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Standard Textbook for Safety in Laboratory

New Persons Engaged in Research Activities

Ministry of Science and ICT

National Research Safety Headquarters

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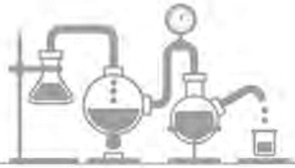

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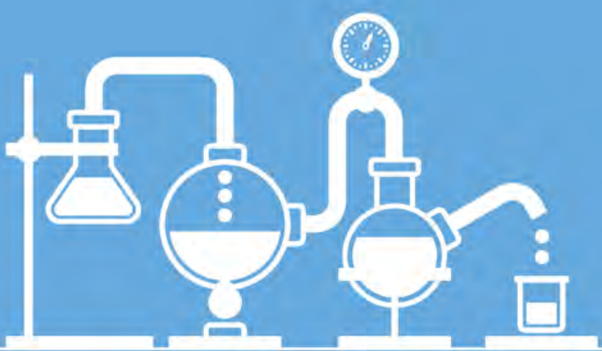


CHAPTER 1

Importance of Laboratory Safety

1

CHAPTER New Persons Engaged in Research Activities

Importance of Laboratory Safety

1. Are You a Safe Researcher?

It is very difficult to have proper judgement towards safety issues and maintain safe practices.

Blind imitation of laboratory practices and customs are severe threats to safety. Seniors pass down basic rules to juniors without proper explanation, making them develop a "this should do" attitude towards safety.

For example, if a senior researcher dresses in short pants and wears a pair of slippers in the summer, junior researchers will naturally be more lenient in observing safety rules in the laboratory. When those junior researchers become seniors, they will believe that it is acceptable to wear short pants in the summer since accidents have not occurred previously. Those who try to adhere to safety rules might even be considered peculiar, with the majority regarding safety as "cumbersome" and "a waste of time." The researchers will only dress appropriately and clean up the laboratory for safety inspections. This deceptive maintenance of laboratory safety will cause researchers to deviate from safe practices.

New persons engaged in research activities are bound to experience safety issues and ethical conflicts in laboratories.

However, most laboratory accidents can be prevented by observing safety rules, and human casualties can be minimized even in the event of accidents. The conclusion, derived from Einstein's logic, as explained in the next page, is that "all accidents can be prevented."

Examine the case studies of laboratory accidents in the following section, and think about the possible actions that could have been taken to prevent disasters.

Ask yourself the following.

Are you a safe researcher?
Have you left hazards unattended to?
Do you conduct research under a "Safety First" approach?

Your answers to the above are a matter of life and death.

You are not exempt from the accidents introduced in the following section.

Do not put your own life, the lives of your colleagues, and valuable property at risk by neglecting safety management and safety rules.

Do not gamble with the lives of you and your colleagues.

Einstein's Story

Absence of Safety.

Albert Einstein, one of the most prominent scientists in history, left many memorable sayings.

During a class taught by an atheist professor,
Einstein argued for the existence of God using the following argument when the professor claimed that God is evil since God created everything, including evil.

Albert Einstein says...

"Evil is simply the absence of God. It is a word that man has created to describe the absence of God."

"It's like the cold that comes when there is no heat or the darkness that comes when there is no light."

Light and heat exist and can be defined in scientific terms, but not darkness and cold. The latter are words used to describe the absence of the former.

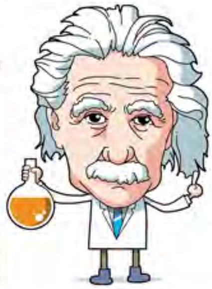
That's right.
Darkness can only be explained as an absence of light. Likewise, cold can only be explained as an absence of heat.

The same applies to laboratory accidents.

More than 90% of accidents are man-made calamities caused by negligence or carelessness.

This means that most accidents result from poor knowledge of safety management and failure to observe safety rules.

New researchers!
Remember that most accidents can be prevented.
As you can see from the example of Einstein, accidents are merely the absence of safety.



Can be defined in scientific terms; exists in reality	↔	Cannot be defined on its own (explained as an absence of the opposite concept)
Light	↔	Darkness (Absence of light)
Heat	↔	Cold (Absence of heat)
Strict observance of safety rules Sufficient acquisition of safety knowledge	↔	Accident (Absence of safety)

That is, accidents do not exist if we understand and enforce safety.

As falling love must be "Zero Hate", safety must be "Zero Harm".
– Dave Collins –

2. Why is Laboratory Safety Important?

The following case studies of laboratory accidents within and outside Korea demonstrate the importance of laboratory safety.

As you will see below, human casualties can be avoided if effective preventive measures are implemented.

Case 1 High pressure gas explosion at College of Engineering, OO University

■ Accident overview

Date/time	August 6, 2013 at 10:30	
Location	Laboratory at College of Engineering, OO University, Busan Metropolitan City	
Type	High pressure gas explosion	
Extent of damage	Human	One death
	Property	Damage to most experimental equipment


Self-designed equipment was used under high-pressure conditions without conducting internal pressure tests.


Scene of laboratory accident

■ Details

1) A device (high pressure cell) used to test rock interactions exploded during installation and testing by the subcontractor.

2) The worker's forehead and chest were hit by the lid while he increased the device pressure. He was sent to the emergency room of a nearby hospital but died during treatment. Two students who participated in the test run were uninjured.

■ Cause and preventive measures

1) Cause: The lid flew open when the worker was injecting carbon dioxide to test its stability.

2) Preventive measures

① **Safety certificates** must be submitted and approved before purchasing or installing dangerous machines and tools.

② Hazard elements must be specified in the specifications sheet when outsourcing the manufacture of devices.

Lessons learned

1) **Human casualties could have been avoided** through internal pressure tests, overpressure control devices, and protective measures for worker safety.

2) Use standard experimental devices if possible. When manufacturing new devices, perform thorough inspections to identify potential hazards. **Consult a professional at the safety department and conduct safety verification tests**.

3) Inform the manufacturer of potential hazards. **Implement appropriate protective measures to minimize human casualties**, and **conduct experiments in areas free of hazard elements (i.e. outside the building)**.

If proper safety rules had been observed,
the results would have been different.

Case 2 Sulfuric acid burn at OO University

■ Accident overview

Date/time	May 12, 2014 at 15:00	
Location	Laboratory at College of Natural Resources, ○○ University, Daegu Metropolitan City	
Type	Sulfuric acid leakage	
Extent of damage	Human	4 burn victims (3 hospitalized, 1 outpatient)
	Property	-

Fig. 1-1 Burns on victims

■ Details

1) A student dropped a bottle of sulfuric acid while making sulfuric acid solution (0.1N H_2SO_4) in a group experiment.
2) The students were wearing lab coats, but four suffered burns as they were **wearing short pants or skirts that exposed their legs**.
3) The instructor told students to flush the affected area with running water. The students received first aid at a nearby hospital and were transferred to a hospital specializing in burns.
4) The university's safety department restricted access to the scene, and removed residual sulfuric acid using a chemical spill kit.

