providing physical protective barrier.

e. 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 turbulence. The small space below the airfoil functions to discharge the air of the hood in the laboratory when the sash is completely closed.

② Precautions at the time of use and maintenance of fume hood

- 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 cleanly all the time.

- Avoid putting head into the hood.
- Those engaged in research activities must wear supplementary personal protective equipment when using the hood.
- Sash should be used minimally opening it to an 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.
- When not using the fume hood, close the sash completely.
- Do not situate sources of generation of sparks such as power outlet in the hood.
- Prohibit spray works in the fume hood since there are risks of fire and explosion.
- Do not use the fume hood as the storage and disposal location for the chemical substances

Basic rules of managing equipment in experimental laboratory

Refrigerator

When storing chemical substances in the refrigerator, check to ensure that the containers are tightly sealed and use the refrigerator by making distinction between the specimen and reagents.

Storage cabinet

When storing them in the laboratory, store them in a location with good ventilation by separating them into different types.

Glass devices

Use borosilicate glass (glass made with boric acid and silicic acid as the main ingredient used for heat resistant cooking utensil or chemical container), and use soft glass only for the reagent bottle, rod and tubing.

Fume hood

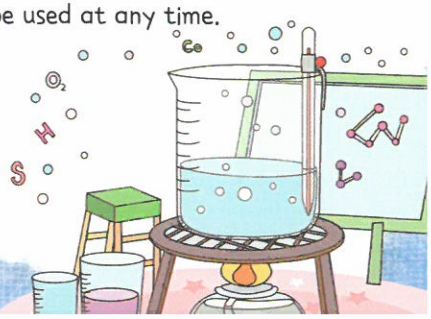
Make sure to work in the hood when using harmful flammable and/or toxic substances. Check the hood performances on a regular basis and keep record of the date and results of inspection.

Eye washing facility

Install at a location that can be reached within 10 seconds or at a distance of less than 15m from all locations in the laboratory along with the sign that is clearly visible.

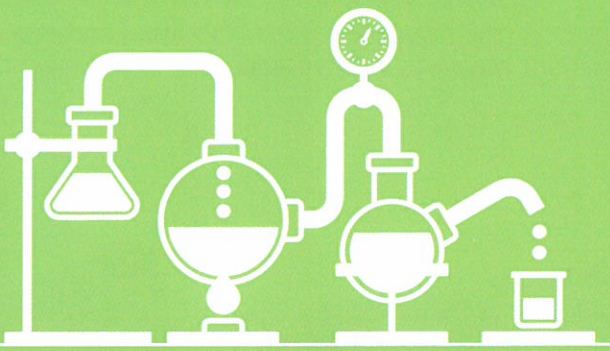
Shower facility

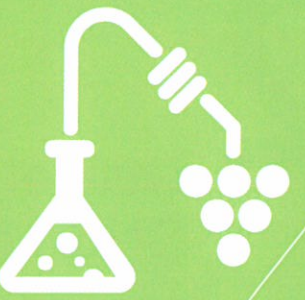
Adjust the height to be suitable for the height of all the people using the laboratory and remain the same height so that it can be used at any time.



Standard Textbook for Safety in Laboratory

Safety Before the Experiment





CHAPTER

2

Utilization of GHS/MSDS

1. Understanding GHS/MSDS
2. Classification of harmfulness and hazard in accordance with GHS
3. Searching GHS/MSDS information
4. Examples of accidents related to failure to familiarize with GHS/MSDS

CHAPTER 2 Safety Before the Experiment

Utilization of GHS/MSDS

1. Understanding GHS/MSDS

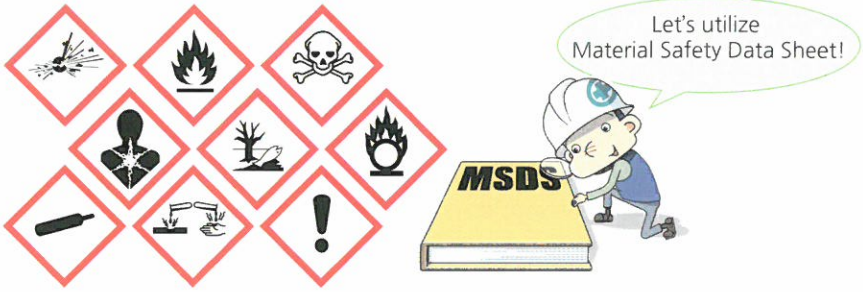
(1) MSDS and GHS/MSDS

① Material Safety Data Sheet

'MSDS(MSDS, Material Safety Data Sheet)' refers to the document drafted and provided by the manufacturer or supplier for each of the chemical substance in order to understand the characteristics, harmfulness and hazard of the substances, to seek safety in all the processes of handling, and to guarantee effective prevention of the accidents involving chemical substances.

This data is being used widely in handling chemical substances by the administrators and staffs of industries as well as in schools and research centers with chemical and biological laboratories. However, there had been difficulties in accurately providing information necessary to the workers in

work places, consumers, transporters as well as international traders or staffs involved in prevention of accidents, because some of the contents of the hazard or classification of the chemical substances and warning labels differ between countries or companies, and warning labels.



② GHS system drafted by the United Nation (UN)

In 1989, ILO passed the resolution for adoption of the unified classification and labeling system in order to provide information on the classification and labeling of the harmfulness and hazards of the chemical substances that can be commonly understood and used 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 5th guideline on the GHS system that the UN drafted edition (2013 with 536 pages) is currently being published and distributed in English language. The time of implementation and application of this system differs slightly between the countries.

③ GHS/MSDS system

The system on classification and labeling of the chemical substances drafted by the UN is referred to as GHS or GHS system. MSDS drafted in compliance with GHS is referred to as 'MSDS' in Korea, the term that had been used until now. It is called the UN Guideline and GHS/MSDS in the EU region with the foremost characteristic in terms of contents that they convey the classification, and harmfulness and hazardousness information of the chemical substances in a unified format. The existing MSDS was first drafted by 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 operated by the American Chemical Society. Regarding the harmfulness and hazardousness, the format of allocating the scores in the range of 0~4 for 3 items including hazardousness to human body, fire hazard and reactivity with other substances presented by the National Fire Protection Association of USA has been utilized.

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 pictogram and sign words, and utilize the designated statements for the measure necessary in prevention, coping, storage and disposal. Therefore, MSDS drafted by adopting the GHS system is equipped with the classification criteria, harmfulness and hazardousness information that are unified throughout the world regardless of the language it is translated into. Accordingly, GHS/MSDS is a very helpful guideline for those engaged in importing and exporting, general manufacturing and using the chemical substances by more easily and clearly understanding and managing the characteristics of the chemical substances.

Majority of the advanced countries including the US, EU and China that are ranked at the top of the market share in the chemical products have adopted and applied the GHS system for all the chemical substances including the single and mixed substances since May 1, 2011. However, each of these countries has established their own standard for the classification of hazardousness of harmful substance by making reference to the recommended standards of the UN. Differences between the countries stem from the differences in the selection of the toxicity test data used in the classification of hazard by each country.

In Korean, the National Institute of Environmental Research determines the detailed classification of the substances including hazardousness of the chemical substances by making reference to the latest test data obtained from the globally proven database, while Japan makes determination by applying the test data Japan has established with foremost priority. Although unification of classification is not being achieved in short period of time due to the differing interests of different countries, unification through step-wise approach by means of sharing of information between the surrounding countries and between the continents is forecasted, eventually.

English abbreviation of MSDS

- The formal name in accordance with the relevant announcements is 'MSDS'. However, in order to distinguish the difference in the explanations between the existing MSDS that had been used for a long time and spread widely in Korea and overseas until now and the data sheet newly adopted and implemented, the former is referred to as MSDS and the latter as GHS/MSDS. The UN and European countries are using the term GHS/MSDS for the latter.

Regarding description and labeling

- Description has strong connotation of illustration and explanation while labeling refers to the signs that briefly indicate the contents of description. Therefore, description is recognized as illustrated explanation while labeling is used as an independent noun. Since the title of the announcement by the Ministry of Employment & Labor and the Ministry of Environment uses the term 'description', it will be recognized as the short term for illustrated explanation while 'labeling' in GHS is interpreted as indicating the contents or form of the warming labels.

(2) Composition and overview of the drafting and contents of GHS/MSDS

① Composition of the contents 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.

- 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)

② Classification of harmfulness and hazardousness

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 existing 16 categories of harmfulness in accordance with the law on the management of hazardous chemical substances by the Ministry of Labor were reclassified into 28 categories in accordance with the GHS system of the UN. The Ministry of Employment and Labor has reclassified the health hazard from 10 categories to 11 categories in its law on industrial safety & health and public notification, and further dividing the environmental hazard into 28 hazardousness and harmfulness by changing some of the contents from 2 types into 1 type. Most of the items to be listed and method of listing in the warning sign is similar to the contents presented by the GHS system of the UN.

③ Information on harmfulness and hazardousness

Information on the harmfulness and hazardousness require inclusion of the product name, pictorial symbols, sign words, description of harmfulness, preventive measures and supplier, and emergency contact numbers. If labeling method for the information has not been set or if there is no information, it must be indicated that there is no data available. 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.

④ Protection of information on the substance

In the event of acknowledgement that there is a need to protect the information as confidential business information, listing of the ingredients and contents can be omitted. However, if there is a need to take precautions for safety and health in handling, effect on the body and environment, physiochemical characteristics, and means of coping or emergency measures at the time of explosion and fire must be indicated in the MSDS along with the classification information on the harmfulness and hazard.

⑤ Time of implementation of GHS/MSDS

Drafting of GHS/MSDS on a single 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

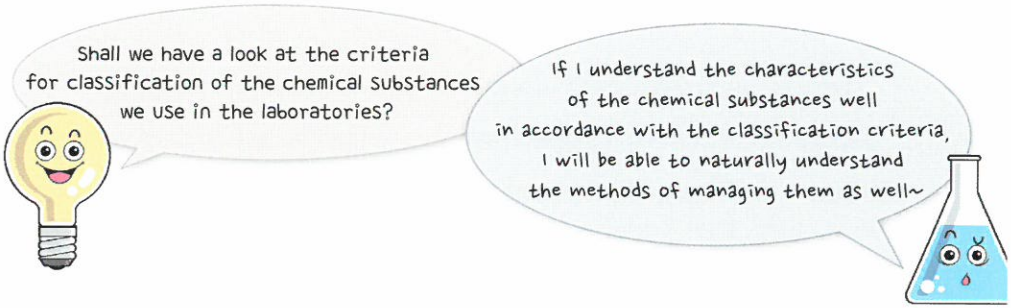
the warning sign in accordance with the Law on the safety management of hazardous substances.

⑥ Provision of GHS/MSDS data

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 is 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.



2. Classification of harmfulness and hazard in accordance with GHS

Classification of harmfulness and hazardousness of chemical substances under the GHS system is determined by making reference to the classification criteria presented by the UN and the detailed standards necessary for classification of new substance. Korea classified 18 categories of physical hazards, 11 categories of health hazards and one category of environmental hazard in accordance with the following principles of classification (refer to the Ministry of Employment & Labor Announcement No. 2013-37 (amended on 2013.01.26.), and the Article 4 (classification of chemical substances, etc.) of the 'Standard for classification, description and MSDS of chemical substances' and the announcement of this Standard <Annex 3>). When this is compared with the classification presented by the UN, there is one more category of health hazard and one less category of environmental hazard.

(1) Common principles on classification

① Classification of harmfulness and hazardousness

Physical hazards, health hazards and environmental hazards of the chemical substances are classified through the following available harmfulness and hazard evaluation data.

- Classify by using the harmfulness and hazard evaluation and test data.
- Classify by considering the epidemiologic or empirical data on people
- If there are various types of data for evaluation of a single harmfulness and hazard, then, classify on the basis of the expert determination with considerations for the following:

- If there are more than two data for people or animal and the results differ from each other, then, apply the data with greater reliability by evaluating the quality and reliability of such data.
- As the results of the research on the exposure route, action mechanism and metabolism, it can be excluded from the category of hazardous substances if it is clear that no harm for human is generated.
- If both positive and negative results exist, classify the substance in accordance with the weighted value by combining both.

② Classification of mixture

a. Health and environmental hazard

- **If there are data from test on mixture**

  Apply the classification criteria of single substances in accordance with the results of such tests. However, results of tests on carcinogenicity, germ cell mutagenicity and reproduction toxicity must be sufficient for determination of the hazardousness in terms of dose, duration, details of observation, analysis method, and etc.

- **If there is no data from text on mixture**

  If there is a source that enables the substance to be determined as a mixture through classification data for similar mixture, classify by using bridging principles such as dilution, batch, enrichment, interpolation, similar mixture or aerosol, and etc.

  – **Dilution**: In the event of diluting the mixture with the substance that has toxicity that is the same or lower than the substance with the lowest toxicity among the substances contained in the mixture, the newly made mixture can be classified into the same category as the mixture prior to the dilution. Such case is limited to the situation in which the diluting ingredient does not affect the toxicity of other ingredients in the mixture.

- **Batch**: Mixture manufactured from the same batch and the same type of products (different manufacturing batch) manufactured and managed by the same manufacturer can be deemed to have the same toxicity. However, new category must be applied if there is a change in the toxicity depending on the differing batch.
- **Enrichment**: If the mixture corresponds to the "Harmfulness and hazard category 1" and the quantity of the ingredient that belongs to the "Harmfulness and hazard category 1" increases among the constituting contents of the mixture, the new mixture is classified as "Harmfulness and hazard category 1" without supplemental test.
- **Interpolation**: If there are 3 mixtures, A, B and C, that contain the same ingredients, and the mixture A and the mixture B belongs to the same harmfulness and hazard category, and the mixture C has ingredients that has the concentration and toxic activity that corresponds to the level between those of the mixture A and the mixture B, then, the mixture C can be deemed to belong to the same harmfulness and hazard category that the mixture A and the mixture B belong to.
- **Similar mixture**: If there is a mixture composed of ingredients A & B, and another mixture composed of ingredients B & C, and if the concentration of B is practically the same and the toxicity of A & C are the same and does not affect the toxicity of C, then both mixtures can be classified into the same harmfulness and hazard category.
- **Aerosol**: If the propulsion agent used for aerosolization does not affect the toxicity of the mixture in the process of aerosolization, the hazardousness can be classified by using the results of the oral or epidermal toxicity test carried out under non-aerosol state. However, aspiration toxicity of the aerosol must be considered separately.

• If there is no data for evaluation of the hazardousness of the mixture but data for the hazardousness evaluation of the constituent ingredients exist, comply with the classification method for mixture for each of the hazard.

③ Classification of chemical substances, etc.

a. Classification in accordance with physical hazard (16 categories)

- Explosives
- Flammable gases
- Flammable Aerosols
- Oxidizing gases
- Gases under high pressure
- Flammable liquids
- Flammable solids
- Self-reactive substance
- Natural pyrophoric liquid
- Natural pyrophoric solid
- Self-heating substance and mixture
- Water reactive substance (emits flammable gases when contacted with water)
- Oxidizing liquids
- Oxidizing solid
- Organic peroxide
- Metal corrosive substance (corrosive to metals)

b. Health hazards (11 categories)

- Acutely toxic substance (acute toxicity)
- Dermal corrosive or irritating substance (dermal corrosion/irritation)

- Serious eye injury or irritating substance (serious eye damage/eye irritation)
- Respiratory sensitizing substance (respiratory sensitization)
- Skin sensitizing substance (skin sensitization)
- Germ cell mutagenic substance (germ cell mutagenicity)
- Carcinogenic substance (carcinogenicity)
- Reproductively toxic substance (reproductive toxicity)
- Systemic target organ-specific toxic substance (single exposure) (specific target organ toxicity/single exposure)
- Systemic target organ-specific toxic substance (repetitive exposure) (specific target organ toxicity/repeated exposure)
- Breathing hazard (aspiration hazards)

c. Environmental hazard (1 category)

- Aquatic environmental hazard substance (aquatic environmental hazards)

d. Substances that have been omitted from the classification are as follows.

- Radioactive substance according to the atomic energy law
- Medical drug, non-medical drug and cosmetic products according to pharmaceutical affairs law
- Narcotics and psychotropic drug according to the law on management of narcotic drugs
- Agricultural chemical according to the law on management of agricultural drug
- Animal feeds according to the law on management of feeds

- Fertilizer according to the law on management of fertilizer
- Food and food additives according to food sanitation act

④ Definition and classification of harmfulness and hazardousness

a. Classification in accordance with physical hazard (16 categories)

- Explosive substance

  Refers to the solid, liquid or mixture that generates gases with the temperature, pressure and speed that can impart damages to the surrounding environment in accordance with its own chemical reaction. However, pyrotechnic articles are included in the category of explosive substances even if they do not generate gas.

- Flammable gases

  Refers to the gases that belong to those that are ignited when mixed with air at the temperature of 20℃, and standard atmospheric pressure (101.3 kPa).

- Flammable aerosols

  Refers to the aerosol (natural pyrophoric substance, self-heating substance or water reactive substance is excluded) that contains flammable ingredients such as flammable gas, flammable liquid,flammable solid, and etc. At this time, "aerosol (or aerosol sprayer)" refers to the spraying device made of metal, glass or plastic container filled with compressed gas, liquefied gas or dissolved gas that cannot not be refilled, and discharges these gases in foam, paste or powder phase from the collide or liquid state generated when the contents have been dispersed.

- Oxidizing gases

  Refers to the gas that makes contribution towards combustion or better combustion of other substances by ordinary generating oxygen.

- Highly pressurized gas

  Refers to the gas, or liquefied or refrigerated liquefied gas filled in containers under the temperature of 20℃ and pressure of more than 200 kPa.

- Flammable liquids

  Refers to the liquid with flash point of less than 60℃ under the standard atmospheric pressure (101.3 kPa).