▪ Cause and preventive measures

1) Cause: The students **handled sulfuric acid carelessly** due to **insufficient supervision** by the principal investigator (instructor), and were **dressed inappropriately** in clothes that exposed their legs.

2) Preventive measures

① Conduct experiments involving chemical substances only after providing sufficient safety education.

② Wear **appropriate clothes** (avoid short pants, skirts, slippers, etc.) and **personal protective equipment** (safety goggles, gloves, etc.)

③ **Be aware of emergency measures** to be taken in the event of chemical spills on skin.

- Know where the emergency shower, eye wash, and medical kits are located and how to use them; be familiar with emergency response and MSDS
- Quickly remove contaminated shoes or clothes to prevent spreading to skin
- Flush affected area with copious amounts of running water for at least 15 minutes

Lessons learned

1) This accident, caused by exposure of legs to chemical substances, demonstrates the importance of wearing personal protective equipment and appropriate clothes. If the principal investigator had been more thorough in safety management and the students more observant of safety rules, **human casualties could have been avoided**.

2) Extra caution must be exercised when handling dangerous substances. Since human mistakes are inevitable, **appropriate self-defense measures must be implemented to minimize human casualties**.

Don't learn safety after an accident.

Case 3 High pressure gas explosion at OO University in Korea

■ Accident overview

Date/time	May 13, 2003 at 14:30	
Location	Laboratory at College of Engineering, ○○ University, Daejeon	
Type	High pressure gas explosion	
Extent of damage	Human	1 death, 1 serious injury
	Property	Damage to majority of property

Fig. 1-2 Scene of accident

■ Details

1) Gas that leaked from a gas tank due to inadequate management acted as an explosive.
2) Sparks caused while two PhD students were moving a gas tank blocking the passageway to the laboratory.

■ Cause and preventive measures

1) Cause: Leakage of gas from gas tank while conducting an experiment on catalytic reactions of hydrogen peroxide

2) Preventive measures

① Move gas tanks to high pressure gas cabinets outside the building, and keep all gas tanks fixed.

② Do not use gas tanks that have expired and immediately return all gas tanks that are not in use (gas valves may loosen from long-term storage).

③ Receive safety training before using gas tanks (request assistance from advisor or professional).

④ Specify elements acting as safety hazards when submitting requests to manufacturers.

Lessons learned

1) The above accident revealed a lack of safety awareness in laboratories, and led to an enforcement of safety training and emergency drills for graduate students. It served as a basis for the Act on the Establishment of Safe Laboratory Environment, enacted in 2006.

2) The accident **could have been prevented** by returning the gas tank, which had not been in use for a long period, to the supplier. Experiments involving high pressure gas should be conducted **under strict observance of safety guidelines.**

3) Risk factors should be minimized by conducting a preliminary risk analysis of hazard factors when using highly reactive or flammable substances such as hydrogen peroxide. Research should be carried out under the supervision of a safety professional or advisor, **using multi-faceted methods to reduce the risk of accidents.**

Success comes after safety!
Never let an accident take your **FUTURE!**

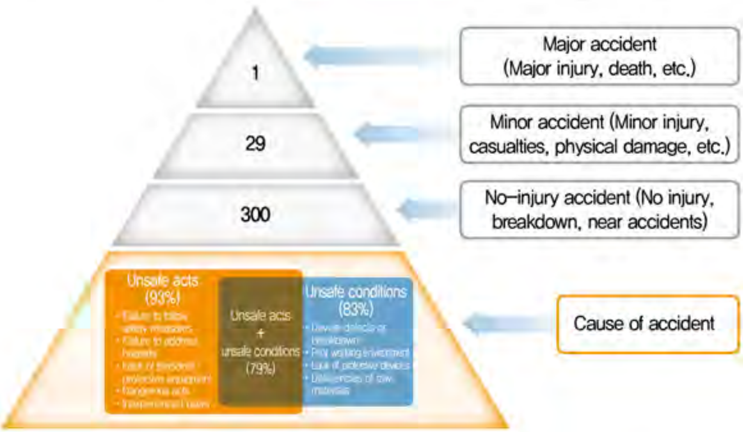
3. Knowledge is Power for Safety

This section introduces basic theories related to safety, thereby allowing more effective response to dangerous situations that may occur in laboratories, and safer research practices.

Knowledge is Power for Safety!

(1) Heinrich's Law

- **In the 1920s, based on a study of 75,000 workplace accidents, Herbert W. Heinrich, a manager and safety technician of a travel insurance company, discovered the 1:29:300 law**
- For every accident that causes a major injury, there are 29 accidents that cause minor injuries, and 300 accidents that came close to but escaped injuries (near accident[1]).
- An analysis of the causes behind workplace accidents showed that workers' unsafe actions accounted for 93%, inadequate devices/environment accounted for 83%, and a combination of the two accounted for 79%.



1) Coming close to an accident due to the negligence of workers (persons engaged in research activities) or defective facilities.

Implications on Laboratory Safety Management (1)

- Near accidents are precursors leading to a major accident.
  Major accidents can be 100% prevented if researchers alert others of potential hazards and share experiences of near accidents with the laboratory safety manager and colleagues.
- Be aware of causes of accidents before starting your research, and exercise caution to avoid the same mistakes that resulted in near accidents.

An accident is just the tip of the iceberg,
a sign of a much larger problem below the surface.
- Don Brown -

(2) Domino Theory of Heinrich

– As can be seen from Heinrich's ratio of 1 : 29 : 300, major accidents are always preceded by signs, and irreversible disasters occur when we ignore such signs. Disasters can be prevented only by removing middle blocks in the line of dominoes.

– Unsafe conditions or unsafe acts resulting from inadequate social environment, research organization and supervisors are basic causes of accidents. Accidents occur when protective measures (Fail Safe, Fool Proof[2], etc.) are not taken against unsafe conditions and unsafe acts, which can then snowball to major accidents if the initial response is insufficient. One or more domino blocks can be removed by enforcing safety management, thus breaking the chain of events leading to major accidents.

2) Fail Safe, Fool Proof: Safety measures and devices to prevent accidents. See Appendix 2 for more information.

Implications on Laboratory Safety Management (2)

- According to Heinrich's domino theory, major accidents can be prevented by enforcing safety management and removing blocks that represent unsafe actions and conditions.
- Accident prevention is more effective if more domino blocks can be removed.
- Before your experiment, check the number of domino blocks leading to accidents, and remove as many blocks as possible.

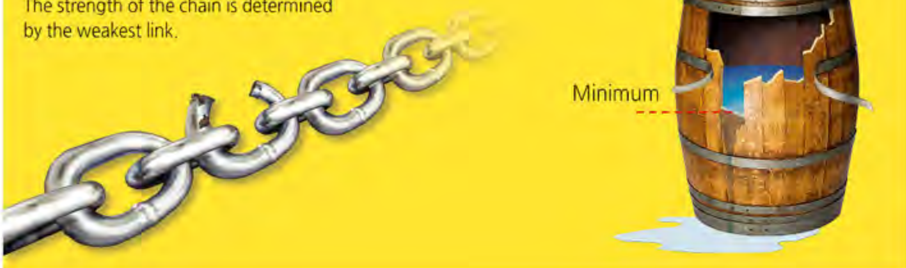
A chain is only as strong as the weakest link.

Law of the minimum: The level of safety is determined by the weakest link, even if all other safety requirements are fulfilled.

Similar to how the capacity of a barrel is limited by the shortest stave, it is important to improve overall safety by identifying the most unsafe element.

Law of the minimum

The strength of the chain is determined by the weakest link.



(3) Priorities for safety management

To ensure safety within the labs, it is most advisable to completely remove any source of risk. If that is not possible, it is important to avoid the risk, and if that also is impossible, measures to protect participants in research activities must be taken. Lastly, in preparation for any accident, it is advisable to take action to prevent accident escalation.

① Risk removal 〉② Risk avoidance 〉③ Self-defense 〉④ Accident control

① Risk removal: Removing risks completely the most fundamental approach to accident prevention

Example 1) **Dispose** of reagents using appropriate methods if they have not been used for several years or have expired.
Example 2) **Return** high pressure gas cylinders not in use to the supplier.

② Risk avoidance: Avoiding risks by spatial or temporal means if risks cannot be removed

Example 1) When conducting research involving flammable substances in a laboratory located near a construction site, avoid working at the same time as welding workers.

③ Self-defense: Protecting yourself using personal protective equipment and protective barriers if risks cannot be avoided

Example 1) Wear heat-resistant gloves when handling hot equipment
Example 2) When working with explosive substances, handle them from a distance that allows **self-defense** or install blast walls to reduce human casualties

④ Accident control: Effective response to prevent damage from spreading in the event of accidents

Example 1) Know where fire extinguishers and fire hydrants are located and how to use them to effectively respond to fires in the early stage.

Practice 1

Apply the above priorities for safety management to your own laboratory.

Item	Applicability	Possible solution
① Risk removal	Example) Combustion experiment involving a new gas	Example) Think of alternative methods (i.e. computational analysis) that present less hazards compared to combustion.
② Risk avoidance	Example) Combustion experiment involving a new gas	Example) If the combustion experiment is difficult to perform in the laboratory, look up a professional organization to entrust your experiment to.
③ Self-defense	Example) Combustion experiment involving a new gas	Example) If conducting the combustion experiment in the laboratory, keep the control room separate from the experiment area.
④ Accident control	Example) Combustion experiment involving a new gas	Example) Install gas detectors to check for leakage and flame arrestors to stop flames. Organize emergency drills to ensure effective response to fires and explosions.

Item	Applicability	Possible solution
① Risk removal		
② Risk avoidance		
③ Self-defense		
④ Accident control		

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New Persons Engaged in Research Activities

CHAPTER 2

Roles, Responsibilities and Rights of Persons Engaged in Research Activities

CHAPTER 2 New Persons Engaged in Research Activities

Roles, Responsibilities and Rights of Persons Engaged in Research Activities

This section introduces the roles and responsibilities of persons engaged in research activities, so as to enhance understanding of the necessary preventive measures and the rights of researchers in the event of an accident.

1. Introduction of Laboratory Safety Act

As listed below, Korea has various laws related to laboratory safety. Different laws may apply depending on the field of research, materials involved in research, and facilities. Research that violates related laws results in not only human casualties and property loss, but also legal penalties. Persons engaged in research activities must be aware of safety laws as these laws ensure the rights of researchers to safe research, including safety measures, safety inspections, compensation for damage arising from laboratory accidents, and health checkups.

(1) Laboratory safety
- Act on the Establishment of Safe Laboratory Environment
- Occupational Safety and Health Act

(2) Hazardous substances and chemical safety
- Act on the Safety Control of Hazardous Substances
- Chemicals Control Act

(3) Environment safety
- Water Quality and Aquatic Ecosystem Conservation Act
- Wastes Control Act
- Sewerage Act
- Clean Air Conservation Act

(4) Fire safety
- Building Act
- Act on Fire Prevention and Installation, Maintenance, and Safety Control of Fire-Fighting Systems

(5) Electric and facility safety
- Electric Utility Act
- Urban Gas Business Act
- High-Pressure Gas Safety Control Act
- Safety Control and Business of Liquefied Petroleum Gas Act
- Energy Use Rationalization Act

(6) Biological safety
- Transboundary Movement of Living Modified Organisms Act
- Biotechnology Support Act
- Infectious Disease Control and Prevention Act
- Act on the Control of the Manufacture, Export and Import, Etc., of Specific Chemicals and Chemical Agents for the Prohibition of Chemical and Biological Weapons
- Act on the Prevention of Contagious Animal Diseases
- Aquatic Life Disease Control Act
- Bioethics and Safety Act
- Act on the Acquisition, Management, and Utilization of Biological Research Resources
- Animal Protection Act
- Laboratory Animal Act

The legal system for the Act on the Establishment of Safe Laboratory Environment (hereafter Laboratory Safety Act) is as follows. The Act covers essential topics for persons newly engaged in research activities. For more details, visit the National Law Information Center (http://www.law.go.kr/). Provided below are provisions especially relevant to persons engaged in research activities.