- Flammable solids

  Refers to the solids that easily combust or induce fire by friction, or contribute to combustion.

- Self-reactive substance

  Refers to the liquid, solid or their mixture that can easily generate heal and decompose fiercely without oxygen supply due to their thermal instability.

- Natural pyrophoric liquid

  Refers to the liquid that can ignite within 5 minutes upon contact with air even at small quantity.

- Natural pyrophoric solid

  Refers to the solid that can ignite within 5 minutes upon contact with air even at small quantity.

- Self-heating substance and mixture

  Refers to the liquid, solid or their mixture that can generate heat by itself by reacting with air without being supplied with energy from the surrounding, with the exception of natural pyrophoric substance.

- Water reactive substance (emits flammable gases when contacted with water)

  Refers to the liquid, solid or their mixture that can be spontaneously ignited or generate flammable gas through mutual reaction with water.

- Oxidizing liquids

  Refers to the liquid that combusts or promote the combustion of other substances by ordinarily generating oxygen although the substance itself does not combust.

- Oxidizing solids

  Refers to the solid that combusts or promote the combustion of other substances by ordinarily generating oxygen although the substance itself does not combust.

- Organic peroxides

  Refers to the liquid or solid organic matter with the structure of "-O-O-", which is a derivative of peroxide for which 1 or 2 hydrogen atoms have been substituted by free radical.

- Metal corrosive substance

  Refers to the substance or its mixture that incurs damages or corrosion to metal through chemical reaction

b. Health hazard (11 categories)

- Acutely toxic substance

  Refers to the harmful effect of substance when exposed for 4 hours through respiratory system or if administered singly or over several times within 24-hour period through the mouth or skin.

- Dermal corrosive or irritating substance

  Dermal corrosion refers to the substance that induces non-irritating damages to the skin, that is, necrosis that can be visually identified from the epidermis to derma of the skin (typically, ulcer and bleeding) while dermal irritation refers to restorable damages to the skin.

- Serious eye injury inducing or irritating substance

  Serious eye injury refers to the manifestation of damages to the eye tissues or deterioration of eyesight when the substance comes in

contact with the frontal surface of the eye that does not fully recover within 21 days while eye irritation refers to the changes in the eyes when the substance comes in contact with the frontal surface of the eye that fully recover within 21 days.

- Respiratory system sensitizing substance

  Refers to the substances that generate hypersensitive reaction in the respiratory tract when inhaled through the respiratory system.

- Skin sensitizing substance

  Refers to the substance that induces skin allergic reactions by coming in contact with the skin.

- Germ cell mutagenic substance

  Refers to the substance that induces permanent changes in the quantity or structure of the genes in the reproductive cells of people that can be inherited to the next generation. It includes both the visually confirmable genetic changes and changes at the level of DNA.

- Carcinogenic substance

  Refers to the subjects that induces cancer or enhances the manifestation of cancer.

- Reproductively toxic substance

  Refers to the substance that imparts harmful effect on the reproductive function or capabilities, or to the creation and growth of fetus. Harmful effect on the reproductive function or capabilities includes all the effects such as changes in the reproductive organs, fertile period, generation and transfer of reproductive bodies, reproduction cycle, sexual behavior, bearing or giving birth to a child, results of pregnancy, early aging of reproductive functions and other functions affected by the reproductive system. Harmful effects on the creation and growth of fetus include all the effects that interfere with the normal growth of the fetus prior to and after the birth, that is, the effect of the exposure to the parent prior to pregnancy, to fetus during pregnancy, and to child from birth to maturation.

- Systemic target organ specific toxic substance / single exposure

  Refers to the characteristic and non-lethal target organ specific toxicity arising from a single exposure other than acute toxicity, dermal corrosiveness/dermal irritation, serious eye injury/eye irritation, respiratory sensitization, skin sensitization, germ cell mutagenicity, carcinogenicity, reproduction toxicity and aspiration hazard.

- Systemic target organ specific toxic substance / repeated exposure

  Refers to the characteristic and non-lethal target organ specific toxicity arising from repeated exposure other than acute toxicity, dermal corrosiveness/dermal irritation, serious eye injury/eye irritation, respiratory sensitization, skin sensitization, germ cell mutagenicity, carcinogenicity, reproduction toxicity and aspiration hazard.

- Aspiration hazards

  Refers to the serious acute effect such as chemical pneumonia, pulmonary damages at various stages or death manifested when liquid or solid chemical substances enter into the organs and lower ranked respiratory system directly through mouth or nose, or indirectly through vomiting.

c. Environmental hazard (1 category)

- Aquatic environmentally hazardous substance

  Acute aquatic environmental hazard refers to the hazards that impart harmful effect on the aquatic environment through a short period of exposure, while chronic aquatic environmental hazard refers to the hazards manifested when the aquatic organisms are exposed to the substances or their mixtures throughout the period that corresponds to their life cycle.

⑤ Detailed classification and illustration for each of the classes of chemical substances

The system based on the GHS, as explained above, has classified the chemical substances into 28 categories which are further subdivided.

For example, subdivision of the 'explosive substance', which is the first subcategory of the 'physical hazard', one of the 28 categories under GHS, is as follows.

Table 2-1 Classification of explosive substance for each of the classe

Categories	Criteria for categorization
Unstable explosive substance	Explosive substance and mixture that is too sensitive or thermodynamically unstable for handling, transportation and use in ordinary method
Class 1.1	Explosive substance and mixture with the risk of major explosion
Class 1.2	Explosive substance with risk of eruption although there is no risk of major explosion
Class 1.3	Explosive substance and mixture with risk of fire without the risk of major explosion, and with risk of eruption or weak blast ① Combusts while irradiating large quantity of radiant heat or ② Sequentially combusts while generating weak blast or eruption
Class 1.4	Explosive substance and mixture with slight risk due to ignition or detonation although there is no serious risk ① Effect is limited only to the packaged product without eruption of fragments with sizes or range that require precautions, and ② Practically, almost all contents of the packaged product do not explode simultaneously due to external fire
Class 1.5	Explosive substance and mixture with low possibility of ignition and detonation under normal state due to its insensitivity or have almost no possibility of combustion developing into explosive detonation although there is risk of major explosion
Class 1.6	Highly insensitive product with no risk of major explosion since there is no possibility of accidental detonation or propagation

⑥ Classification of toxic substances in accordance with GHS system

Based on the 'Regulation on the criteria for classification and description method for toxic substances' (National Institute of Environmental Research Announcement No. 2014-6) in accordance with the Law on 'Management of Harmful Chemical Substances' of the Ministry of Environment, the classification of toxic substances includes total of 27 categories made up of 16 categories for physical hazards, 10 categories for health hazards and 1 category for environmental hazard. The classification of the classes within each of the categories is similar to the contents of the Announcement (No. 2013-37) by the Ministry of Employment & Labor in general.

(2) Items to be listed in the label for harmfulness and hazard, and warning in accordance with the GHS system

① Items to be listed in the label for harmfulness and hazard, and warning

a. Product identifier

Product information used in the GHS label must coincide with the product information used in SDS. If the recommendation on transportation and model rules for the hazardous substances of the US is applied to the corresponding substance or mixture, the UN's product name must also be listed.

b. Pictograms

The following pictograms are the standard signs used under the GHS system. With the exception of the exclamation mark, fish and tree, which are the new signs used for health hazard, coincides with the standard signs used in the recommendation and model rules on transportation of transportation of hazardous materials of the UN.

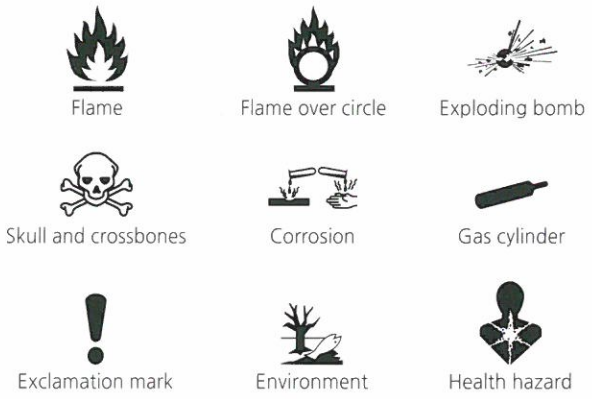


Fig. 2-1 Pictogram in accordance with the classification of hazards

Fig. 2-2 Examples of the use of the hazard pictogram

c. Signal word

Signal word illustrates the relative level of the seriousness of the hazard and signifies the terms used to warn the users of the potential hazards. Signal words used in the GHS are 'dangerous' and 'warning'. 'Dangerous' is used for more serious hazards while 'warning' for less serious hazards.

d. Harmfulness and hazardousness statement

Harmfulness and hazardousness statement refers to the statement allocated to the classification and categorization of the hazard that illustrates the harmful properties of the product including the extent of hazardousness. Harmfulness and hazardousness statement that can be allocated to each of the hazard categories of GHS is listed in the Table on the each of the hazard classifications (refer to the Appendix 3).

e. Precautionary statement

Precautionary statement refers to the statement or pictogram that describes the recommended measures for prevention or minimization of the damages induced by the exposure to or inappropriate storage or handling of the harmful products (Refer to the Appendix 3).

f. Supplier information

The name, address and telephone number of the manufacturer or supplier of the substance or mixture must be listed on the label.

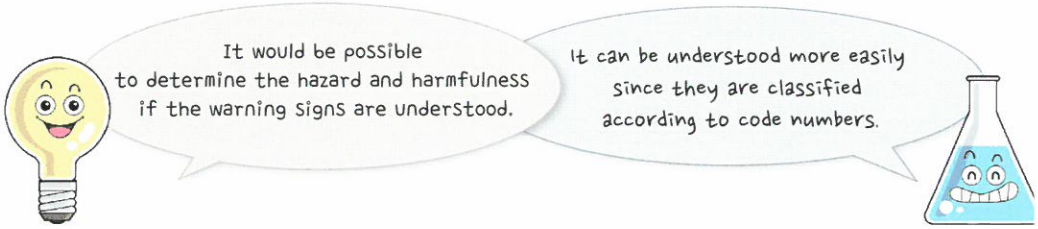
② Items to be listed in the warning label and illustration of the harmfulness and hazardousness statements (code)

Items to be listed in the warning label for the carcinogenic substances among the explosive substance and health hazard substances in the category of physical hazards is Illustrated below. The details of the harmfulness and hazardousness statements (code) for each of their class can be found in the Appendix 3.

Table 2-2 Items to be listed in the warming label of the explosive substance

Categories		Unstable explosive substance	Class 1.1	Class 1.2	Class 1.3	Class 1.4	Class 1.5	Class 1.6
Pictogram							No. 1.5 on orange background	No. 1.6on orange background
Signal words		Dangerous	Dangerous	Dangerous	Dangerous	Warning	Dangerous	
Harmfulness and hazardousness statement		H200	H201	H202	H203	H204	H205	
Pre-cautionary statement	Pre-vention	P201 P202 P281	P210 P230 P240 P250 P280	P210 P230 P240 P250 P280	P210 P230 P240 P250 P280	P210 P240 P250 P280	P210 P230 P240 P250 P280	
	Counter measures	P372 P373 P380	P370 +P380 P372 P373	P370 +P380 P372 P373	P370 +P380 P372 P373	P370 +P380 P372 P373 P374	P370 +P380 P372 P373	
	Storage	P401	P401	P401	P401	P401	P401	
	Disposal	P501	P501	P501	P501	P501	P501	

Table 2-3 Items to be listed in the warming label of the carcinogenic substance



Categories		1A	1B	2
Pictogram				
Signal words		Dangerous	Dangerous	Warning
Harmfulness and hazardousness statement		H350	H350	H351
Precautionary statement	Prevention	P201 P202 P281	P201 P202 P281	P201 P202 P281
	Counter measures	P308+P313	P308+P313	P308+P313
	Storage	P405	P405	P405
	Disposal	P501	P501	P501

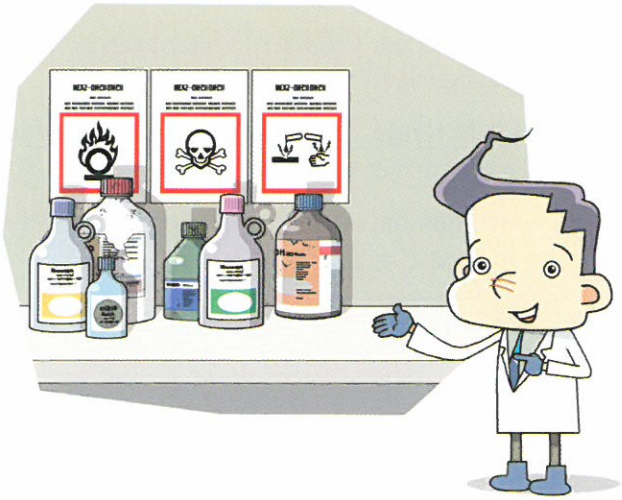
The details of the statements (code) ranges indicated with number are as follows:

a. Description for the classification of harmfulness and hazard

- **H200 range**: Description of physical hazards including explosion, fire and reaction with water, etc.
- **H300 range**: Description of health hazard at the time of oral and dermal contamination, and inhalation
- **H400 range**: Description of short and long-term environmental hazard on aquatic organisms

b. Description for the classification of preventive and countermeasures

- **P200 range**: Preventive measures for prevention of accidents including securing of handling manual, wearing of protection equipment, precautions against fire, distancing of water no smoking, and etc.
- **P300 range**: Measures to be taken in the event of occurrence of accidents including contamination, inhalation, fire, and etc.
- **P400 range**: Precautions at the time of storage including isolation, ventilation, avoidance of direct sunlight, limitation on the temperature, and etc.
- **P500 range**: Precautions at the time of disposal of contents, containers, and etc.



③ Example and form for drafting of warning label

Product Identifier (put the name of the substance of product)

(Example of pictogram)

Signal word :

Harmfulness and
hazardousness statement :

Precautionary statement :

Supplier information :

Benzene

Signal word: Dangerous

Harmfulness and
hazardousness statement

Highly flammable liquid or vapor
Can induce cancer
Induces severe irritation to the eyes
Harmful when swallowed

Precautionary statement

Prevention : Tightly seal the container. Keep distance or isolate from the source of ignition such as heat, spark and flame.
-No smoking and take measures to prevent generation of static electricity. Do not handle before you have read and understood all the safety Precautionary statements. Wear the required respiratory personal protective devices and eye and facial protection equipment. Do not swallow, drink or inhale when using this product
Countermeasure : If there has been exposure or concerns for exposure, seek medical advice. If swallowed, wash out the mouth and seek assistance of medical institution (medical doctor). If it came in contact with the eyes, carefully wash the eyes with water for several minutes. If possible, remove contact lens.
Storage : Store in a location with good ventilation and by tightly sealing the container.
Disposal : Dispose of the contents and the container in accordance with the regulations stipulated in the relevant laws
Supplier information : OO Chemical Co., Ltd., #345 00-dong, 00 City, Gyeonggi-do ☎: 82-2-1234-5678

④ Other harmfulness and hazards not included in the criteria for classification of harmfulness and hazardousness

It is one of the indices of the harmfulness and hazard of chemical substances. The National Fire Protection Association (NFPA) has been using

the indices that categorized the health hazard, fire hazard and stability or reactivity with other substances for each of the chemical substance into the following 5 stages, 0~4, widely.

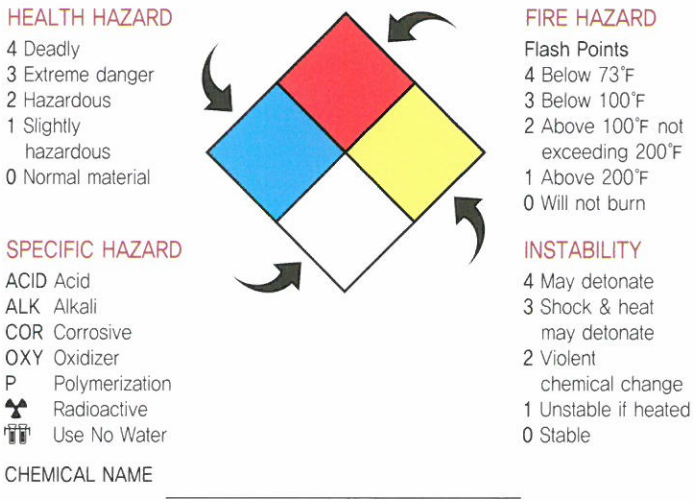


Fig. 2-3 NFPA Label

Examples of NFPA label for acetone and benzene are given below.

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.

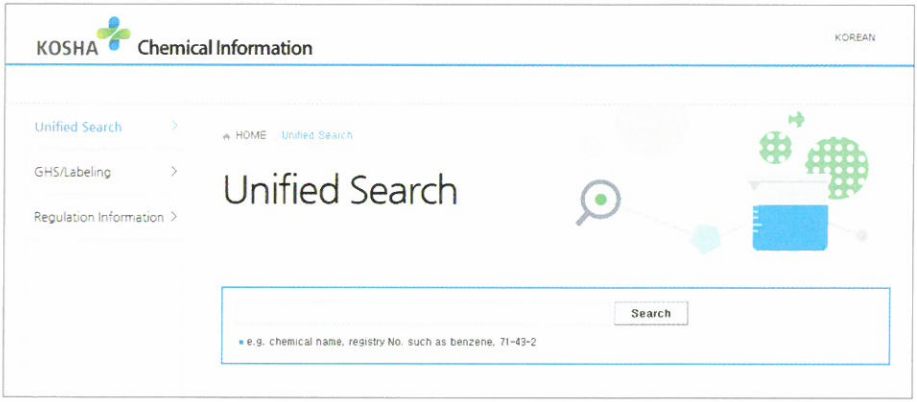
CAS No. 67-64-1

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

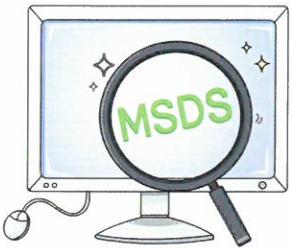
3. Searching GHS/MSDS information



KOSHA is operating the program for drafting of the GHS/MSDS. Not only the manufacturer and supplier but also the ordinary users can easily search the ordinary MSDS information on the chemical substances needed through the following websites.

- KOSHA Information Center msds.kosha.or.kr
- MSDS Portal Site ilpi.com/msds/index.html
- MSDS Solution Center www.msds.com

As an example, the summary of the MSDS information that can be obtained by searching with the term 'acetic acid' 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℃	Melting point	17℃
Ignition point	39℃		
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

4. Examples of accidents related to failure to familiarize with GHS/MSDS

Most of the major and minor laboratory safety accidents occurred due to the failure to familiarize with GHS/MSDS. Safety accidents arising due to this could have been sufficiently prevented in advance through small efforts and attention to prevent the safety accidents including research collection and familiarization of GHS/MSDS prior to the activities, appropriate preparations for safety accidents in advance after having familiarized with GHS/MSDS, completion of relevant safety education, and etc. The following are the examples of safety accidents that occurred due to execution of the experiments by ignoring the properties of chemical substances for which precautions need to be made. These accidents occurred because of the failure to familiarize with GHS/MSDS and insensitivity to safety issues.

(1) Example of accidents

① Explosion of hydrogen gas

- Overview of the Accident: Explosion accident due to the residual hydrogen gas within the reactor following the completion of antibiotics synthesis reaction
- Cause of the Accident: Causes included failure to review MSDS in advance, failure to familiarize with the explosion limit of hydrogen gas (4~75 %), inadequacy in safety education on the establishment of inert experiment environment in advance, lack of safety equipment including explosion proof facility, gas detector and alarm

② Explosion of mixture gas

- Overview of the Accident: Leakage of hydrogen gas and explosion accident in the supply line for the hydrogen and oxygen mixture during the hydrogen peroxide decomposition experiment
- Cause of the Accident: Causes included lack of knowledge on the explosion hazard of mixed gas in advance, failure to check the breakage in the valve section of the supply line, failure to recognize the possibility of ignition by static electricity and lack of preparation for such possibility in advance, and insufficient ventilation and exhaust facility in preparation for gas leakage.

③ Explosion during the heating process

- Overview of the Accident: Explosion accident in the process of heating the reagent bottle to be used in dissolving DMSO (Dimethyl sulfoxide)
- Cause of the Accident: Causes included increase in internal pressure due to direct heating of closed reagent bottle, failure to check the physiochemical characteristics, isolation of fire or safety of high

temperature in advance, non-execution of education on the indirect heating method using warmer, and expansion of injuries owing to not wearing personal protection equipment

④ Explosion during polymerization reaction

- Overview of the Accident: Explosion accident due to the leakage of reactant in the train line of the batch reactor with the capacity of 10L during the copolymerization reaction of 1,3-Buadiene and Acrylonitrile
- Cause of the Accident: Causes included lack of knowledge on the polymerization reaction and the characteristics of the reagent used, lack of pressure resistance of the reaction facilities including valve, inadequate detection of leakage, execution of forceful experiment and with risk although the facility was non-explosion proof, lack of fire extinguishing facility and training in advance.

⑤ Explosion during decomposition

- Overview of the Accident: Explosion accident in the process of refilling MEKP (Methylethylketone peroxide)
- Cause of the Accident: Causes included lack of assessment of the characteristics of MEKP including high temperature decomposition, pyrophoric and bodily hazard in advance, inadequate preparation and failure to wear personal facial protection equipment necessary in handling MEKP, lack of advance knowledge and preparations for the method of dealing with decomposition and leakage, and knowledge of disaster facility in advance.

⑥ Explosion during thermal decomposition

- Overview of the Accident: Accident that resulted in the damage to reaction chamber due to the rapid increase in temperature in the

process of producing CPD through thermal decomposition of DCPD (Dicyclopentadiene)

- Cause of the Accident: Causes included lack of knowledge on the physical hazard and bodily hazard of DCPD and CPD in advance, lack of knowledge on the polymerization characteristics and reaction heat control of CPD, lack of knowledge on the possibility of occurrence of abnormal reaction at the time of mixing these substances in advance, and lack of preparation in advance of the generation of harmful gas and proliferation of foul odor as well as lack of measures against disasters.

⑦ Explosion of residual substances

- Overview of the Accident: General of chlorine gas and explosion accident due to the contact with water at the time of disposal of residual POCl3 following the experiment
- Cause of the Accident: Causes included failure to familiarize with the characteristics of POCl3, which is a water reactive compound, and lack of relevant safety education in advance, lack of preparations for the chlorine gas that generated from contact with water in advance, and failure to wear personal protection equipment and lack of exhaust facility.

⑧ Fire accident during drying process

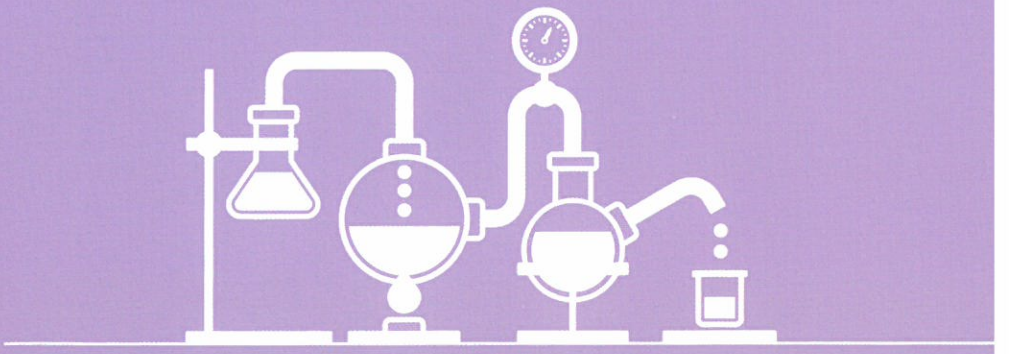
- Overview of the Accident: Fire accident due to acetone left behind in the drier during the experiment on purification of soil purification
- Cause of the Accident: Causes included failure to familiarize with the characteristics of acetone with high possibility of combustion and explosion, and lack of relevant education in advance, non-performance of regularly scheduled inspection of the temperature control function of the drier and failure to use explosion proof drier.

⑨ Fire accident due to leakage

- **Overview of the Accident**: Ethanethiol leakage accident in the process of development of electrolyte of fuel cell
- **Cause of the Accident**: Causes included the failure to execute the experiment in the hood equipped with exhaust and exhaust post-processing equipment, and evacuation due to failure to tidy up the experimental lab and non-activation of exhaust activities.

Standard Textbook for Safety in Laboratory

Safety Before the Experiment



CHAPTER

3

Classification and storage of chemical substances

1. Characteristics of chemical substances
2. Classification of chemical substances
3. Method of storing chemical substances
4. Illustration of the classification and storage method of chemical substances
5. Examples and prevention of accidents that occur during storage of chemical substances

CHAPTER 3 Safety Before the Experiment

Classification and storage of chemical substances

Chemical substances that include a diverse range of harmfulness and hazard can induce fire, explosion and serious injuries. For safer research environment, chemical substances must be classified in accordance with their chemical characteristics and appropriately store only the minimum quantity that can be used for short-term in the laboratory. In addition, stocktaking should be carried out for the hazardous substance annually and it is advisable to organize the list of reagents.

1. Characteristics of chemical substances

Chemical substances can be divided largely into combustible and flammable liquid and gas, corrosive substances, reactive substances, explosive substances, toxic substance, self-reactive substances and substances that cannot be stored together. Understanding the characteristics of the hazards of the chemical

substances, and classifying and storing them accordingly is the most economical and effective method of preventing safety accidents.

For example, the most easily found hazardous elements in combustible and flammable substances in the laboratories must be stored in locations with good ventilation but without any source of ignition. In addition, store only the minimum quantity that can be used in short period of time and in cabinet for exclusive use. Corrosive substances such as strong acid, strong alkaline, organic and inorganic halide, desiccant and halogen, etc. must be stored in cool and dry location with good ventilation. Since toxic chemical products can induce serious bodily injuries due to inhalation, swallowing and contact, they must be stored in cabinets with locking device. Explosive substances include solid, liquid and gaseous chemical substances that can emit non-voluntary pressure, gas and heat when subjected to impact, pressure and high temperature. Reactive substance such as flammable solid, oxidizing agent, peroxide, natural pyrophoric substance and water reactive substances react violently in the event of negligence in handling and have the possibility of discharging relatively large quantity of energy and hazardous toxic gases. Therefore, particular precautions need to be taken in their storage.

2. Classification of chemical substances

Although the system of classification of substances in accordance with the law on safe management of hazardous substances ([Table 3-1]) is concurrently implemented at the moment, the classification of the chemical substances has been improved with the classification system that includes categorization into physical hazards (16 categories), health hazards (11 categories) and environmental hazards (1 category) that can cope with GHS/MSDS since July

1, 2010. However, establishment of systemic and staged plans for execution is necessary for complete application of GHS.

Chemical substances or harmful and hazardous substance are being classified into various formats in accordance with the method of categorization in accordance with the physical hazards such as explosion and ignition, etc. that can occur during handling and storage, and health or environmental hazards such as corrosion, sensitization and carcinogenicity when inhaled or contacted as well as in accordance with the subjects of the categorization and laws. Among these substances, those that forms explosive mixture in the air or induce fire and explosion through heating and contact are commonly referred to as hazardous substances, which are divided largely into explosive substance, pyrophoric substance, oxidizing substance, flammable substance and combustible gas, and etc. depending on their states. In addition, substances that cause harm to the human body can be classified into corrosive substances and toxic substance. Brief summary of the explanations on these substances is given below.

(1) Explosive substance

Explosive substances are those that can induce violent reaction such as explosion even without the supply of oxygen or oxidizing agent only through heating, friction, impact or contact with other combining substances. Examples including acetic ester, nitro compounds and organic peroxide, etc., and majority are combustible substance that contains oxygen.

These substances have properties that are different from other combustible substances since combustion occurs by consuming oxygen on their own and their combustions are rapid and explosive. Explosive substance is highly hazardous if a source of ignition is provided since it exists in the state of coexistence of combustible substance and supplier of oxygen. Heating, impact, friction or contact with other chemical substances must be avoided. Since there are substances that undergo spontaneously igniting through prolonged

decomposition, precautions must be taken for temperature, moisture and ventilation in storage as they easily become decomposed.

In addition, combustion of explosive substance differs from those of the combustible substances. Combustion is violent since oxygen supply is abundance through decomposition, and decomposition of the explosive substance itself also occurs violently. Therefore, measures for prevention of combustion in advance including prohibition of decomposition during extinguishment are necessary. Fire extinguishers that use suffocation effect do not have sufficient effect on these substances. As such, it is necessary to secure the method of lowering the temperature to that below the decomposition temperature by cooling them with water in order to stop their decomposition and the method of inhibiting the combustion of the combustible substances (cooling extinguishment, fire cloth and sand) simultaneously.

Table 3-1 Explosive substances

Explosive substances	
Alkali metal dinitrophenolates	Diethylene glycol dinitrate
Ammonium nitrate-fuel oil mixture	Dinitroglycoluril
Ammonium nitrate mixtures	Dinitrophenol
Ammonium perchlorate	Dinitroresorcino
Ammonium picrate	Dinitroso dimethylterephthalamide
Azobisisobutyronitrile	Dintrosopentamethylenetetraamine
Barium azide	Dinitrosobenzene
Barium styphnate	Dipicryl sulfide
Cyclotetramethylenetetranitramine	Guanyl nitrosaminoguanylidene hydrazine
Cyclotrimethylenetrinitramine	Guanyl nitrosaminoguanyltetrazene
Diazo naphthol sulfonyl chloride	Hexanitrodiphenylamine
Diazodinitrophenol	Hexanitrostilbene

Explosive substances	
Hexatonal	Sodium salts of aromatic nitro-derivatives
Hexolite	Sodium picramate
Lead azide	Tetranitroaniline
Lead mononitroresorcinate	Tetrazol-1-acetic acid
Lead styphnate	Trinitro-m-cresol
Mannitol hexanitrate	Trinitroaniline
Mercaptotetrazol acetic acid	Trinitroanisole
Mercury fulminate	Trinitrobenzene
Nitrourea	Trinitrobenzenesulfonic acid
Nitrobenzotriazole	Trinitrobenzoic acid
Nitrocellulose	Trinitrochlorobenzene
Nitroglycerin	Trinitrofluorenone
Nitroguanidine	Trinitronaphthalene
Nitrosoguanidine	Trinitrophenetole
Nitrostarch	Trinitrophenol
Nitrotriazolone	Trinitrophenylmethylnitramine
Octolite	Trinitroresorcinol
Pentaerythritol tetranitrate	Trinitrotoluene
Pentolite	Tritonal
Sodium dinitro-o-cresolate	Urea nitrate
Sodium salts of aromatic nitro-derivatives	
Deflagrating metal salts of aromatic nitro derivatives	
Potassium salts of aromatic nitro-derivatives, explosive.	

(2) Pyrophoric substances

Substances that generate combustible gas by igniting upon contact with water or those for which self-ignition in the atmosphere is easy are referred to as pyrophoric substances. Hazardous substances that are classified as pyrophoric substances include metal potassium, metal sodium, calcium carbide, and etc. These substances combust or explode by generating exothermic reaction or combustible gas by reacting with water with examples such as white phosphorous, red phosphorous, magnesium, and etc, which are easily ignited at relatively low temperature.

Breakage or corrosion to the storage container for water reactive substances must be prevented. In particular, they must be handled cautiously to avoid contact with moistures including rainwater, leaked water and ice. It is advised to use dried sand as an extinguishment method and spraying water must be prohibited. They must be stored by dividing them into small appropriate quantities, and in the event of storing them in petroleum, it must be ensured that they are not exposed to outside.

Ordinarily, combustible substances that can easily be ignited at low temperature display high rate of combustion, and are toxic substances or generate toxic gases at the time of combustion. Therefore, contact with oxidizing agents must be avoided, and contact with or approach to flame, embers and high temperature object must be prohibited strictly. For the majority of pyrophoric substances, the extinguishing method of cooling with water is effective. However, metal powder ignites and causes explosion or sends combusted metal flying when it comes into contact with water. Therefore, extinguishment with water must be prohibited strictly. For metal fire, extinguisher that contains extinguishing agent for metal fire (dry powder) or fire blanket must be used.

Table 3-2 Water reactive substance

Water reactive substance	
Acetic anhyride	Barium oxide
Acetyl bromide	Barium sulfide
Acetyl chloride	Benzene phosphorus dichloride
Alkyl aluminum chloride	Benzoyl chloride
Allyl trichlorosilane	Benzyl silane
Aluminum aminoborohydride	Beryllium tetrahydroborate
Aluminum borohydride	Beryllium hydride
Aluminum bromide	Borane
Aluminum chloride	Bismuth pentaflouride
Aluminum fluoride	Boron dibromoiodide
Aluminum hypophosphide	Boron bromodiiodide
Aluminum phosphide	Boron tribromide
Aluminum tetrahydrobroate	Boron phosphide
Amyl trichlorosilane	Boron triiodide
Anisoyl chloride	Boron trichloride
Antimony tribromide	Bromine pentafluoride
Antimony trichloride	Bromine monofluoride
Antimony trifluoride	Bromo diethylaluminum
Antimony triiodide	Bromine trifluoride
Antimony trivinyl	n-Butyl trichlorosilane
Arsenic tribromide	n-Butyl lithium
Arsenic trichloride	Cadmium amide
Arsenic triiodide	Cadmium acetylide
Barium	Calcium
Barium carbide	Calcium carbide

Water reactive substance	
Calcium oxide	Diisocyanate
Calcium hydride	Dodecyl trichlorosilane
Calcium phosophide	Ethyl dichloroarsine
Cesium amide	Ethyl dichlorosilane
Cesium phosphide	Ethyl trichlorosilane
Cesium hydide	Fluorine
Chlorine monofluoride	Fluorine monoxide
Chlorine dioxide	Fluorosulfonic acid
Chlorine trifluoride	Gold acetylide
Chlorine pentafluoride	Hexadecyl trichlorosilane
Chlorodiisobutyl aluminum	Hexyl trichlorosilane
Chloroacetyl chloride	Hydrobromic acid
Chromyl chloride	Iodine monochloride
Chlorophenyl isocyanate	Lithium
Cyclohexenyl trichlorosilane	Lithium aluminium hydride
Copper acetylide	Lithium amide
Decaborane	Lithium ferrosilicon
tri-chlorosilane	Lithium hydride
Diethyl aluminum chloride	Lithium peroxide
Diborane	Lithium silicon
Diethyl zinc	Methyl aluminum sesquibromide
Diethyl dichlorosilane	Methyl aluminum sesquichloride
Dimethyl dichlorosilane	Methyl dichlorosilane
Diisopropyl beryllium	Methyl isocyanate
Disulfury chloride	Methyl magnesium bromide
Dimethylmethane	Methyl magnesium iodide

Water reactive substance	
Methyl magnesium chloride	Silicon tetrachloride
Methyl trichlorosilane	Silver acetylide
Methylene diisocyanate	Sodium
Nickel antimonide	Sodium aluminum hydride
Nonyl trichlorosilane	Sodium amide
Octadecyl trichlorosilane	Sodium hydride
Octyl trichlorosilane	Sodium methylate
Phenyl trichlorosilane	Sodium oxide
Phosphonium iodide	Sodium peroxide
Phosphoric anhydride	Sodium-potassium alloy
Phosphorus oxychloride	Stannic chloride
Phosphorus (amorphous red)	Sulfonyl fluoride
Phosphorus oxybromide	Sulfonyl fluoride
Phosphorus pentachloride	Sulfuric acid (70%)
Phosphorus pentasulfide	Sulfur chloride
Phosphorus sesquisulfide	Sulfur pentafluoride
Phosphorus trisulfide	Sulfur trioxide
Phosphorus tribromide	Sulfuryl chloride
Phosphorus trichloride	Thiocarbonyl chloride
Polyphenyl polymethyl isocyanate	Thionyl chloride
Potassium	Thiophosphoryl chloride
Potassium hydride	Titanium tetrachloride
Potassium oxide	Toluene diisocyanate
Potassium peroxide	Trichlorosilane
Propyl trichloride	Triethyl aluminum
Pyrosulfuryl chloride	Triisobutyl aluminum

Water reactive substance	
Trimethyl aluminum	Tripropyl stibine
Tri-n-butyl aluminum	Trisilyl arsine
Tri-n-butyl borane	Trivinyl stibine
Tricotyl aluminum	Vanadium trichloride
Trichloroborane	Vinyl trichlorosilane
Triethyl arsine	Zinc acetylide
Triethyl stibine	Zinc acetylide
Trimethyl arsine	Zinc peroxide
Trimethyl stibine	Zinc phosphide

(3) Oxidizing substances

Oxidizing substance ordinarily has the property of oxidizing other substances and, as such, is also referred to as oxidizing agent. These are solid and liquid substances with powerful oxidizing ability that reacts violently due to heating, impact and contact with other chemical substances, and etc. Hazardous substances that belong to the category of oxidizing substance ordinarily are non-flammable substance and are strong oxidizing agents that contain large quantity of oxygen that can oxidize other substance. Therefore, it has strong reaction and easily discharges oxygen by being degraded by hating, impact, friction, and etc. However, when they are mixed with combustible substance, which can be considered the reductants with opposite properties, they violently combust and can even explode depending on the situations. In addition, they can be decomposed through contact with other chemical substances such as concentrated sulfuric acid.