Classification	Enactor	Title	Jurisdiction	Binding power
Act	National Assembly	Act on the Establishment of Safe Laboratory Environment	Supreme Court	
Enforcement decree	President	Enforcement Decree of the Act on the Establishment of Safe Laboratory Environment	Government offices	Administrative order (fine, suspension of operation, etc.)
Enforcement rules	Ministry of Science and ICT	Enforcement Rules of the Act on the Establishment of Safe Laboratory Environment		
Administrative rules	Ministry of Science and ICT	• Guidelines on Compensation for Laboratory Accidents (Notice) • Guidelines on Laboratory Safety Inspection and Precision Inspection (Notice) • Rules on Certification as Laboratory with Outstanding Safety Management (Notice) • Notice on Criteria and Procedures of Safety Inspections and Thorough Safety Inspections (Notice) • Detailed Guidelines on Preparation of Laboratory Safety and Maintenance Expenses Statement (Notice) • Rules on Organization and Management of Laboratory Accident Investigation Team (Order) • Guidelines on Implementation of Pre-hazard Risk Analysis for Laboratories (Notice)		

① Purpose of the Act (Article 1)

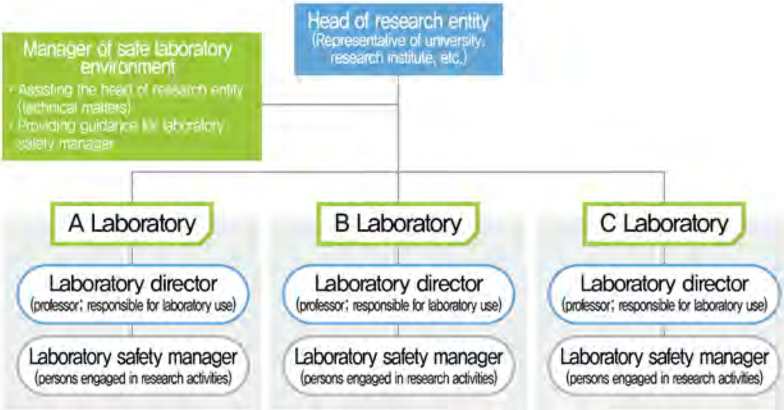
The purpose of this Act is to **efficiently manage research resources** and thereby to **contribute to the revitalization of scientific and technical research and development activities** by **ensuring the safety of laboratories** in the fields of science and technology established at universities, research institutes, etc., and ensuring proper compensation for damage caused by a laboratory accident.

② Scope of application (Article 3)

Any laboratory established by a university, research institute, etc., in order to carry out research and development activities

③ Laboratory safety management system and designation of laboratory directors (paragraph 2 of article 5)

The laboratory safety management system is shown below. To prevent laboratory accidents and ensure the safety of persons engaged in research activities, the head of a research entity shall designate a laboratory director in the relevant laboratory. To efficiently perform safety management duties in the relevant laboratory, each laboratory director may designate a laboratory safety manager from among persons engaged in research activities.



④ Education and training of persons engaged in research activities (Article 18)

Type	Trainees		Hours and period	Topics covered
New education	Worker	One employed in a laboratory requiring thorough safety inspection	At least eight hours (within six months of employment)	· Matters concerning the laboratory safety act · Matters concerning laboratory hazards · Matters concerning handling and use of protective equipment and safety devices · Matters concerning laboratory accidents and preventive measures · Matters concerning safety labels · Matters concerning material safety data sheets · Matters concerning pre-hazard risk analysis · Other matters concerning laboratory safety management
		One employed in a laboratory not requiring thorough safety inspection	At least four hours (within six months of employment)	
	Non-worker	An undergraduate or graduate student participating in research and development activities	At least two hours (within three months of participation in research and development activities)	

Type	Trainees	Hours and period	Topics covered
Regular education	Research personnel at a laboratory requiring thorough safety inspection	At least six hours every six months	• Matters concerning the laboratory safety act • Matters concerning laboratory hazards • Matters concerning safe research and development activities • Matters concerning material safety data sheets • Matters concerning pre-hazard risk analysis • Other matters concerning laboratory safety management
	Research personnel at a laboratory not requiring thorough safety inspection	At least three hours every six months	
Special safety education	Research personnel at a laboratory in which accidents have occurred or is deemed by the head of the research entity to be facing such a risk	At least two hours	• Matters concerning laboratory hazards • Matters concerning safe research and development activities • Matters concerning material safety data sheets • Other matters concerning laboratory safety management

Note

1. "Worker" shall be as defined in Article 2 (1) 1 of the Labor Standards Act.
2. Persons engaged in research activities who have attended new education may be exempt from regular education for the corresponding six-month period.
3. Regular education for persons engaged in research activities may be provided online. Those who receive at least 60 out of 100 points shall be considered as having successfully completed the program.

⑤ Safety inspections (Article 8 and Article 9)

- Each head of a research entity shall conduct a safety inspection on the laboratories under his/her jurisdiction in accordance with guidelines for safety inspections in order to maintain and manage the functions and safety of the laboratories.
- The head of a research entity shall conduct a thorough safety inspection if deemed necessary to prevent accidents and to ensure the safety, etc., of laboratories following a safety inspection

Classification	Laboratory	Inspection frequency	inspection items and methods
General inspection	All laboratories	At least once a year	**Naked-eye** inspecting of the storage of machines, tools, electrical supplies, medicine, and pathogens, and the management of protective gear used in research and development activities
Regular inspection	All laboratories	At least once a year	Inspecting the storage of machines, tools, electrical supplies, medicine, and pathogens, and the management of protective gear used in research and development activities **using inspection instruments**
Thorough safety inspection	Laboratories with harmful/ hazardous substances	At least once every two years	1. Matters concerning assessment of exposure to harmful or hazardous substances 2. Matters concerning handling and management of harmful or hazardous substances 3. Matters concerning preliminary impact assessment or analysis of harmful or hazardous substances
Special safety inspection	High-risk laboratories	As required	Conducted if persons engaged in research activities face hazards that may be fatal, such as explosions and fires

⑥ Preliminary risk analysis of hazard factors (paragraph 2 of article 5)

Principal investigators are responsible for conducting a preliminary risk analysis of hazard factors for laboratories under their charge. Preliminary risk analysis of hazard factors, which is **a series of steps performed before the start of research activities to analyze hazard factors**, was announced and established by the Ministry of Science and ICT.

- Procedures

- Applicable laboratories
  - Toxic chemicals as defined in subparagraph 7 of Article 2 of the Chemicals Control Act
  - Harmful agents as defined in Article 29 of the Occupational Safety and Health Act
  - Toxic gases as defined in Article 2 (1) 2 of Enforcement Rules of High-Pressure Gas Safety Control Act

⑦ Subscription to insurance (Article 14)

Each head of a research entity shall subscribe to insurance, with person engaged in research activities, as the insured and beneficiary against his/her injury or death.