When storing or handling oxidizing substance, conditions that easily allow decomposition such as easy heating, impact, friction and etc. must be avoided. In

addition, contact with drugs that can accelerate decomposition must be prohibited and they have to be stored in cool location with good ventilation. In particular, moist proofing measures must be taken for substances with hydroscopic property and have to be stored in tightly sealed container.

In the event of fire by oxidizing substance, unlike the ordinary combustion in the air, supply of oxygen occurs due to decomposition of the oxidizing agent, thereby resulting in violent combustion but also fierce decomposition of the hazardous substances themselves occurs. Therefore, extinguishing method that prevents the decomposition of the oxidizing agent must be chosen. For example, cooling with water to lower the temperature below the decomposition temperature to inhibit the combustion of the combustible substances as well as preventing continued combustion simultaneously would be a recommended method.

Furthermore, peroxides of alkaline metals such as potassium peroxides, sodium peroxide, barium peroxide and etc. among the oxidizing substances have the property of generating heat by reacting with water (decomposes on their own by the moisture in the air). Therefore, particular care must be taken to prevent them from coming in contact with water or moisture during storage or handling and water must not be used to extinguish them. They must not be stored with other oxidizing substance in the same location in consideration for the issues to be noted for extinguishing of fire.

(4) Flammable substances

Flammable substances are combustible liquids with flash point of less than 65℃ under atmospheric pressure and are easily ignited and combust at room temperature. Even the substances with high boiling point require particular precautions if they have low flash point because they can be easily ignited by embers or flame, and etc. with temperatures above their flash point.

It must be remembered that substances such as 2-butanol with flash point

of 24℃, which is in the vicinity of room temperature, has the risk of being ignited indoors although ignition during winter is difficult. During the summer, the atmospheric temperature exceeds the flash point of 2-butanol with substantially increased risk of ignition. Therefore, particular precautions must be taken for the temperatures of the liquid and gas of substances with flash point in the vicinity of room temperature.

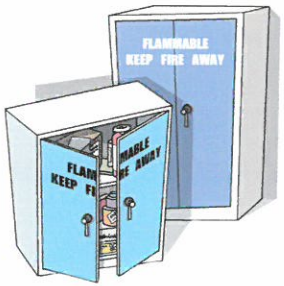
Majority of the vapor generated from the flammable substance is heavier than air and has the risk of inducing violent explosion even by insignificant sources of ignition when it is mixed with air. In addition, many liquids that belong to the category of flammable substance are not soluble and widely spread on the surface of the water due to their density lower than that of water. Therefore, major accident can occur if flammable substance unexpectedly flows into lower locations such as sewers and ignited by insignificant source of ignition.

When managing and using flammable substance, aforementioned states and hazards of these substances must be considered sufficiently by using GHS/MSDS data or chemical handbook, and it is important to make preparations for measures to be taken against sources of ignition such as static electricity and fire, and etc. Also, emergency measures should be taken in the event of ignition in advance to prevent leakage of liquid or vapor.

Example of chemicals with low flash point

- Pentane(-49)
- Acetaldehyde(-38)
- Cyclohexane(-21)
- Tetrahydrofuran(-14)
- Methanol(11)
- Allyl alcohol(21)
- Ethyl ether(-45)
- Carbon disulfide(-30)
- Acetone(-17)
- Ethyl acetate(-4)
- Isopropanol(12)
- Xylene(25)

(No. in the parenthesis is the flash point in Celsius (℃))



(5) Combustible gas

Hazardous substances that belong to the category of combustible gas include hydrogen, acetylene, ethylene, methane, ethane, propane, butane and etc. that exist in gaseous state at the temperature of 15℃ and one atmospheric pressure. These combustible gases undergo gaseous explosion when ignited at prescribed concentration range for each of the gases if they are mixed with air or oxygen and confined within closed space.

The range of concentration in which gaseous explosion is induced is referred to as the explosion limit. Combustible gases being regulated by law has lower limit of the explosion limit concentration of less than 10% or the difference in the upper and lower limit of more than 20%. Substances such as timber that are not in gaseous state but can easily combust if heated although they do not ignite at room temperature are referred to as combustible substance. Many liquids and solids belong to this category and majority of organic chemical substances are combustible substances.

Recently, combustible gases are being stored and consumed under highly pressurized state and, in such case, the risk of accidents increases substantially. Accidents that occur due to the high pressure of the combustible gases include gas explosion due to the ignition of gases erupted from the gas tank that has been ruptured or ignition of leaked gas because of the breakage or damages to the joints of the pipeline being used. Precautions are needed since damages are incurred not only by the personnel involved but also the surrounding researchers in many cases.

(6) Corrosive substance

These are oxidizing substances or strong acidic substances that easily corrodes metal or plastic, etc. and induces serious injuries such as burns when they come into contact with human body. Following are some of the examples.

① Acids

- Acids such as hydrochloric acid, sulfuric acid and nitric acid with concentration of more than 20% and those with similar or higher level of corrosiveness
- Acids such as phosphoric acid, acetic acid, hydrofluoric acid, etc. with concentration of more than 60% and those with similar or higher level of corrosiveness

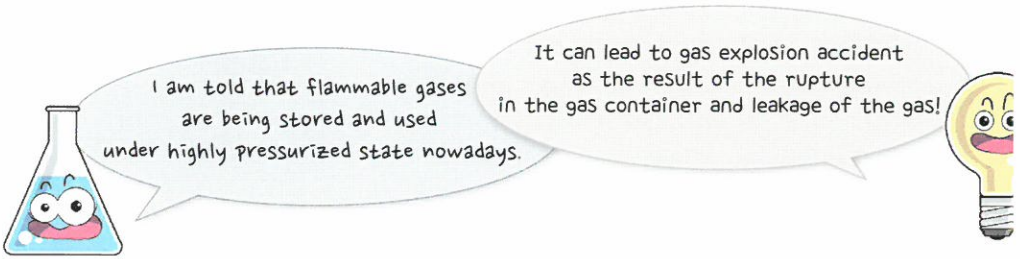
② Bases

- Bases such as sodium hydroxide and calcium hydroxide with concentration of more than 40% and those with similar or higher level of corrosiveness

Table 3-3 Classification of chemical substances in accordance with the chemical and physical properties

Type (properties)	Chemical substances
Oxidizing solid (Class 1 hazardous substances)	Chlorite
	Perchlorate
	Inorganic peroxides
	Chlorate
	Bromate
	Nitrate
	Iodate
	Permanganate
	Dichromate
Chlorate Bromate Nitrate Iodate Permanganate Dichromate	White phosphorous
	Red phosphorous
	Sulfur
	Iron
	Magnesium
	Metal powder
	Flammable solid
Natural pyrophoric and water reactive substance (Class 3 hazardous substances)	Potassium
	Sodium
	Alkyl aluminum and alkyl lithium
	White phosphorous
	Alkaline metal (with exclusion of potassium and sodium) and alkaline earth metals
	Organic metal compounds (with the exception of alkyl aluminum and alkyl lithium)
	Metallic hydrogen compounds
	Metallic phosphorous compound
	Calcium or aluminum carbides

Type (properties)	Chemical substances
Flammable liquid (Class 4 hazardous substances)	Special phosphorous substances
	Category 1 petroleum (non-aqueous), flash point of less than 21℃
	Alcohols
	Category 2 petroleum (non-aqueous), flash point in the range of 21℃~70℃
	Category 3 petroleum (non-aqueous), flash point in the range of 70℃~200℃
	Category 4 petroleum, flash point in the range of 200℃~250℃
	Animal and vegetable oils
Self-reactive substance (Class 5 hazardous substances)	Organic peroxides
	Nitrate ether
	Nitro compounds
	Nitrous compounds
	Azo compounds
	Diazon compounds
	Hydrazine and derivatives
Oxidizing liquid (Class 6 hazardous substances)	Perchloric acid
	Hydrogen peroxide
	Nitric acid
	Halogenated compound



3. Method of storing chemical substances

(1) General issues

- Store in cool and dark locations with good ventilation but without direct sunlight.
- Do not keep chemical substances on the floor.
- Store appropriate quantity of reagents on the shelves with bars to prevent the containers from falling off the shelves.
- Classify the substances in accordance with their respective characteristics and separately store them in designated locations.
- Do not store reagents at heights higher than the height of the eyesight.
- Store glass containers at low and safe location in preparations for their breakage.
- Store chemical substances with large volume on the lower portion of the shelves.

(2) Safety and appropriate description (label)

- Gas leakage alarm, fire detection system and fire extinguisher must be equipped.
- Acid neutralizer [$NaHCO_3$, $Ca(OH)_2$, $Mg(OH)_2$, MgO, etc.] to cope with acid leakage and alkaline neutralizer [$FeSO_4$ H_2O, $Al_2(SO_4)_3$ H_2O, etc.] to cope with alkaline leakage as well as substances to be used for removal of the leakage must be prepared.

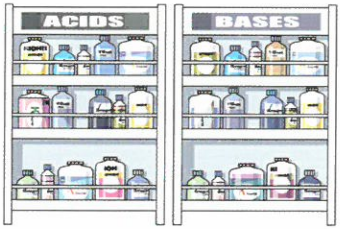
- Emergency shower and eye washer must be installed.
- Contents must be listed clearly on the label, which must not be defaced and must be read easily.
- In the location where combustible and flammable vapor stay, do not use equipment and devices that generate spark, and electric equipment must be earthed and be of explosion proof type.

(3) Locking

- Toxic chemical products must be stored in safety cabinet with locking devices.
- Solvents must be tightly sealed for storage.
- Substances that generate gases must be treated regularly to remove the gas (pressure) generated.
- Continuously check the presence of damages to the cover of the container for storage of substances.

(4) Acids and bases

- Store acids and bases separately.
- Store acids in exclusive cabinet.
- Store nitric acid, which has a strong oxidation property, separately.



Hazardous acids that require particular precautions

- Nitric acid

  It is a highly corrosive and combustible oxidizing agent. Nitric acid is a hazardous substance that forms combustible and explosive compound by being combined with many other substances that needs to be stored separately particularly from other combustible substances.

- Perchloric acid

  It must not be stored for more than a year since it voluntarily forms explosive substance. In particular, it forms highly explosive and unstable compound when combined with organic compound and metals. As such, only the minimum quantity should be purchased and stored.

- Picric acid

  It can explode if stored in dried state. It must be stored in locations with high moisture contents since it can explode even when shaken. In particular, it must be kept separately from combustible substance since it can form explosive compound when combined with such.

- HF

  It is highly corrosive and can even corrode glass. Enrichment as well as diluted solution can penetrated deep into the skin when contacted and induce severe burns. Inhalation of HF vapor can induce serious inflammation of the respiratory tissues and may be detrimental. Therefore, it must be handled highly prudently.

(5) Combustible liquid

- Generates vapor that can catch fire or explode.
- Store in location without any source of ignition.
- Store in cool and dry location with good ventilation by using cabinet exclusively for the substance.

- Keep only the minimum quantity of combustible liquid that can be used in a short period of time.
- Explosion prevention equipment must be available.
- Use explosion proof refrigerator if possible.

(6) Peroxides

- They are one of the most hazardous substances handled in the laboratory.
- Highly sensitive towards oxidizing agent, reductants, heat, friction, impact and light
- Some compound forms peroxide with passage of prolonged period of time.
- Store the peroxide in metal container.
- Peroxide or substances that generate peroxide must be stored in cool and dark locations.
- Check the presence of hazards at every 3~6 month intervals and dispose of them if deemed hazardous.

(7) Corrosive substance

- Corrosive substances are divided into 4 major categories, namely, strong acid, strong base, desiccant and oxidizing agent.
- When mixing or diluting solution, only a small quantity of the acid must be diluted in large quantity of water.
- Store in cool and dry location with good ventilation
- Store separately from metal, combustible substance and oxidizing substance.

(8) Oxidizing agent and reactive substance

- Special precautions are necessary for highly reactive substance and explosive substances.
- If the reaction rate is high, abundance of heat is generated and even explosion can be induced.
- Reacts with water violently.
- It must be handled in wide location with sufficient cooling system.
- Store separately from combustible liquid, organic substances, desiccant and reductants.

Table 3-4 Standard for prohibition of storing together the hazardous substances belonging to different categories

Classification of hazardous substances	Oxidizing solid	Combustible solid	Spontaneously igniting and water reactive substance	Flammable liquid	Self-reactive substance	Oxidizing liquid
Oxidizing solid		×	×	×	×	○
Combustible solid	×		×	○	○	×
Spontaneously igniting and water reactive substance	×	×		○	×	×
Flammable liquid	×	○	○		○	×
Self-reactive substance	×	○	×	○		×
Oxidizing liquid	○	×	×	×	×	

※ ○: Can exist as a mixture × : Cannot exist as a mixture

※ This table will not be applied to the hazardous substances less than 1/10 of the designated quantity.

(9) Carcinogenic and toxic substance

Exposure to harmful elements at the level below the exposure standard does not impart adverse health effect in most cases. However, if harmfulness chemical substances induce cancer by being exposed to large quantity of the corresponding chemical substances for prolonged period of time, they can be classified as carcinogen.

The carcinogen monitoring network and the carcinogen information center of the Institute of Labor Environment and Health Research drafted the 'Carcinogen List 1.0' containing a total of 1,420 types of chemical substances designated as carcinogen by utilizing the databases of the 5 international institutions related to carcinogen (International Agency for Research on Cancer, EU, National Toxicity Program, Environmental Protection Agency of USA and the American Conference of Governmental Industrial Hygienists) in 2012. The 'Carcinogen List 1.0' includes 368 Class 1 substances (substances carcinogenic to human), 719 Class 2 substances (substances presumed to be carcinogenic to human) and 333 Class 3 substances (substances with possibility of being carcinogenic to human). Although this List currently does not include mutagenic substance, reproductively toxic substance, environmental hormone or biologically accumulated residual substance, List is scheduled to be updated by including these substances in the future. The corresponding excel file of the List can be downloaded from the following website.

Institute for Labor Environment Health Research, Work and Health
safedu.org/pds1/10686

In addition, the Ministry of Employment & Labor specified the exposure standard of a total of 717 types of harmful chemical substances with carcinogenicity, germ cell mutagenicity and reproduction toxicity through the Announcement No. 2013-38, "Standard for exposure to the chemical substances and physical elements" <Attachment 1> (refer to the Appendix 8). Among these, 190 types of carcinogenic substance were included and descriptions on the carcinogenic information were given on their harmfulness in accordance with the

「Standards on the Classification and Description of Chemical Substances, and MSDS」. The standards for classification of carcinogen are as follows:

- 1A: Substances with sufficient evidence of carcinogenicity in man
- 1B: Substances with sufficient evidences of carcinogenicity in experimental animal or limited evidence of carcinogenicity in both experimental animal and man
- 2: Substances with limited evidences in man and animals, but not sufficient evidences for classification into Category 1.

The list of the chemical substances of the 'Carcinogen List 1.0' and "Exposure Standard for the Chemical Substances and Physical Elements" <Attachment 1> can be utilized in making reference to the hazardousness of the chemical substances used during research activities and their exposure limits, and to evaluate the extent of the harmfulness of the research environment by those engaged in research activities themselves.

Toxic substances are classified into those with serious to no or weak toxicity due to chronic exposure, intermediate toxicity and virulent toxicity. Substances that are particularly hazardous are the virulently toxic substances. When using virulently toxic substance, it is advisable to attain the approval of the laboratory administrator. The standards for the toxic substances that require the approval of the personnel responsible for the laboratory are as follows:

- Chemical substance for which the quantity that can induce death of 50% of experimental animal through oral administration to rat, that is LD_{50} (oral, rat) is less than 200mg per kg (of the body weight), etc.
- Chemical substance for which the quantity that can induce death of 50% of experimental animal through percutaneous absorption by rat or rabbit, that is LD_{50} (percutaneous, rabbit or rat) is less than 400mg per kg (of the body weight), etc.