- Recuperation: Actual expenses paid (no more than KRW 50 million)
- Physical disability: Amount specified by Ministry of Science and ICT according to severity
- Hospitalization: KRW 50,000 per day
- Family of deceased: KRW 200 million
- Funeral service: KRW 10 million

Insurance Subscription of Y Research Institute

- Applicability: Damage sustained during laboratory experiments
- Insurance period: Effective from the starting date of research activities
- Insurance claim
  : Beneficiary → University → Safety department → Insurance company
- Coverage
  - Death, physical disability (Class 1): KRW 100 million
  - Medical fees: KRW 10 million
  - No deductibles

You have the right to receive monetary compensation as insurance money in the event of unfortunate accidents caused by research activities. But remember that the best approach is **prevention**.

⑦ Health checkups (Article 18)

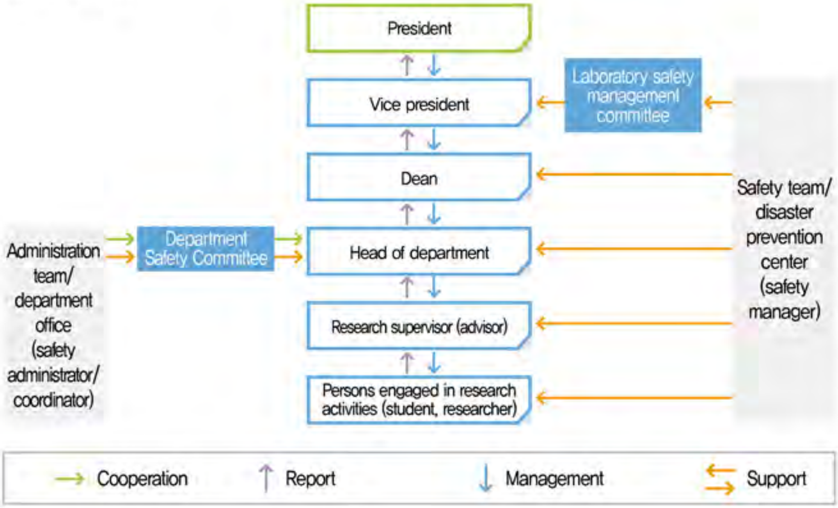
Each head of a research entity shall conduct regular health checkups for persons engaged in research activities with a danger of being exposed to substances, viruses, etc., fatal to human bodies.

- Type of checkup: General health checkup and special health checkup
- Subjects: Researchers handling chemical/physical hazards
- Hazard factors: 178 types (Occupational Safety and Health Act, and Article 10 of Enforcement Rules of the Act on the Establishment of Safe Laboratory Environment)
- Frequency
  General health checkup: At least once a year
  Special health checkup: See Attached Table 12-3 of Enforcement Rules of the Occupational Safety and Health Act)
- Items covered in general health checkup
  Interview and screening
  Blood pressure, blood and urine tests
  Height, weight, eyesight, and hearing
  Chest X-ray

Practice 2

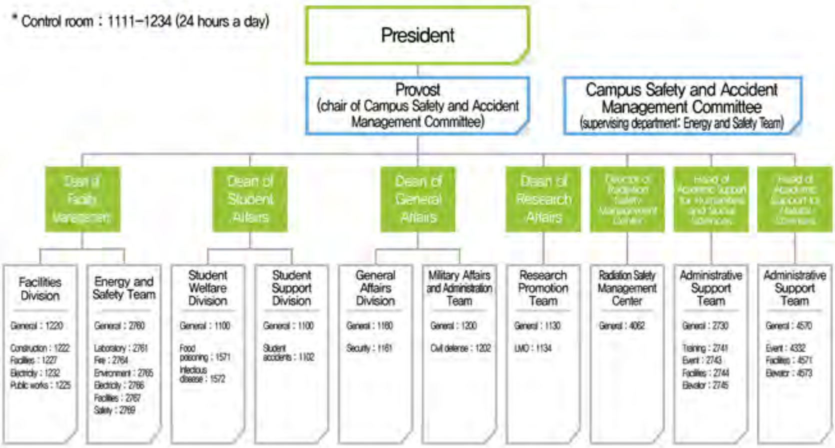
Draw the laboratory safety management system of your research institute.

(Example 1)



(Example 2)

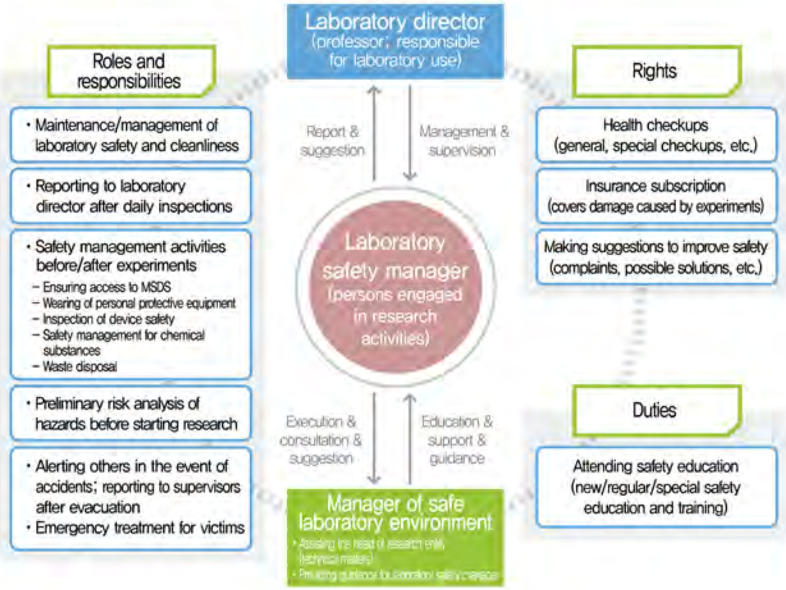
Campus safety organization and emergency contact



2. Roles/Responsibilities/Rights of Persons Engaged in Research Activities

As specified in the Act on the Establishment of Safe Laboratory Environment, persons engaged in research activities have specific roles and responsibilities related to laboratory safety. This is summarized in the figure below.

Persons engaged in research activities are the ones with the best knowledge of research characteristics and potential hazards. Researchers should actively discuss possible risks with principal investigators or laboratory safety managers, make suggestions to improve laboratory safety, and request technical assistance from laboratory safety managers if required.