- Chemical substance for which the quantity that can induce death of 50% of experimental animal through 4 hours of aspiration by rat, that is LD_{50} (rat, 4 hours of aspiration) is less than 2,000mg per kg (of the body weight), etc.

Prevention of exposure to carcinogenic substance or toxic substance in advance is essential in establishment of safe research environment. Therefore, prior to using the chemical substances, all researchers must obtain information on the carcinogenicity and toxicity of the chemical substances by using GHS/MSDS and familiarize themselves with their characteristics. In addition, they must be prepared for safety accidents by familiarizing with the following issues:

- Minimize the quantity of the carcinogenic and toxic substance stored and handled in the laboratory.
- Regularly inspect the storage and handling location, and the joints for any leakage.
- Highly toxic substance must be stored in a safe location with locking device.
- Storage area must be equipped with ventilation equipment.
- Wash hands thoroughly and immediately after having used carcinogenic and toxic substances.
- Never taste chemical substances, or eat food or drink beverage in the laboratory.

4. Illustration of the classification and storage method of chemical substances

Following are the illustrations of the storage methods for chemical substances using shelves. Guide bar for prevention of tipping over and falling as well as furnish ledger for management of the reagents in the corresponding reagent cabinet.

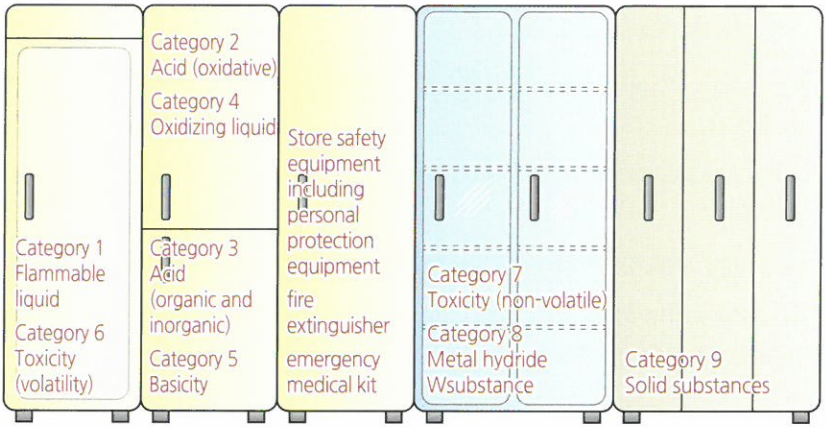
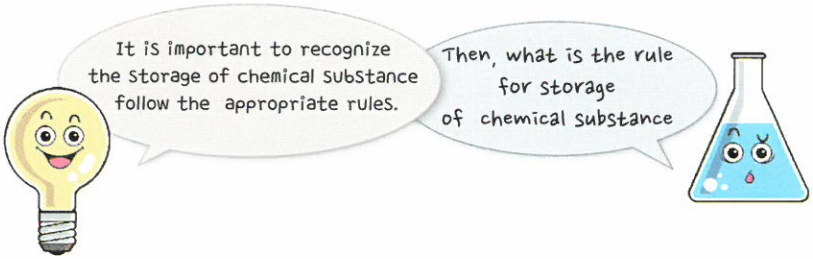
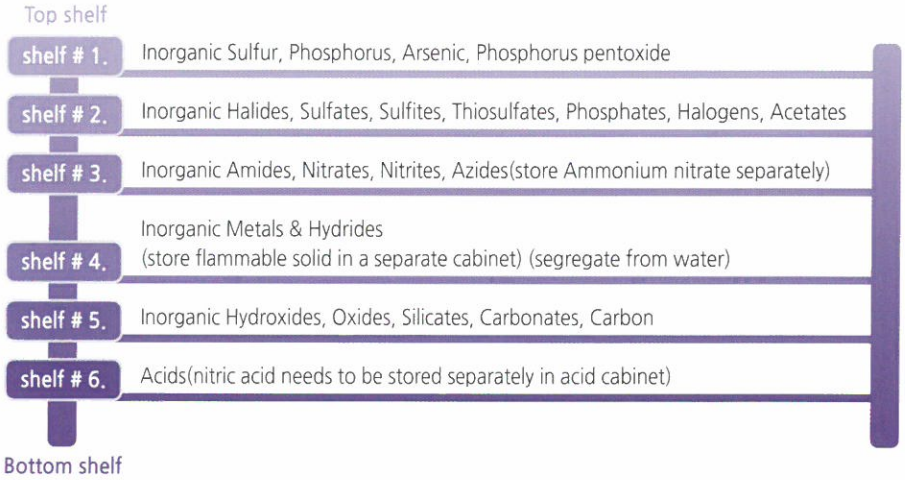


Fig. 3-1 Safe method of storing chemical reagents

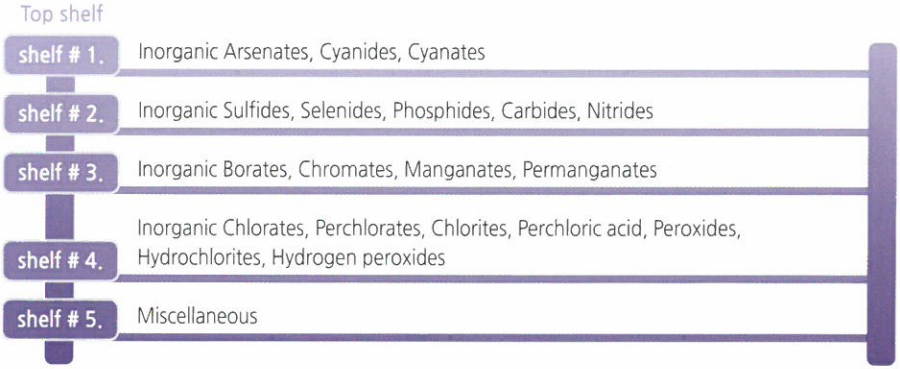


(1) Storage of inorganic substances

- Illustration 1

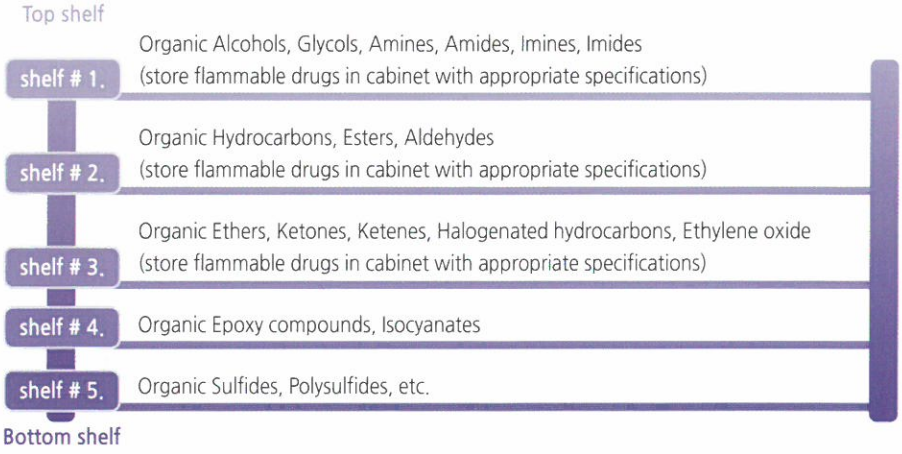


- Illustration 2



(2) Storage of organic substances

- Illustration 1



- Illustration 2

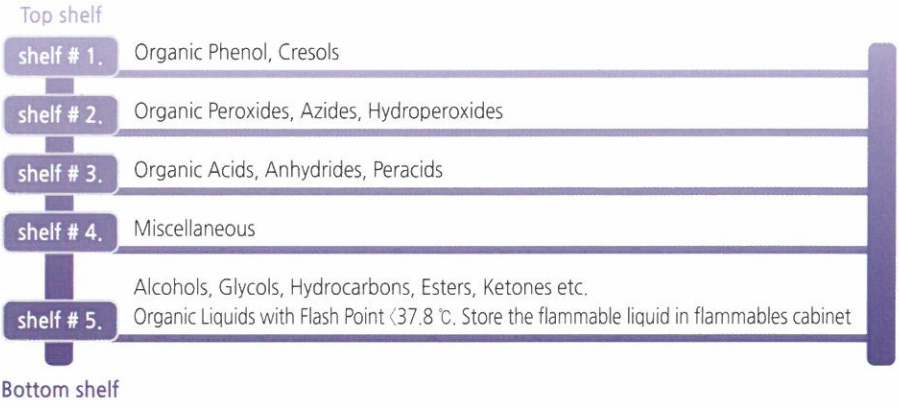


Fig. 3-2 Storage of chemical substances (for each characteristics and phases, and distinguish those that cannot be stored together)

Fig. 3-3 Closed type ventilated reagent cabinet for hazardous reagents

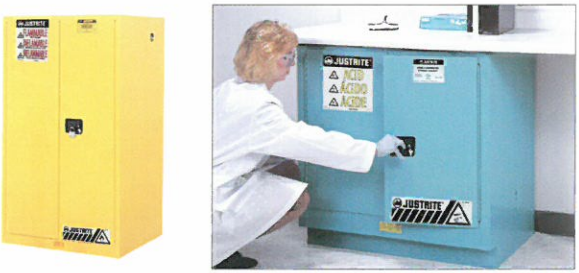


Fig. 3-4 Example of safety cabinets exclusively for flammable solution (left) and corrosive solution (right) (UL specification)

Fig. 3-5 Example of compression tank for storage of volatile organic substances

Table 3-5 Guideline on separation and storage of chemical substances

Categories	Recommended storage methods	Examples of chemical substances	Substances that cannot be stored together *Always refer to MSDS!
Flammable liquid	Store separately in the safety cabinet exclusively for flammable solution	Acetone, benzene, do-ethyl ether, methanol, hexane, pentane, xylene, toluene, etc.	Oxidizing agents, acids
Organic acid & base	Store separately in the safety cabinet exclusively for acid	〈Acid〉 Aldehydes, peracids, acetic acid, lactic acid, tri-chloroacetic acid, formic acid, etc. 〈Base〉 Hydroxyl amine, tri-ethyl amine, piperazine, etc.	Flammable liquids, flammable solids, bases, oxidizing agents and inorganic acids
Inorganic acid & base	Separately store in safety cabinet exclusively for acid	〈Acid〉 Phosphoric acid, hydrochloric acid, sulfuric acid, chromic acid, nitric acid, etc. 〈Base〉 Ammonium hydride, ammonia, calcium oxide, hydrazine, sodium hydroxide, calcium hydroxide, etc.	Flammable liquids, flammable solids, bases, oxidizing agents and inorganic acids
Water reactive substance	Store in cool and dry location Separately store water and source of ignition Attach hazardous substance label	Sodium metal, calcium metal, lithium metal, metal hydride, etc.	All aqueous solutions and all oxidizing agents
Oxidizing agent	Store separately in non-flammable cabinet	Sodium hypochloride, benzyl peroxide, potassium permanganate, potassium chlorite, etc.	Reductants, flammable substance, substances that can be the source of ignition, organic substances

Table 3-6 Features of the reagent cabinet for storage of chemical substances

	Ordinary reagent cabinet	Closed type reagent cabinet	Exhaust type reagent cabinet	
Features	Ordinary wooden reagent cabinet	Internal circulation type (ion cluster)	Indoor exhaust type (filter type)	Outdoor exhaust type (duct type)
Advantages	• Can store reagent and glasses • Ease of classified storage and management of reagent due to use of drawers	• No energy loss • Ion cluster that can be used semi-permanently	• Harmful gas do not remain in the cabinet • No need for ducting system • No energy loss	• Maintains the laboratory safely • Can store a diverse range of reagents
Dis-advantages	• Storage of a limited range of reagents • Cannot store harmful substance • Cannot store substances that generate harmful gas	• Inappropriate for storing of acid • Limitation on the reagents that can be stored • Generation of ozone due to the use of ion cluster • Harmful gas stays in the cabinet	• Cost incurred due to replacement of filter • Indoor discharging of contaminated air if the filter system is damaged • Use filters appropriate for the use (HEPA, Carbon)	• Environmental pollution due to discharging of harmful substance to outdoor • Loss of energy • Require construction of ducting facility
Others	• (Overseas) Store the hazardous reagents together by systemizing the classification and labeling of them • Can convert it into exhaust type by additionally installing ducting facility	• (Overseas) Not used ordinarily and use exhaust type or safety reagent cabinet instead • Appropriate for storage of powdered reagents stored for prolonged period of time	• (Overseas) For storage of non-flammable substance	• (Overseas) Use for the purpose of external discharging after having installed filter system • For storage of non-flammable substance

5. Examples and prevention of accidents that occur during storage of chemical substances

(1) Examples of accidents

Examples of safety accidents that occur at the time of long term storage of the chemical substances in methods that are not appropriate for the substances are given below.

① Fire accident in accordance with flammable, explosive substance

- Overview of the accident: Fire accident due to spark generated by the generator in the refrigerator of the laboratory
- Overview of the accident: Accumulation and staying of the hazard substance within the refrigerator due to the use of ordinary refrigerator without ventilation, failure to separately store flammable, pyrophoric and explosive substance such as molybdenum oxide, butyl lithium, diazomethane, acetic ester and organic peroxide, etc., and failure to install explosion proof facility.

② Heat generation due to reactions between the substances

- Overview of the accident: Generation of heat due to the mutual reaction of oil vapor generated from the chemical substance
- Overview of the accident: Falling off of the reagent in the reagent cabinet that has not been stored separately was the causes of the accident.

③ Natural explosion due to wager reactive substance

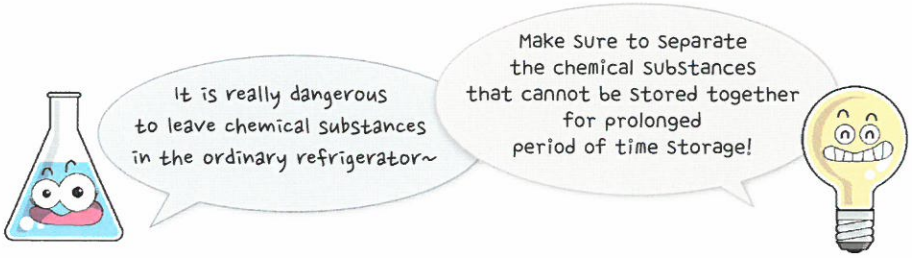
- Overview of the accident: Explosion accident due to aluminum powder stored for long term in the ordinary reagent storage cabinet
- Overview of the accident: Spontaneously ignition and explosion of the aluminum powder, which is a wager reactive substance, due to the absorption of the moisture in the air was the cause.

Fig. 3-6

Site of explosion accident involving reagent in refrigerator

Fig. 3-7

Site of accident due to falling over of reagent stored in reagent cabinet



(2) Method of prevention and coping with accidents

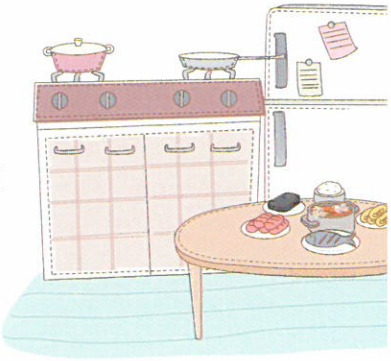
- Separately store chemical substances by categorizing them in accordance with their characteristics.
- Check the GHS/MSDS prior to storage to assess the chemical substances with different properties, in particular, the substances that cannot be stored together, avoid mixing and storing them in the same reagent cabinet.
- Do not store flammable, pyrophoric and explosive chemical substances in ordinary refrigerator.
- Store in flammable reagent cabinet or exhaust type reagent refrigerator that can prevent the leakage of liquid or vapor by sufficiently considering the state and hazardousness of the substances.
- Store reactive chemical substances in cool location with good ventilation by separating them from each other, and by maintaining distance between the reagents to avoid contact between the chemical substances.
- Take precautions for the temperature, moisture and ventilation for the storage of substances that induce spontaneously igniting through progressing of decomposition for prolonged period of time.
- Prepare measures against sources of ignition such as static electricity and fire, etc. and emergency measures to be taken at the time of ignition in advance.

Wisely block out the chemical substances that has infiltrated into our daily lives

Wisely reduce and find out about chemical substances meticulously!

Countless number of chemical substances that we are in contact with in our daily lives

Although it may not be possible to completely block them, wisely reduce the incidences of coming in contact with them in order to safeguard our health!



Glass devices

★ Kitchen where you cook food
★ Wardrobe closet for storage of clothes

Wash frequently

★ Washing hand prior to meal and after having visited the washroom

Use less oil

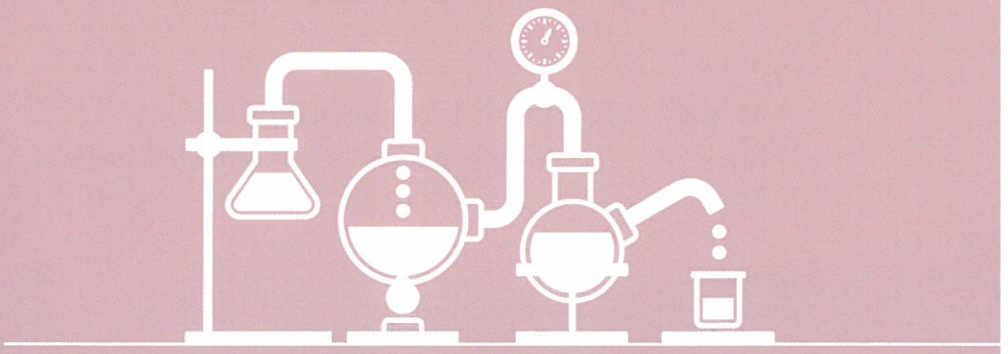
★ Refrain from stir frying or deep frying food in oil
★ Using less oil when cooking food
★ Steaming or boiling at high temperature

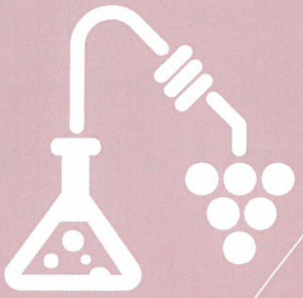
Use and store well

★ Make sure to properly put the cap on the cosmetic products or detergents you used

Standard Textbook for Safety in Laboratory

Safety Before the Experiment





Appendix

1. Summary of legal basis related to MSDS
2. Definition of terminologies used under the GHS system
3. Integrated harmfulness, hazardousness and precautionary statements (code) under GHS
4. Content composition of GHS/MSDS
5. Example of GHS/MSDS (Benzene)
6. Method of search data in GHS/MSDS
7. Substances that must not be stored together
8. Substances for comparison of physical hazards of GHS/MSDS

Appendix 1 Summary of legal basis related to MSDS

Drafting, familiarizing and execution of MSDS are very important for safe handling and management of chemical substances. Drafting documents and execution related to this should be on the basis of the Industrial Safety and Health Act of the Ministry of Employment & Labor. However, it is possible to further enhance the effects by understanding the law on management of harmful chemical substances of the Ministry of Environment, law on the registration and evaluation of harmful chemical substances, and law on management of chemical substances and the Law on safe management of hazardous substances of the Ministry of Public Safety & Security (hereinafter the implementation order and act, and relevant announcements). Brief introduction of the key contents of the relevant laws is given below.

1 Industrial Safety and Health Act

Article 41 (Drafting and furnishing of MSDS, etc.)

① Those who assign or provide chemical substances that correspond to the classification standards stipulated by the Order of the Ministry of Employment & Labor must draft and provide "MSDS".

1. Name of the chemical substances subjected, and name and contents of the constituent ingredients

2. Safety and health precautions in handling
3. Health hazard and physical hazard
4. Other issues stipulated by the Order of the Ministry of Employment & Labor

② Those assigning or providing chemical substances acknowledged to have the justification for protection of confidential business information may be exempted from disclosing the information in accordance with the stipulations made by the Order of the Ministry of Employment & Labor. However, the subject chemical substances with concerns for inducing material health disability in workers will be excluded from such exemption.

③ Business operator must post or furnish MSDS in the work place that handles the subject chemical substances.

④ Those assigning or providing the subject chemical substances must put warning sign and description on the container and packaging of the substances.

2 Articles 86 and 92 of the Implementation Rule of the Industrial Safety and Health Act

Article 86 (Submission of examination report on the harmfulness and hazard of new chemical substances)

① Those wishing to manufacture or import new chemical substances must submit data, toxic test performance report, documents recording the methods of manufacturing, using and handling the substance, manufacturing or application procedure diagram, and other relevant documents on the safety and health of the corresponding new chemical substances to the Minister of Employment & Labor.

3 Announcement No. 2013-37 of the Ministry of Employment & Labor

Standard on the classification, description and MSDS of chemical substances

Article 4 (Classification of chemical substances, etc.)

① Detailed standards for classification for each of the categories of chemical substances are given in the Attachment 3.

② The detailed standards of the test necessary in classification of the chemical substances shall comply with the Guidelines of the [Globally Harmonized System of classification and labelling of chemicals (GHS)] stipulated by the United Nations (UN).

Article 5 (Attachment of warning label)

① Those assigning and providing the subject chemical substances must indicate clearly the harmfulness and hazard information of the corresponding subject chemical substances by attaching or printing warning label in Korean language (including the warning label that contains information in both the Korean and foreign language) on the container or packaging. However, for the reagent used for the purpose of testing and research in experimental laboratory with warning label written in foreign language attached to it or articles in storage or transportation for shipping, the requirement for attachment of warning label in Korean language can be exempted.

Article 6 (Method of drafting warning label)

① Pictogram, signal word, harmfulness and hazardousness statement and precautionary statement to be included in the warning label are illustrated in the Attachment 3.

Article 6-2 (Method of drafting of the items to be included)

① The name of the product under MSDS shall be entered.

② Pictogram shall describe all the issues that corresponds to the Attachment 3. However, if any of the following items apply, comply with the corresponding item.

1. If it corresponds to both the "Skull and crossed bone" and "Exclamation mark(!)" pictograms, attach only the "Skull and crossed bone" pictogram.
2. If it corresponds to both the corrosive pictogram and irritation pictogram, attach only the corrosive pictogram.
3. If it corresponds to both the respiratory sensitizing pictogram and skin sensitizing pictogram, attach only the respiratory sensitizing pictogram.
4. If it corresponds to more than 5 pictograms, it is allowed to attach only 4 pictograms.

③ Signal words include "dangerous" and "warning". If the subject chemical substances correspond to both the "danger" and "warning", attach only "dangerous"

④ Describe all the corresponding harmfulness and hazardousness statements.

⑤ Describe only the corresponding precautionary statement. However,

1. Repeated precautionary statement can be omitted or describe by combining the similar precautionary statement.
2. If there are more than 7 precautionary statements, describing only 6 statements that include more than 1 each of the prevention, countermeasure, storage and disposal statements.

Article 10 (Items to be listed)

① Comply with the items and order of the listing to be included at the time of drafting MSDS (refer to the Chapter 4. Items and issues to be listed in drafting MSDS(GHS/MSDS)).

Article 11 (Principles in drafting)

① In principle, MSDS should be drafted in Korean language but proper nouns such as the name of the chemical substances and foreign institution can be written in English.

② In spite of the Clause ① above, if the reagent used for the purposes of testing and research in experimental laboratory is drafted in foreign language in MSDS, the content need not be translated into Korean language.

③ In the event of reflecting the test results at the time of drafting each of the items of the Clause ① of Article 10, the results of test that has been executed in accordance with the Good Laboratory Practice (GLP) of the corresponding country and Korea Laboratory Accreditation Scheme (KOLAS) must be considered with priority.

④ In the event of translating the MSDS written in foreign language, the name of the institution that drafted the MSDS first and the time of this drafting must be listed in order to secure the reliability of the data, and, in the event of drafting MSDS by utilizing other forms of relevant data, the sources must be listed in the Reference section.

4 Article 28 of the Implementation Rules of the Law on management of harmful chemical substances

(Method of describing toxic substances, etc.)

① In the description of the toxic substances, all of the following must be included:

1. Name: Information on the name of the toxic substances or the product
2. Pictogram: Diagram that illustrates the contents of the hazardousness
3. Signal word: Statement that describes the extent of the hazard as 'dangerous' or 'warning'
4. Harmfulness and hazardousness statement: Statement to describe the hazardousness

5. Precautionary statement: Statement of the measures to be taken to minimize or prevent hazard arising from inappropriate storage and handling, etc.
6. Supplier information: Information on the manufacturer or supplier, including name, telephone number and address

② The specifications for the description of the location for storage, keeping and displaying toxic substances to be placed on the transportation vehicle, container and packaging of the toxic substances is given in the Attachment 7.

- Attachment 6 related to Clause ① of Article 28 of the Implementation Rule: Hazard items for the description of the toxic substances

Classification of the hazardousness of toxic substances includes 16 categories of physical hazards, 10 categories of health hazards and 1 category of environmental hazard, and the details are as per the Announcement No. 2014-14 by the Ministry of Employment & Labor. However, for the health hazard, the respiratory sensitizing substances and the skin sensitizing substances are grouped into a single category for the total of 27 categories as in the case of GHS system of the UN.

5 Implementation Order on the Law on safe management of hazardous substances

Articles 2 and 3, and relevant Attachment 3

It is subjected only to the substances with properties such as flammability and pyrophoric (hazardous substances), which are managed by establishing the standard of designated quantity, and are classified into the following 6 categories.

Category 1 Oxidizing solid

"Oxidizing solid" refers to the solid [those that is not liquid (those in liquid state at the temperature of 20℃ under 1 atmospheric pressure or in the temperature range of 20℃ ~ 40℃) or gases (those in gaseous state at the temperature of 20℃ under 1 atmospheric pressure), and hereinafter the same] that display the properties and state stipulated by the announcement in the test determined and announced by the Minister of Public Safety & Security (hereinafter referred to as announcement) in order to determine the sensitivity towards the potential hazard or impact of oxidizing ability.

Category 2 Combustible solid

"Combustible solid" refers to the solid that display the properties and state stipulated by the announcement in the test determined and announced by the Minister of Public Safety & Security in order to determine the risks of ignition or combustion due to fire.

Category 3 Natural pyrophoric substance and water reactive substance

"Natural pyrophoric substance and water reactive substance" refer to solid or liquid that has the risk of ignition in the air, risk of ignition or generation of combustible gas when they come in contact with water.

Category 4 Flammable liquid

"Flammable liquid" refers to liquid (those belonging to the Category 3 petroleum, Category 4 petroleum, and animal and vegetable oil that is in liquid state at the temperature of 20℃ under 1 atmospheric pressure) with the risk of combustion.

Category 5 Self-reactive substance

"Self-reactive substance" refers to solid or liquid that display the properties and state stipulated by the announcement in the test determined and announced by the Minister of Public Safety & Security in order to determine the risks of explosion or fierceness of the decomposition when heated.

Category 6 Oxidizing liquid

"Oxidizing liquid" refers to liquid that display the properties and state stipulated by the announcement in the test determined and announced by the Minister of Public Safety & Security in order to determine the potential risks of oxidizing ability.

6 Law on registration and evaluation of chemical substances

implemented since 2015. 1. 1

Article 14
(Data to be submitted at the time of application for registration of chemical substances)

Article 18
(Hazardousness examination)

Article 19
(Hazardousness evaluation, etc.)

Article 29
(Provision of information on chemical substances)

① Information designated by the Order of the Ministry of Environment including registration number, name and information on the harmfulness and hazardousness and well as information on safe use of the corresponding chemical substances must be drafted and provided to the assignee of the chemical substances registered in accordance with the Article 10 or mixture that contains such substances by the assignor in accordance with the regulations stipulated by the Order of the Ministry of Environment. However, in the event of having to draft and

provide MSDS in accordance with the Article 41 of the [Industrial Safety and Health Act], the corresponding information must be recorded in the MSDS for provision.

7 Implementation Order on the Law on registration and evaluation of chemical substances

Article 8
(Subjects excluded from the reporting of manufacturing of chemical substances, etc.)

1. Chemical substances including reagent that are manufactured and imported for the purposes of scientific experimental analysis or chemical researches
2. Chemical substances that are manufactured and imported for the purpose of research and development, and corresponds to any one of the following:
   A. In the event of development of chemical substances or products, etc.
   B. In the event of improving and/or developing manufacturing process
   C. In the event of testing the application areas of the chemical substances in work places
   D. In the event of trial manufacturing of chemical substance or products
3. Non-separated intermediate product
4. Chemical substances announced after the Minister of Environment has decided on the chemical substances for which sufficient information that the harmfulness is very low has been known

8 Law on management of chemical substances implemented since 2015. 1. 1

Article 39 (Designation of the substance in anticipation of accident) The Minister of Environment shall designate and announce the substance among the chemical

substances that corresponds to any one of the following for which there is high level of concern for the occurrence of the chemical accident or concern that the damage will be substantial in the event of occurrence of chemical accident in anticipation of the accident in accordance with the stipulation by the Presidential Order.

1. Substances with high level of physical and chemical hazardousness including flammable, explosive and reactive substances and those with possibility of leakage.
2. Substances with high acute toxicity when administered orally, inhaled or exposed to skin
3. Substances that have been determined to impart hazard to the human health and environment by international organizations and international conventions
4. Other substances for which it is acknowledged that special management is necessary due to high level of concerns for occurrence of chemical accidents.

Article 48
(Establishment and operation of integrated information system for chemical substances)

① The Minister of Environment can establish and operate integrated information system for chemical substances in order to collect and distribute information related to the preparations and coping with the safety management of chemical substances and chemical accidents.

② The Minister of Environment shall information related to the safe management of chemical substances secured through the integrated information system for chemical substances in accordance with the Clause ① above to those who handle chemical substances, institutions related to coping with chemical accidents or to the people in accordance with the stipulations made by the Presidential Order.

9 Implementation Rules of the Law on management of chemical substances

Article 9 (Wearing of personal protective devices by those handling the substances) The "situations stipulated by the Order of the Ministry of Environment" in the Clause 1-4 of the Article 14 of the Law refers to the situation that corresponds to any one of the following:

1. In the event of handling harmful chemical substances in indoors such as experimental laboratory
2. In the event of having to take safety measures in the process of transferring harmful chemical substances to other facilities for handling
3. In the event of handling harmful chemical substances that are toxic when inhaled
4. In the event of loading or unloading harmful chemical substances
5. In the event of handling harmful chemical substances that induces irritation of the eyes or skin
6. In the event of carrying out maintenance and repair works for the facilities that handle harmful chemical substances
7. In the event of the making announcement by the Minister of Environment with the acknowledgement of the need for safe management of harmful chemical substances, other than the situations stipulated in the Clauses ① to ⑥ above.

10 Implementation Rules on the Law on management of chemical substances

[Attachment 3](Standards on handling of the harmful chemical substances)

1. Do not consume food or beverages while handling harmful chemical substances
2. Do not mix, store or transport harmful chemical substances along with grocery, animal feed, pharmaceutical products or food

3. When handling harmful chemical substances, do not wear contact lens. However, contact lens may be worn if appropriate protective eye glasses are worn.
4. Shower facility or eye wash must be installed within close vicinity of the location in which harmful corrosive chemical substances are handled in anticipation of emergency situations
5. When handling harmful chemical substances that can react with water, manage the corresponding substances to avoid their coming in contact with water.
6. In the event of handling harmful chemical substances that can react with water, make sure there is no accumulation of water in the water discharging wall, water collection facility and reservoir installed around the storage facility
7. Remove the sources of ignition such as heat, spark or flame, etc. from harmful chemical substances with high risk of fire or explosion
8. Make sure to earth the equipment used in handing harmful chemical substances with high risk of explosion. However, it may be exempted when there is no concern for occurrence of chemical accident.
9. Ensure that harmful chemical substances with high level of risks for fire or explosion do not come in contact with combustible substance
10. Do not smoke in the areas surrounding the location of manufacturing, keeping, storing and using harmful chemical substances
11. Do not handle harmful chemical substances within the range of scattering of embers generated from welding or cutting works using welding machines.
12. Do not perform welding works on the surfaces contaminated with harmful chemical substances. However, it may be performed after having taken safety measures including approval for fire related works.
13. Do not perform welding or cutting works with welding device on the container for harmful chemical substances with high level of fire and explosion hazard when source of ignition such as heat and spark comes into contact. However, if such works have to be performed unavoidably, perform the task after having substituted the inner part of the container with inert gas or after having secured safety through neutralization or cleaning.

14. Handle harmful chemical substances in closed space after having checked the presence of combustible, explosive gases or toxic gas, or deficiency in oxygen in the air.
15. In the event of storing different types of chemical substances in the same storage facility, compartmentalize the storage space by means of partition or division likes on the floor to put gaps necessary between them in considerations for the possibility of reaction between the chemical substances
16. Unstable substances such as explosive substances must be stored in the format of preventing explosion reactions
17. Package the harmful chemical substances to ensure that the contents are not leaked into the environment during handling, storing, loading and warehousing.
18. Store the harmful solid chemical substances in tightly closed state, and store liquid and gases under completely closed state.
19. The container must be made of material that is not deformed or damaged by the harmful chemical substances, and be equipped with appropriate material, thickness and structure in accordance with the properties of the harmful chemical substances
20. Container for storage of harmful chemical substances must be managed to ensure that it does not become damaged, corroded or cracked.
21. Do not use container with the risk of being damaged, or induce efflux or leakage during transportation. However, if containers with concerns for breakage such as glass given the characteristics of the harmful chemical substances have to be used unavoidably, it must be packed sturdily to withstand impact and does not become broken during transportation.
22. Ensure that the material used for the container including the cap does not undergo reaction with harmful chemical substances
23. Container must be the type not affected by atmospheric conditions including temperature, pressure and moisture
24. Container must be equipped with tightly sealing cap that can be tightly closed after having used the contents.

25. Do not smoke in or around the vehicle while unloading harmful chemical substances
26. Do not allow harmful chemical substances to come into food or animal feeds
27. Do not transport harmful chemical substances with other flammable substance or combustible substance
28. When transporting harmful chemical substances by using vehicle, comply with the stipulated speed limit
29. Do not transport harmful chemical substances by means of public transportation including bus, rail and subway
30. Do not forward harmful chemical substances through ordinary postage mail
31. Do not put harmful chemical substances in the area next to the driver's or passenger's seat of vehicles. Make sure to transfer them by placing them in the designated cargo section, which is covered with appropriate material after loading.
32. Make sure that the vapor or gas of the chemical substances are not leaked into the atmosphere when transporting harmful chemical substances
33. In the event of storing harmful chemical substances that are different from the chemical substances stored earlier, thoroughly clean internal aspect of the tank lorry and storage tank and dispose of the waste liquid in accordance with the [Law on management of wastes]
34. Take measures to prevent the risk of fire, explosion, efflux or leakage of the harmful chemical substances that may exist during their transportation
35. When transferring harmful solid chemical substances, make sure there is no scattering of the dust from such solid
36. When dropping harmful solid chemical substances into the hopper, conveyor or container, make sure that the distance of the fall is minimized. In such case, dust collecting facility must be installed to collect the dust generated when harmful solid chemical substances fall.
37. When transferring harmful solid chemical substances by putting it in container, make sure that it is not filled more than 90% of the capacity of the container

38. Handle harmful flammable chemical substances in liquid or atmospheric environment in which such substance does not react
39. Do not store or transport harmful flammable chemical substances with self-heating and self-reactive substance
40. In the event of generation of vapor when harmful chemical substances are measured and inputted into the process, install localized exhaust equipment to collect corresponding vapor
41. If all the harmful chemical substances in the container had been inputted into the process, tightly seal the container to prevent generation of vapor in the empty container or put it in the location installed with localized exhaust equipment.
42. Processes such as reactions, extraction, agitation, mixing, pulverization, sorting, filtering, dehydration and drying through which harmful chemical substances are generated must be carried out under closed or isolated state.
43. In the event of leakage of harmful chemical substances, take measures to prevent wide spreading of the leaked harmful chemical substances to wider areas
44. In the event of efflux and leakage of harmful chemical substances, restrict the access of other people and vehicles
45. Empty container after having used the harmful chemical substances should be disposed of in accordance with the 「Law on management of wastes」
46. In the event of handling harmful chemical substances, wear the personal protection equipment in accordance with the Clause 2 of the Article 14 of the Law

Remarks: In addition to the above criteria, specific criteria for handling for each of the harmful chemical substances will be announced by the Director of the National Institute of Chemical Safety though consultation with the heads of relevant institutions.