Stop experiments upon identifying hazards, and resume only after **ensuring safety through communication.**

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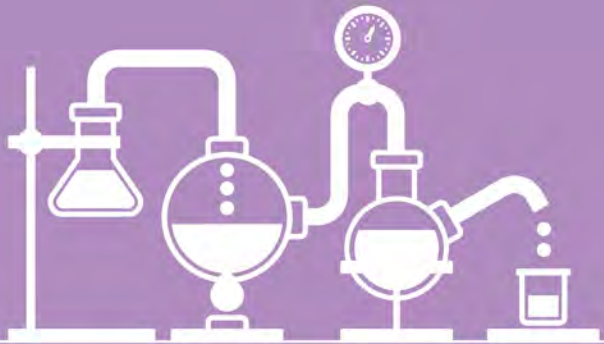


CHAPTER 3

Safety Precautions by Research Area

1. General Safety
2. Mechanical Safety
3. Electrical Safety
4. Chemical Safety
5. Fire Safety
6. Gas Safety
7. Biological Safety
8. Emergency Response Guide for Safety Accidents

CHAPTER 3 New Persons Engaged in Research Activities

Safety Precautions by Research Area

This section provides a summary of safety precautions by research area. Pay special attention to the safety rules relevant to your field of research.

Research area	Types of hazards	Health effects
Chemistry/ biochemistry	• Organic solvents • Acid and alkali solutions • Oxidizing substances • Catalysts • Resins • Heavy metal particles • Other chemical substances	• Development of cancer due to long-term exposure to chemicals • Adverse effects on health due to exposure to corrosive substances and substances of acute toxicity • Adverse effects on organs such as liver and kidney • Infertility in men and women
Biology/ medicine	• Bacteria, fungi • Viruses, pathogens • Antiseptics • Liquid nitrogen, etc.	• Primary adverse effects from exposure to chemicals • Inflammation caused by secondary infections • Damage to skin, eyes, and upper airway
Physics/ mechanical engineering	• Noise, vibration • Heat, low temperature • Ionized rays, laser • Oil solvent, etc.	• Hearing loss, metal fume fever • Puncture wounds, laceration or amputation from use of machinery • Insomnia, carpal tunnel syndrome, burns, conjunctivitis, cataracts

1. General Safety

The ultimate responsibility for laboratory safety lies with the persons engaged in the research activities themselves. Even if various preventive measures are implemented, accidents are inevitable if researchers are unwilling to cooperate or if they violate safety rules. The risky behavior of researchers results in accidents, and this also interferes with research activities. Safety rules must be observed not only for your own safety, but also to ensure the smooth running of research operations.

3.1.1. Main Causes of General Accidents

Most laboratory accidents are caused by improper handling of hazardous substances, which arises from poor posture or non-standard procedures adopted by researchers. Other causes include insufficient emergency medical kits, lack of protective equipment, and failure to update daily inspection records. Sleeping, cooking, or smoking in laboratories can also result in accidents.

3.1.2. Primary Hazards of General Accidents

As shown below, most causes of general safety accidents can be easily resolved.

Insufficient emergency medical kits	• Emergency treatment may be required for wounds and abrasions occurring in laboratories. Emergency medical kits needed to respond to accidents caused by the use of glassware and reagents.
Insufficient protective equipment	• Appropriate personal protective equipment, such as gas mask, dust mask, safety goggles, and gloves, needed according to laboratory characteristics.
Unavailability of daily inspection records and safety regulations	• Daily inspection records and safety regulations must be readily available. Records should be checked before experiments and updated. Immediate correction required for inconsistent items.
Sleeping and cooking in laboratories	• Accidents may result from the storing of food with research materials in refrigerators, or from cooking in laboratories. • Persons sleeping in laboratories face higher risk in the event of accidents caused by machines running 24 hours a day.

3.1.3. General Safety Rules

General Safety Rules

(1) Quickly survey the scene to identify any potential hazards.
(2) Be familiar with the performance of machines, tools, and experimental equipment.
(3) Always wear appropriate personal protective equipment.
(4) Investigate potential hazards before conducting experiments.
(5) Inspect facilities and experimental devices before use.
(6) Keep the surroundings well-organized.
(7) Do not play pranks or run in laboratories.
(8) Do not clean, maintain or remove chips from running equipment.
(9) Do not handle unapproved firearms.
(10) Do not handle firearms in areas containing flammable substances or explosives.
(11) Smoke only in designated smoking areas.
(12) Danger zones can only be accessed by authorized persons.
(13) Do not handle unfamiliar machinery.
(14) When loading objects, begin from large to small, and from heavy to light.

3.1.4. References and Websites for General Safety

Standard Teaching Material on Laboratory Safety, Ministry of Science and Technology, 2006

Development of Laboratory Safety Model for Universities, Ministry of Education & Human Resources Development, 2007

Laboratory Health and Safety Guide, KIST, 2008

Case Studies of Laboratory Accidents, Ministry of Education, Science and Technology, 2011

Manual for Laboratory Inspection Items and Improvement Methods, Support Center for Laboratory Safety, 2012

Laboratory Safety for Persons Engaged in Research Activities, Ministry of Education, Science and Technology, National Research Foundation of Korea, 2012

Guide to Safe Laboratory Practices, Ministry of Science and ICT, 2014

2. Mechanical Safety

Machines used in laboratories are more unstable than general industrial machines as they are designed or fabricated for experimental purposes. Because researchers are unfamiliar with handling new experimental tools and show a lack of safety awareness in conducting experiments, they face a higher risk of accidents.

3.2.1. Main Causes of Mechanical Accidents

Below is a list of the eight main causes behind mechanical accidents in laboratories, categorized using the 4Ms (Man, Machine, Media, Management).

Classification	Main Cause	Solution
Machine	Poor safety of machines developed for experimental purposes	Enforce safety in design and manufacturing
Media	Frequent changes to guidelines on use of machines or insufficient time	Enforce and comply with safety rules
Man	Students having lack of experience and technical knowledge	Provide training before and after experiments
Man	Frequent change of personnel interfering with accumulation of technical experience	Properly transfer duties and responsibilities
Management	Disorganized laboratory environment with machines stored in one place	Improve working environment
Machine	Accidents caused by defective machines	Use certified products (S mark certification)
Management	Accidents caused by breakdown or lack of protective devices	Enforce and comply with safety rules
Man	Accidents caused by lack of personal protective equipment	Enforce and comply with safety rules

3.2.2. Primary Hazards of Machines

Squeeze point (shear point)	• Formed between a reciprocating part and a fixed part. • Example: Press, shear, molding machine, press brake, etc.
Nip point	• A point between two rolling parts where the hand or clothes can become caught and drawn in. Hazards caused when the two parts are rolling in different directions. • Example: Points between rollers, points between gears, etc.,
Tangential nip point	• A point between two rolling parts where the hand or clothes can become caught and drawn in at a tangential direction. • Example: Points between belts, pulleys, chains, and sprockets.
Cutting point	• Hazards due to the moving part itself or the machine. • Example: Belt saw, milling blade, etc.,

3.2.3. General Rules for Mechanical Safety

Safety rules for each machine must refer to safety manuals supplied by relevant machine manufacturer. Standard teaching materials for lab safety produced by the National Research Safety Headquarters and related websites may also be consulted.