Appendix 2 Definition of terminologies used under the GHS system

- Terminologies are arranged in their alphabetical order.

Aspiration

Entry of liquid or solid chemical products into the respiratory tract or lower ranked respiratory system directly through mouth or nose, or indirectly through vomiting.

BOD/COD

Biochemical oxygen demand/chemical oxygen demand

Carcinogen

Chemical substances or mixture of chemical substances that induces cancer or increases manifestation of cancer

CAS

Chemical Abstract Service

Chemical identity

Name that allows accurate confirmation of the chemical substance. Name of the chemical substance in accordance with the naming system of IUPAC, CAS or technical names

Compressed gas

Pressurized gas, which is in completely gaseous state at the temperature of -50℃ (including all gases with critical temperature of less than -50℃)

Contact sensitizer

Substance that induces allergic reaction after it came in contact with the skin. Has the same meaning as skin sensitizer

Corrosive metal

Substance or mixture that practically damages metal (even destruction) due to chemical reaction

Critical temperature

Critical temperature at which pure gas can be liquefied regardless of compression

Dermal corrosion

Refer to the skin corrosion

Dermal irritation

Refer to skin irritation

Dissolved gas

Gas dissolved in liquid solvent due to compression

Dust: Solid particles scattered in the gas (commonly air) in the form of single substance or mixture

EC_{50} (Effective concentration)

Effective concentration of the substance that imparts measurable harmful effect on 50% of the subject organism

EU

European Union

Explosive article

Article that includes more than 1 explosive substance

Explosive substance

Solid and liquid substance or mixture of such substance that generates gas (that can induce damages to the surrounding with high speed under substantially high temperature and pressure) by its own chemical reaction. Although pyrotechnic substance may not generate, it is included in the category of explosive substance.

Eye irritation

Changes in the eyes that manifest after having treated the frontal surface of eyes with test substance, which are completely recovered within 21 days

Flammable gas

Substance in gaseous state at the temperature of 20℃ and under 1 atmospheric pressure that has combustion limit (flammable range)

Flammable liquid

Liquid with flash point of less than 93℃

Flammable solid

Solid that easily combusts or generates flame through friction

Flash point

The minimum temperature at which the substance can be ignited when the source of ignition is provided by having the substance form combustible vapor under particular test conditions

Gas

Substance whose vapor pressure exceeds 300 kPa at the temperature of 50℃ or substance that is in gaseous state under standard atmospheric pressure(101.3 kPa) at the temperature of 20℃

GHS

Globally harmonized System of Classification and Labelling of Chemicals

Harmfulness and hazard category

Divided standard within each of the harmfulness and hazard classes

Harmfulness and hazard class

Characteristic properties of physical hazard, health hazard and environmental hazard (example, combustible solid, carcinogenic substance and acutely toxic substance)

Harmfulness and hazardousness statement

Statement determined in accordance with the classification and categorization of harmfulness and hazardousness that illustrates the unique hazard of the harmful product including the extent of the appropriate harmfulness

ILO

International Labor Organization

Initial boiling point

Temperature at which the vapor pressure of liquid achieves equilibrium with the standard atmospheric pressure(101.3 kPa)

IPCS

International Program on Chemical Safety

ISO

International Standards Organization

IUPAC

International Union of Pure and Applied Chemistry

Label

It refers to the appropriate selection of the appropriate statement, prints or graphic information element on the harmful product in accordance with the relevant subject area. Label is fixed, printed or attached to the container, harmful product or its packaging and container

Label element

Harmonized form of information used in label (example, pictogram and signal word)

LD_{50} (50% lethal concentration)

It is the half lethal concentration, which is the concentration of chemical substances in air or water that kills 50% of the experimental animals

LD_{50} (50% lethal dose)

It is the half lethal dose, which is the quantity of chemical substance that kills 50% of the experimental animals

Liquefied gas

Pressurized gas, which is in partially liquid state at temperatures in excess of -50℃

(i) High pressure liquefied gas: Critical temperature is in the range of –50℃~ +65℃

(ii) Low pressure liquefied gas: Critical temperature is in excess of +65℃

Liquid

Substance for which the vapor pressure is less than 300 kPa(3 bar) at the temperature of 50℃ and is not in a completely gaseous state under the standard atmospheric pressure(101.3 kPa) at the temperature of 20℃, the melting point (or initial melting point) is less than 20℃ under the standard atmospheric pressure(101.3 kPa)

Mist

Minute particles of liquid of single substance or mixture dispersed in the gas (commonly air)

Mixture

Mixture or solution made of 2 or more chemical substances that do not react with each other

Mutagen

Inducer that generates or increases mutation in cells or organic body

Mutation

Permanent changes in the quantity or structure of genetic substance within the cell

MSDS

Material Safety Data Sheet

NGO

Non-governmental organization

OECD

Organization for Economic Cooperation and Development

Organic peroxide (Organic peroxide)

Liquid and solid substance or their mixture that contains 2 units of (-O-O-) structure and can be deemed as a derivative of hydrogen peroxide for which 1 or 2 hydrogen atom of hydrogen peroxide has been substituted by organic radicals

Oxidizing gas (Oxidizing gas)

Gas that combusts other substances better than air by ordinarily supply oxygen

Oxidizing liquid (Oxidizing liquid)

Liquid that is not combustible in its own but induces combustion of other substances by ordinarily generating oxygen

Oxidizing solid (Oxidizing solid)

Solid that is not combustible in its own but induces combustion of other substances by ordinarily generating oxygen

Pictogram (Pictogram)

A graphic combination that signifies addition of other graphic composition element to the symbol (boundary line, background pattern or color)

Pyrophoric liquid(Pyrophoric liquid)

Liquid that can ignite within 5 minutes of coming in contact with air even if in small quantity

Pyrophoric solid

Solid that can ignite within 5 minutes of coming in contact with air even if in small quantity

Pyrotechnic article

Product that includes more than 1 pyrotechnic substance or mixture

Pyrotechnic substance

Substance or mixture of substances made to generate heat, light, noise, gas, smoke or combination of such (as the result of non-explosive exothermic reaction that voluntarily continues)

Readily combustible solid

Substance in the form of powder, granule or paste that immediately becomes ignited when comes in contact with the source of ignition. It is a hazardous substance since the flame spread quickly

Refrigerated liquefied gas

Pressurized gas that is partially in liquid state due to low temperature

Respiratory sensitizer

Substance that induces sensitivity in the respiratory tract after inhalation

Self-accelerating decomposition temperature (SADT)

The lowest temperature at which self-accelerating decomposition occurs in package substance

Self-heating substance

Solid substance or liquid substance (with the exclusion of natural pyrophoric substance) that generates heat by itself by reacting with air without the supply of energy. Since large quantity of these substances are ignited when exposed for prolonged period of time (time or work), they are different from natural pyrophoric liquid or solid

Self-reactive substance

Thermodynamically unstable liquid, solid or mixture (with the exclusion of explosive substance, organic peroxide or oxidizing substance) that can undergo powerful exothermic decomposition process easily even without the involvement of oxygen

Serious eye injury

Damages to the eye tissues such as deterioration of eyesight, which is a serious physical injury, manifested after having treated the frontal surface of the eyes with test substance

Signal word

Words used to illustrate the extent of hazardousness (severity) on the label, and to warn people reading the label of the potential hazards. Signal words used under GHS are "Dangerous" and "Warning"

Skin corrosion

Irreversible damages of skin that manifest after having processed the test substance for 4 hours

Skin irritation

Reversible damages of skin that manifest after having processed the test substance for 4 hours

Skin sensitizer

Substance that induces allergic reactions when it comes in contact with the skin. Skin sensitizer and contact sensitizer are the same

Solid

Substance or mixture that does not correspond to the definition of liquid or gas

Substance

Chemical elements and their compounds obtain in nature or through production process. Includes the additives necessary to preserve the safety of product and impurities generated in the process used. Exclude solvent that can be separated without changes in the safety or composition of the chemical substances

Water reactive substance
(Substances which, in contact with water, emit flammable gases)

Solid substance, liquid substance or their mixture that voluntarily combusts through mutual reaction with water, or discharges quantity of flammable gas at the level of becoming hazardous

Supplemental label element

Supplementary non-standardized information that is not required or specified under GHS. Competent authority may request supplemental information or manufacturer/distributor may voluntarily provide supplementary information

Symbol

Graphic compositional elements to convey information simply and clearly

Technical name

Names that are used ordinarily in commercial activities, regulations and legal documents, and acknowledged by science societies, and names of chemical substances other than IUPAC name or CAS name. For example, the composite mixture (classification of petroleum or natural products), agricultural chemicals (ISO or ANSI System), dye (Color Index System) and mineral, etc.

UNCETDG/GHS
(United Nations Committee of Experts on the Transport of Dangerous Goods and on the Globally harmonized System of Classification and Labelling of Chemicals)

Committee of experts of UN on global harmonization system for transportation of hazardous substances and classification and labeling of chemical substances

UN

United Nations

UNEP

United Nations Environment Program

Vapor

Single substance of mixture in gaseous state discharged from liquid or solid state

WHO

World Health Organization

Appendix 3 Integrated harmfulness, hazardousness and precautionary statements (code) under GHS

(Ministry of Employment & Labor Announcement No. 2013-37)

1 Harmfulness and hazardousness statement

(1) Physical hazard

Code	Statement
H200	Unstable explosiveness
H201	Explosiveness: Major explosion hazard
H202	Explosiveness: Serious eruption hazard
H203	Explosiveness: Fire, blast or eruption hazard
H204	Fire or eruption hazard
H205	Can create major explosion at the time of fire
H220	Extremely flammable gas
H221	Flammable gas
H222	Extremely flammable aerosol
H223	Flammable aerosol
H224	Extremely flammable liquid and vapor
H225	Highly flammable liquid and vapor
H226	Flammable liquid and vapor
H228	Flammable solid
H240	If heated, can explode

Code	Statement
H241	If heated, fire or explosion may result
H242	If heated, fire may break out
H250	If exposed to air, ignites on its own
H251	Self-heating: Can induce fire
H252	Self-heating if exists in large quantity: Can induce fire
H260	Generates flammable gas that can be spontaneously ignited if contacted with water
H261	Generates flammable gas if contacted with water
H270	Induces or strongly arouses fire: Oxidizing agent
H271	Can induce fire or explosion: Powerful oxidizing agent
H272	Induces fierce fire: Oxidizing agent
H280	Including highly pressurized gas: Can explode if heated
H281	Including refrigerated gas: Can cause burns or damaged due to extremely low temperature
H290	Can corrode metals

(2) Health hazard

Code	Statement
H300	Detrimental when swallowed
H301	Toxic when swallowed
H302	Harmful when swallowed
H304	Detrimental when swallowed and enters respiratory tract
H305	Harmful when swallowed and enters respiratory tract
H310	Detrimental when it comes into contact with skin
H311	Toxic when it comes into contact with skin
H312	Harmful when it comes into contact with skin
H314	Induces serious burns on the skin and damages on the eyes
H315	Induces irritation on skin
H317	Can induce allergic skin reactions

Code	Statement
H318	Causes serious damage to eyes
H319	Causes serious irritation in the eyes
H330	Detrimental if inhaled
H331	Toxic if inhaled
H332	Harmful if inhaled
H334	Can induce allergic reaction asthma or breathing difficulties if inhaled
H335	Can induce irritation of respiratory system
H336	Can induce dizziness or giddiness
H340	Can induce genetic defects
H341	Suspected of inducing genetic defects
H350	Can induce cancer
H351	Suspected of inducing cancer
H360	Can induce damages to fetus or reproductive capabilities
H361	Suspected of inducing damages to fetus or reproductive capabilities
H362	Can be harmful to breast fed infants
H370	Causes damages to (...) of the body
H371	Can causes damages to (...) of the body
H372	Causes damages to (...) of the body if exposed for prolonged period of time of repeatedly
H373	Can causes damages to (...) of the body if exposed for prolonged period of time of repeatedly

(3) Environmental hazard

Code	Statement
H400	Highly toxic to aquatic organisms
H410	Highly toxic to aquatic organisms due to prolonged effects
H411	Toxic to aquatic organisms due to prolonged effects
H412	Harmful to aquatic organisms due to prolonged effects
H413	Can induce long term harmful effect on aquatic organisms

2 Precautionary statement

(1) Prevention

Code	Precautionary statement
P201	Secure user manual prior to use
P202	Read all the safety precautionary statements and do not handle unless you fully understand them
P210	Keep distance from heat, spark, flame and high temperature - no smoking
P211	Do not spray on flame or other sources of ignition
P220	Store by segregating it from clothing (...) combustible substance
P221	Take measure such that it is not mixed with combustible substance (...).
P222	Do not let it come into contact with air
P223	Do not let in come into contact with water as there is possibility of violent reactions and fire.
P230	Keep in wet condition with (...)
P231	Handle under inert gas
P232	Prevent moisture
P233	Tightly seal the container
P234	Only store in its original container
P235	Maintain at low temperature

Code	Precautionary statement
P240	Combine the container with aqueous facility or earth it
P241	Use explosion proof electrical ventilation and lighting (...)·equipment
P242	Use only the tools that does not generate spark
P243	Take measures to prevent generation of static electricity
P244	Ensure that grease or oil does not get smudged on the decompression valve
P250	Avoid grinding, impact·(...)·friction
P251	Pressurized container: Do not puncture holes or burn after use
P260	Do not inhale (dust, fume, gas, mist, vapor or spray)
P261	Avoid inhaling (dust, fume, gas, mist, vapor or spray).
P262	Do not let it come in contact with eyes, skin or clothing
P263	Do not come in contact during pregnancy and breast-feeding period
P264	Thoroughly clean the areas of handling upon completion of the handling
P270	Do not eat, drink or inhale when using this product
P271	Handle in outdoors or location with good ventilation.
P272	Do not take contaminated clothing out of the work site
P273	Do not discharge into the environment
P280	Wear (safety gloves, protective clothing, protective eye glasses, and facial protection equipment)
P281	Wear appropriate personal protection equipment
P282	Wear (thermally insulated glove, facial protection equipment and protective eye glasses)
P283	Wear fireproof and flame proof clothing
P284	Wear respiratory protection equipment
P285	Wear respiratory protection equipment in location with good ventilation
P231+P232	Handle under inert gas and prevent moisture
P235+P410	Maintain at low temperature and avoid direct sunlight

(2) Countermeasure

Code	Precautionary statement
P301	If swallowed
P302	Contact with skin
P303	Contact with skin (or hair)
P304	Inhaled
P305	Contact with eyes
P306	Contact with clothing
P307	Exposed
P308	Exposed or if there is concern for exposure
P309	If exposed or feel discomfort
P310	Immediately undergo examination by medical institution (doctor)
P311	Undergo examination by medical institution (doctor)
P312	undergo examination by medical institution (doctor) if discomfort is experienced
P313	Seek medical treatment and advices
P314	Seek medical treatment and advices if discomfort is experienced.
P315	Immediately seek medical treatment and advices
P320	Take (...) treatment promptly.
P321	Take (...) treatment
P322	Take (...) measures
P330	Wash out the mouth
P331	Do not induce vomiting
P332	If dermal irritation occurs
P333	If dermal irritation or red spots occurs
P334	Soak in cold water or wrap with wet bandage
P335	Brush off the substances smudged on the skin
P336	Thaw the frozen area with lukewarm water. Do not rub the damaged areas
P337	If irritation in the eyes continue

Code	Precautionary statement
P338	Remove contact les if possible. Continue to wash
P340	Move to location with fresh air and take rest in posture that makes breathing easier.
P341	If breathing becomes difficult, move to location with fresh air and take rest in posture that makes breathing easier.
P342	If symptoms in the respiratory system appear
P350	Gently wash off with large quantity of soap and water
P351	Carefully wash with water for several minutes
P352	Wash off with large quantity of soap and water
P353	Wash the skin with water/ take shower
P360	Wash the contaminated clothing and skin with large quantity of water immediately prior to taking the clothing off
P361	Take off or get rid of all the contaminated clothing
P362	Take off the contaminated clothing and wash them before using it again
P363	Wash the contaminated clothing before using them again
P370	At the time of fire
P371	At the time of major fire
P372	There is risk of explosion at the time of fire
P373	Do not attempt to extinguish fire if the flames reach the explosive substance
P374	Carefully extinguish fire at an appropriate distance
P375	Extinguish fire while maintaining sufficient distance since there is risk of explosion
P376	Stop leakage if it is safe to do so
P377	If it is not possible to safely stop leakage at the time of fire on leaking gas, do not attempt to extinguish fire
P378	Use (...) to extinguish fire
P380	Evacuate people in the surrounding region
P381	Remove all the sources of ignition if it is possible to do so safely.