General Rules for Mechanical Safety

(1) Do not conduct experiments alone.
(2) Do not leave machines unattended for long periods.
(3) Use machines after fully understanding the safety instructions and manuals.
(4) Wear appropriate personal protective equipment.
(5) Ensure that machines are equipped with appropriate protective devices, and check that they are working properly.
(6) Frequently inspect machines to prevent malfunctioning.
(7) Do not use machines or tools for purposes not intended by the manufacturer.
(8) Take a break when tired, and perform stretching exercises.
(9) Perform safety inspections before experiments, and clean up after.
(10) Do not obstruct evacuation routes.

3.2.4. References and Websites for Mechanical Safety

Risk Management Techniques and Program Development, Korea Occupational Safety & Health Agency, 2010

Manual for Laboratory Inspection Items and Improvement Methods, Support Center for Laboratory Safety, 2012

Manual on Safe Work Procedures by Machine, Yeongnam Support Center for Laboratory Safety, 2013

Case Studies of Laboratory Accidents, Ministry of Education, Science and Technology, 2011

Keeping the Workplace Organized, Korea Occupational Safety & Health Agency, 2011

Safe Work Procedures for Centrifugal Hydroextractors, Korea Occupational Safety & Health Agency, 2012

Safe Work Procedures for Low-speed Pulverizers, Korea Occupational Safety & Health Agency, 2012

Safe Work Procedures for Alternating Current Arc Welding Machines, Korea Occupational Safety & Health Agency, 2012

Safe Work Procedures for Shears, Korea Occupational Safety & Health Agency, 2012

Safe Work Procedures for Electric Drills, Korea Occupational Safety & Health Agency, 2012

Safe Work Procedures for Portable Grinders, Korea Occupational Safety & Health Agency, 2012

Safe Work Procedures for Electrical Discharge Machines, Korea Occupational Safety & Health Agency, 2012

Safe Work Procedures for Metal Cutting Machines, Korea Occupational Safety & Health Agency, 2012

Safe Work Procedures for Lathes, Korea Occupational Safety & Health Agency, 2012

Safe Work Procedures for Milling, Korea Occupational Safety & Health Agency, 2012

Safe Work Procedures for Desktop Drills, Korea Occupational Safety & Health Agency, 2012

Safe Work Procedures for Band Saws, Korea Occupational Safety & Health Agency, 2012
Safe Work Procedures for Machining Centers, Korea Occupational Safety & Health Agency, 2012
Safe Work Procedures for Grinders, Korea Occupational Safety & Health Agency, 2012
Safe Work Procedures for Automatic Molding Machines, Korea Occupational Safety & Health Agency, 2012
Safe Work Procedures for Air Compressors, Korea Occupational Safety & Health Agency, 2012
Safety With Hand Tools for Workers, Korea Occupational Safety & Health Agency, 2013
Safety With Press Work for Workers, Korea Occupational Safety & Health Agency, 2013
[Safety Inspection Before Work OPL_By Facility] Lathe, Korea Occupational Safety & Health Agency, 2015
[Safety Inspection Before Work OPL_By Facility Desktop Grinder, Korea Occupational Safety & Health Agency, 2015
[Safety Inspection Before Work OPL_By Facility] Press, Korea Occupational Safety & Health Agency, 2015
[Safety Inspection Before Work OPL_By Facility] Portable Grinder, Korea Occupational Safety & Health Agency, 2015
[Safety Inspection Before Work OPL_By Facility] Shears, Korea Occupational Safety & Health Agency, 2015
[Safety and Health in the Workplace OPL] Centrifuge and Pulverizer, Korea Occupational Safety & Health Agency, 2015
[Safety Inspection Before Work OPL_By Facility] Alternating current Arc Welding Machine, Korea Occupational Safety & Health Agency, 2015
Standard Teaching Material on Laboratory Safety, Mechanical Safety, National Research Safety Headquarters, 2016

3. Electrical Safety

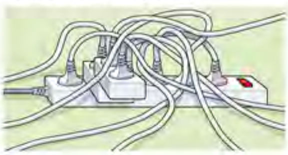
Laboratories in universities and research institutes are equipped with machines powered by electricity, including various measuring instruments, tools, computers, heaters, and lighting facilities. Some devices installed in laboratories are operated 24/7 for experiments. As such, to the use of electrical devices to prevent electrical fires and explosions, persons engaged in research activities must have a high level of safety awareness and observe all precautionary measures related.

3.3.1. Main Causes of Electrical Accidents

Electrical disasters in laboratories refer to human casualties and property damage caused by the **exposure of persons engaged in research activities to electrical energy when handling electrical facilities, equipment, instruments, and research materials**. Such exposure may lead to **electric shock, fire, or explosion**. A list of possible scenarios is given below.

Classification	Description
Electric shock disaster	Death, syncope, or burns and other injuries due to electric shock Includes human casualties resulting from subsequent collisions or falls
Electrical fire	Fire caused by electrical energy acting as a source of ignition for flammable materials, buildings, and facilities
Electrical explosion	Explosion caused by electrical energy acting as a source of ignition for explosive gas or flammable materials, or explosion of electrical facilities

The main causes of electrical accidents in laboratories and corresponding solutions are provided below.

Classification	Main Cause	Solutions
Short circuit, electric confusion, partial disconnection	• Damage to insulating material due to external force • Insulation aging due to local heating • Dielectric breakdown due to external heat 	• Properly manage wires • Strengthen wires of outgoing unit • Use standard wires • Perform repair/maintenance after turning off power
Electric leakage	• Damage to ground wire of earth leakage breaker • Occurrence of leak in a location before the earth leakage breaker	• Maintain safe distance between charging unit and other metals (building structure, water pipes, gas pipes, etc.) • Dampproof electric facilities in humid areas • Use tapes on wire connecting unit to improve insulation • Install leakage detectors and earth leakage breakers • Shut down when not in use • Perform regular inspections to check wire damage, distance between wires and drying agents, and ground wires • Regularly measure insulation resistance
Overcurrent	• Exceeding of permitted current/voltage/time • Use of multi-outlets 	• Use fuses and circuit breakers with appropriate capacities • Prohibit use of multi-outlets • Perform regular inspections to check for poor contact • Prohibit use of defective or leaky devices

Classification	Main Cause	Solutions
Poor contact	• Loose screws due to vibration • Corrosion of contact surface • Deformation of contact unit and plugs	• Ensure proper tightening of connecting units and wires • Perform thorough inspections on heating unit of electric facilities
Overheating	• Overheating of electrical devices – Leaving devices unattended in the active state – Poor handling/ maintenance • Overheating of electrical wires – Increased heating due to excess current – Increased contact resistance due to poor contact • Overheating of electric motors – Interference with ventilation/cooling due to dust – Long-term operation in the overloaded state – Friction from poorly lubricated bearings	• Do not place flammable materials near heating unit • Keep tools and electric motors clean • Maintain safe distance from heating source • Exercise caution against wire damage and overheating near connecting unit • Install automatic power cutoff devices that operate above a certain temperature • Use wires and cords of sufficient capacities • Do not use for purposes other than those initially intended

Heating devices such as hot plates and dryers are a common cause of electrical accidents, burns, and fires in laboratories. Researchers should observe the guidelines below when using such devices. The following safety rules focus on the use of hot plates.