Code	Precautionary statement
P390	Adsorb leaked substances in order to prevent spreading of damages arising from substance.
P391	Gather leaked substances
P301+P310	If swallowed, seek medical treatment by medical institution (doctor).
P301+P312	If swallowed and discomfort is experienced, seek medical treatment by medical institution (doctor).
P301+P330+P331	If swallowed, wash out the mouth. Do not induce vomiting.
P302+P334	If it comes in contact with skin, either soak in cold water or wrap with wet bandages.
P302+P350	If it comes in contact with skin, gently wash off with large quantity of soap and water.
P302+P352	If it comes in contact with skin, wash off with large quantity of soap and water
P303+P361+P353	If it comes in contact with skin (or hair), take off or remove all the contaminated clothing. Wash the skin with water/take shower
P304+P312	If your experience discomfort after having inhaled it, undergo treatment by medical institution (doctor).
P304+P340	If inhaled, transfer to location with fresh air and take rest in a posture that makes breathing easier.
P304+P341	If breathing becomes difficult due to inhalation, transfer to location with fresh air and take rest in a posture that makes breathing easier.
P305+P351+P338	If it comes in contact with eyes, carefully wash off with water for several minutes. If possible, remove the contact lens and continue to wash.
P306+P360	If it comes in contact with clothing, wash off the contaminated clothing and skin with large quantity of water immediately prior to taking off the clothing.
P307+P311	If exposed, undergo treatment by medical institution (doctor).
P308+P313	If exposed or if there is concern for exposure, seek medical treatment and advices.
P309+P311	If exposed or discomfort is experiences, undergo treatment by medical institution (doctor).

Code	Precautionary statement
P332+P313	If there is irritation of skin, seek medical treatment and advices.
P333+P313	If irritation of skin or red spots appears, seek medical treatment and advices.
P335+P334	Brush off the substance that got on the skin and soak in cold water or wrap with wet bandages.
P337+P313	If irritation of the eyes continues, seek medical treatment and advices.
P342+P311	If symptoms of respiratory system appear, undergo treatment by medical institution (doctor).
P370+P376	Stop the leakage if it is safe to do so at the time of fire
P370+P378	At the time of fire, use (...) to extinguish fire
P370+P380	At the time of fire, evacuate people in the surrounding region
P370+P380+P375	At the time of fire, evacuate people in the surrounding region and extinguish fire by maintaining distance as there is risk of explosion.
P371+P380+P375	At the time of major fire, evacuate people in the surrounding region and extinguish fire by maintaining distance as there is risk of explosion.

(3) Storage

Code	Precautionary statement
P401	Store appropriately (in accordance with the regulations stipulated in relevant laws).
P402	Store in dry location
P403	Store in location with good ventilation.
P404	Store in tightly sealed container
P405	Store in storage location with locking device
P406	Store in corrosive-resistant container (stipulated by the manufacturer or administrative authority) since it is a metal corrosive substance.
P407	Keep distance between the substances in storage.
P410	Avoid direct sunlight.

Code	Precautionary statement
P411	Take precaution to ensure the temperature does not exceed (...)℃ during storage since it is a highly reactive substance.
P412	Do not expose it to temperature higher than 50℃.
P413	Take precaution to ensure the temperature does not exceed (...)℃ when storing quantity that is more than (...)kg since it is a highly reactive substance
P420	Store by isolating it from other substances
P422	Store by refilling appropriate (...)
P402+P404	Store in dry location and in tightly sealed container
P403+P233	Tightly seal the container and store in location with good ventilation.
P403+P235	Store in location with good ventilation and maintain low temperature
P410+P403	Avoid direct sunlight and store in location with good ventilation.
P410+P412	Avoid direct sunlight and do not expose the substance to temperatures above 50℃.
P411+P235	Take precaution to ensure the temperature does not exceed (...)℃ during storage since it is a highly reactive substance. Maintain low temperature.

(4) Disposal

Code	Precautionary statement
P501	Discard the contents and container (in accordance with the contents stipulated in the relevant laws).

Appendix 4 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 5 Example of GHS/MSDS (Benzene)

Ministry of Employment and Labor

Material Safety Data Sheet

KOSHA

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 swollen

H304 Can be fatal if swollen 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

	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
Countermeasures	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	If it comes into contact with the eyes, carefully wash with water for several minutes, If possible, remove the contact lens. Continue to wash.
	If irritation of the eyes continues, please seek medical measures and advices.
B. Comes in contact with the skin	Wash the skin with soap and water.
	Remove the contaminated clothes and shoes, and quarantine the contaminated area
	Please seek medical measures and advices if there is skin irritation
	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.
	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.

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_2 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/m3 STEL – 5ppm 16mg/m3 (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 creatine
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.
	f 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

	IIf 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℃
F. Initial boiling point and range of the boiling points	80.10℃
G. Ignition point	-110℃ (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℃)
L. Solubility	0.18g/100ml (250℃)
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℃
Q. Degradation temperature	No data available
R. Viscosity	0.604 cP (250℃)
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

	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

11. Information on toxicity

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	· Special management substances under the Industrial Safety & Health Law (mutagenicity on reproductive cells) · Notice by the Ministry of Employment and Labor 1B
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

12. Effects on the environment

A. Ecological features

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. Residues and degradability

Residue	log Kow 2.13
Degradability	No data available

C. Bio-concentration

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.

◎ MSDS provided can only be used for internal use with prohibition of commercial use, etc. Accordingly, using MSDS for external use may infringe relevant laws such as copyright law etc.

◎ The authority to amend and supplying this material is with the KOSHA and if you have any inquires on the MSDS, please contact us through the following contact details:
-Address: Chemical Substance Center of the Occupational Safety and Health Research Institute (OSHRI)
#30 Expo-ro 339-gil, Yuseong-gu, Daejeon Metropolitan City (305-380)
-Tel: (042) 869-0300 (trunk line)

Appendix 6 Method of search data in GHS/MSDS

Source: KOSHA

Methods of searching the data included in the Industrial Safety and Health Act of the Ministry of Employment & Labor, Law on registration and evaluation of harmful chemical substances, harmful chemical substances as well as the Law on management of chemical substances of the Ministry of Environment, and Law on safe management of hazardous substances of the Ministry of Public Safety & Security, etc. to more easily understand the MSDS are given below.

1 Using Smart Phone App

Download the app referred to as "MSDS" of KOSHA and input the name of the substance to confirm the data

2 Using Domestic and Overseas Internet Sites

① Material safety data sheet of the Korea Occupational Safety & Health Agency (KOSHA) msds.kosha.or.kr

KOSHA Chemical Information

② Chemical substances information system of the National Institute of Environmental Research (NCIS) ncis.nier.go.kr

NCIS Chemicals Information System

③ National Hazardous Substances Information System of the National Emergency Management Agency (NEMA) www.nema.kr

NEMA

④ Toxic Information Provision System of the National Institute of Food and Drug Safety Evaluation (NIFDS) www.nifds.go.kr

NATIONAL INSTITUTE OF FOOD AND DRUG SAFETY EVALUATION Tox-Info

⑤ ILO-ICSC www.inchem.org

ILO-ICSC International Chemical Safety Cards

⑥ EU-ESIS esis.jrc.ec.europa.eu

EU-ESIS European chemical Substances Information System

⑦ OECD-echemportal www.echemportal.org

OECD eChemPortal

Appendix 7 Substances that must not be stored together

The following table is a list of the substances that cannot be stored together for the reasons of being reactive, flammable and explosive on the basis of the chemical substances that can be found easily in the laboratory. The substances that must not be put together or stored separately are described in detail in GHS/MSDS and must be referred to at the time of allocating the arrangement of chemical substances in storage.

Compound	Substances that must not be stored together
Combustible liquid	Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, halogen
Potassium permanganate	Glycerin, ethylene glycol, benzaldehyde, sulfuric acid
Sodium peroxide	Ethanol or methanol, glacial acetic acid, anhydrous acetate, benzaldehyde, carbon disulfide, glycerin, ethylene glycol, ethyl acetate, methyl acetate, furfural
Hydrogen peroxide	Copper, chrome, iron, majority of metals or metallic salts, alcohol, acetone, organic compound, aniline, nitromethane, combustible liquid, gases oxidizing agent
Perchloric acid	Acetic acid, anhydrous water, bismuth and alloy that contains bismuth, alcohol, paper, timber
Potassium perchlorate	Sulfuric acid and other acids
Copper	Acetylene, hydrogen peroxide
Morpholin	Strong acid, strong oxidizing agent

Compound	Substances that must not be stored together
Anhydrous ammonia	Mercury, chlorine, calcium hypochloride, iodine, brome, hydrofluoric acid
Hydrofluoric acid	Aqueous solutions or anhydrous ammonia
Butyl lithium	Water
Brome	ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gas), hydrogen, sodium carbide, turpentine, benzene, micrometal
Oxygen	Oil, grease, hydrogen, combustible liquid, gases and solid
Selenide	Reductants
Mercury	Acetylene, fulmin acid, ammonia
Cyanides (sodium, potassium)	Acid
Hydrocyanic acid	Nitric acid, alkaline
Aniline	Nitric acid, hydrogen peroxide
Acetone	Mixture of concentrated nitric acid and sulfuric acid
Acetylene	Chlorine, brome, copper, fluorine, silver, mercury
Azide	Acid
Nitrite	Acid
Acrolein	Oxidizing agent, acid, alkaline, ammonia
Alkaline and Alkaline earth metal	Water, carbon tetrachloride or other chlorides of hydrocarbon, carbon dioxide, halogen
Hydrochloric acid	Majority of metals, alkaline or reactive metal
Hydrochloric acid potassium	Sulfuric acid and other acids
Chlorine	Ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, turpentine, benzene, micrometal
Chlorate	Ammonium salt , acid, metal powder, sulfur, micro organic or combustible substance
Oxalic acid	Silver mercury
Iodine	acetylene, aqueous solutions or anhydrous ammonia, hydrogen

Compound	Substances that must not be stored together
Organic peroxide	Organic or inorganic acid, friction, heat
Organic solvents	Strong oxidizing agent, acid, highly corrosive compound
Silver	Acetylene, oxalic acid, tartaric acid, ammonium compound
Chlorine dioxide	Ammonia, methine, phosphine, hydrogen sulfide
Nitric acid	Acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, combustible gases, combustible liquid
Ammonium nitrate	Acid, metal powder, combustible liquid, chlorate, nitrite, sulfur, find organic or combustible substance
Nitrate	Sulfuric acid
Acetic acid	Chromic acid, nitric acid, compounds with hydroxyl group, ethyleneglycol, perchloric acid, peroxide, permanganate
Calcium oxide	Water
Cumene hydroperoxide	Organic or inorganic acid
Chromic acid	Acetic acid, naphthalene, camphor, glycerin, turpentine, alcohol, combustible liquid
Hydrocarbon	Flourine, chlorine, bromine, chromic acid, sodium peroxide
Potassium	Carbon tetrachloride, carbon dioxide, water
Hydrazine	Oxidizing agent, hydrogen peroxide, nitric acid, metal oxide, strong acid, multiporous substance
Activated carbon	Calcium hypochloride, all oxidizing agents
Sulfuric acid	Potassium hydrochloric acid, potassium perchloric acid, potassium permanganic acid (or sodium, lithium)
Hydrogen sulfide	Fuming nitric acid, gases oxidizing agent, aqueous solutions or anhydrous ammonia, hydrogen
White phosphorous	Air, oxygen, alkaline, reductants

Appendix 8 Substances for comparison of physical hazards of GHS/MSDS

The following table lists the 105 types of chemical substances included in the announcements by the Ministry of Environment and the Ministry of Employment & Labor for which precautions must be taken in accordance with their physical hazards (water reactive, explosive and flammable, etc.). Particular precautions must be exercised in handling, storing and disposing the corresponding 105 substances.

No.	Substance	CAS No.	No.	Substance	CAS No.
1	Sodium peroxide	1313-60-6	14	Methyl ethyl ketone	78-93-3
2	Hydrogen peroxide	7722-84-1	15	Methyl chloroacetate	96-34-4
3	Urea peroxide	124-43-6	16	Methylhydrazine	60-34-4
4	Sodium	7440-23-5	17	Chromic anhydride	1333-82-0
5	Nitrobenzene	98-95-3	18	Benzene	71-43-2
6	Di-n-butylamine	111-92-2	19	Benzeneacetonitrile	140-29-4
7	Hexamethylene diisocyanate	822-06-0	20	Bronopol	52-51-7
8	Difenoconazole	119446-68-3	21	Bis(2-ethylhexyl)amine	106-20-7
9	Mercaptoacetic acid	68-11-1	22	Bis(2-chloroethyl)ether	111-44-4
10	Methacrylonitrile	126-98-7	23	Propyleneoxide	75-56-9
11	Metaldehyde	108-62-3	24	Nickel oxides, sulfides	12035-36-8 1313-99-1 12035-72-21 6812-54-7
12	Methyl vinyl ketone	78-94-4			
13	Methyl alcohol	67-56-1			

No.	Substance	CAS No.
25	Cyclonite	121-82-4
26	Cyclohexylamine	108-91-8
27	Aniline	62-53-3
28	Ethyl acetate	141-78-6
29	Sodium chlorite	7758-19-2
30	Acrolein	107-02-8
31	Acrylonitrile	107-13-1
32	Allylalcohol	107-18-6
33	Ethoprophos	13194-48-4
34	2,3-Epoxypropyltrimethylammonium chloride	3033-77-0
35	Phosphorus pentasulfide	1314-80-3
36	Isobutylamine	78-81-9
37	Methyl isothiocyanate	556-61-6
38	Carbon disulfide	75-15-0
39	White phosphorus	7723-14-0
40	Zinc phosphide	1314-84-7
41	Aluminum phosphide	20859-73-8
42	Zetacypermethrin	52315-07-8
43	Thallium nitrate	10102-45-1
44	Nitric acid	7697-37-2
45	Potassium	7440-09-7
46	Alloyofpotassiumand sodium	11135-81-2
47	Xylene	1330-20-7
48	Chloromethyl methyl ether	107-30-2
49	Chlorohydrin	96-24-2
50	Toluene	108-88-3
51	Thiosemicarbazide	79-19-6
52	Fenitrothion	122-14-5
53	Phenylhydrazine	100-63-0
54	Fenthion	55-38-9
55	Furfural	98-01-1
56	Picricacid	88-89-1
57	Dimethyl sulfate	77-78-1
58	Diethylsulfate	64-67-5
59	Hydrazine	302-01-2
60	Hydrazine hydrate	7803-57-8
61	Hydroxylamine	7803-49-8
62	2,4-Dinitroaniline	97-02-9
63	2,4-Dinitrophenol	51-28-5
64	1,2-Dibromo-3-chloropropane	96-12-8
65	2,3-Dibromopropanenitrile	4554-16-9
66	Diphenylmethane 4,4'-diisocyanate	101-68-8
67	1,3-Dichloro-2-propanol	96-23-1
68	1,3-Dichloropropene	542-75-6
69	1,1'-Methylenebis[4-isocyanatocyclohexane]	5124-30-1
70	2-Methylpropanenitrile	78-82-0
71	2-Bromoethanol	540-51-2
72	2-Vinylpyridine	100-69-6
73	m-Aminochlorobenzene	108-42-9
74	3-Ethoxypropylamine	6291-85-6
75	2-Chlorobenzenamine	95-51-2
76	2-Chloroethanol	107-07-3
77	N-2-Propenyl-2-propen-1-amine	124-02-7

No.	Substance	CAS No.
78	2-Propyn-1-ol	107-19-7
79	Dichloro(phenyl) phosphine	644-97-3
80	2-Thienylacetonitrile	20893-30-5
81	Tributylamine	102-82-9
82	(Epoxyethyl)benzene	96-09-3
83	1-Methyl-propylamine	13952-84-6
84	2-Furanmethanol	98-00-0
85	4-Nitrotoluene	99-99-0
86	Phosphorochloridic acid diethyl ester	814-49-3
87	Propiononitrile	107-12-0
88	Nonylphenols, 4-tert-Octylphenol	25154-52-3 104-40-5 84852-15-3 139-84-4 136-83-4 140-66-9
89	1,2-Dichloroethane	107-06-2
90	Trichloroacetonitrile	545-06-2
91	2-Methyl-2-propenoylchloride	920-46-7
92	n-Propyl chloroformate	109-61-5
93	Methanesulfonyl chloride	124-63-0
94	Bis(2-ethylhexyl) phthalate	117-81-7
95	Dibutyl phthalate	84-74-2
96	Butylbenzyl phthalate	85-68-7
97	Dimethyl sulfide borane	13292-87-0
98	Acetone cyanohydrin	75-86-5
99	Butanenitrile	109-74-0
100	Diphenyliodonium nitrate	722-56-5
101	Benzoyl peroxide	94-36-0
102	2-Aminothiophenol	137-07-5
103	[(2E)-1, 4-Dichloro-2-butene	110-57-6
104	Glycidol	556-52-5
105	2-Nitrotoluene	88-72-2

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People's Safety Broadcasting of the Ministry of Public Safety & Security: www.nematv.com

National Fire Information Center of the Ministry of Public Safety & Security: www.nfds.go.kr

Korean Academy of Medical Sciences: www.kams.or.kr/health (easy to understand health information)

National Health Information Portal of the Ministry of Health & Welfare: health.mw.go.kr (integrated health information)

Korea Advanced Institute of Science & Technology (KAIST): www.kaist.ac.kr/html/etc/safety/safety_01020401.html (safety in experimental laboratory)

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

Fire Extinguishing Industry Information System: www.sobangin.or.kr/(fire extinguisher)

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

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

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Standard Textbook for Safety in Laboratory

Safety Before and After the Experiment I

- Safety Before the Experiment

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