Safety Rules for Use of Hot Plates

(1) Before experiments
- Check the surface of the plate for cracks.
  (Chemical substances may seep into old hot plates and cause explosions.)
- Make sure that the object placed on the hot plate does not fall or slip.
- Do not place magnetic hot plates or agitators near credit cards, transportation cards, or watches.

(2) During experiments
- Do not heat sealed containers.
- Make sure that substances that turn into powder when dried do not escape or spread in air.
- When the ceramic plate cracks during the experiment, turn off the power and do not proceed.

(3) After experiments
- Do not come into contact with hot plates even after turning off the power as they may stay hot for some time.

(4) Other
- Use hot plate products that have been certified (KC for domestic, CE/CB/PSE for international).
- Use hot plates with a residual heat indicator as burns occur from touching the hot surface.

3.3.2. General Rules for Electrical Safety

General Rules for Electrical Safety

- Do not expose the connecting unit of any devices and wires.
- Ground electrical devices when in use.
- Install earth leakage breakers to prevent disasters from electric shock.
- Do not operate switches without permission from related personnel.
- Do not touch electrical devices with wet hands. Wear insulating shoes when handling electrical devices in humid areas.
- Use standard fuses for switches, and do not use copper/steel wires.
- Do not use faulty electrical products.
- Do not use wires that contain connecting units in the middle.
- Avoid using wires in humid areas. If such areas are inevitable, use metallic or resin conduits.
- Keep cords as short as possible. Use cord connectors to extend if necessary.
- Do not use nails or staples to fix cords as this may cause wires to bend and break.
- Use wiring devices of appropriate thickness. Do not use multi-outlets.
- Install electrical outlet covers, and cover outlets that are not in use.
- Inspect earth leakage breakers at least once a month.

3.3.3. References and Websites for Electrical Safety

Standard Teaching Material on Laboratory Safety, Electrical Safety, National Research Safety Headquarters, 2015

National Lab Safety Education System(http://edu.labs.go.kr/MainHome.do?cmd=indexMain)

Korea Electrical Safety Corporation Blog: blog.naver.com/kescomiri

Static Electricity Disasters and Safety Measures, Korea Occupational Safety & Health Agency, 2002

Prevention of Static Electricity Disasters, Yeong-jun Ahn, Korea Occupational Safety & Health Agency, 2006

Electrical Safety: Measures to Prevent Static Electricity, Korea Occupational Safety & Health Agency, 2009

Analysis of University Fires and Case Studies on Laboratory Accidents, Education Facility Disaster Association, 2010

Case Studies of Laboratory Accidents, Ministry of Education, Science and Technology, 2011

4. Chemical Safety

The development of science and technology has led to an increase in the use of chemical substances in laboratories, highlighting the need for safer management of chemicals. Given the diverse range of harmful chemical substances used in research, researchers must be provided with instructions for the safe use of chemicals.

Such information is contained in the Material Safety Data Sheet (MSDS), which was introduced to protect the right-to-know of researchers or workers.

3.4.1. What is a Material Safety Data Sheet (MSDS)?

- A system that protects the worker's right-to-know
  (Allows workers to protect themselves from occupational diseases by informing them of potential hazards associated with chemical substances)
- Facilitates the safe use of chemicals by providing information on the name of chemicals, hazards, physical/chemical properties, and accidental release measures
- Article 41 of the Occupational Safety and Health Act states that a person who manufactures, imports, uses, stores, or transports chemical substances must prepare and make available relevant data in the form of MSDS
- Persons who supply or transfer chemical substances must provide MSDS

Before using chemical substances, obtain MSDS from manufacturers and be aware of safety precautions.

MSDS Contents

1. Chemical product and company identification
2. Hazard identification
3. Composition/information on ingredients
4. First aid measures
5. Fire-fighting measures
6. Accidental release measures
7. Handling and storage
8. Exposure controls and personal protection
9. Physical and chemical properties
10. Stability and reactivity
11. Toxicological information
12. Ecological information
13. Disposal considerations
14. Transport information
15. Regulatory information
16. Other information

MSDS Sample

Name of substance	CAS No.	KE No.	UN No.	EU No.
CARBON MONOXIDE	630-08-0	KE-04745	1016	211-128-3

1. Chemical product and company identification
A. Product name: Carbon monoxide
B. Product use and restrictions
Recommended use No data
Restrictions No data
C. Manufacturer (specify local distributors for imports)
Name of company No data
Address No data
Emergency contact No data

2. Hazards identification
A. Classification of hazards
Flammable gas: Category 1
High pressure gas: Compressed gas
Acute toxicity (inhalation: Gas): Category 3
Reproductive toxicity: Category 1A
Specific target organ toxicity (single exposure): Category 1
Specific target organ toxicity (repeat exposure): Category 2
B. Labels including precautionary statements
Pictogram

Signal word Danger
Hazard statement
H220 Unstable explosive
H280 Contains gas under pressure; may explode if heated
H331 Toxic if inhaled
H360 May damage fertility or the unborn child
H370 Causes damage to organs
H373 May cause damage to organs through prolonged or repeated exposure

An MSDS provides information on hazards using warning signs shown below. Chemical substances associated with certain hazards are marked with warning signs.

3.4.2. Safety Rules for Handling Chemical Substances

Wear appropriate personal protective equipment when storing or handling chemical substances

Type	Name of protective gear or facility	Photo
Respiratory protection	• Supplied-air respirator • Filtering face-piece • Manual air-purifying mask • Powered air-purifying mask • Surgical mask and dust mask	 
Skin protection	• Gloves (made from polyethylene, latex, etc.) • Gloves for ultra-low temperatures and fireproof use (for special chemical/fire experiments) • Lab coat (cotton gown, disinfected garment, disposable lab coat, etc.) • Footwear	    
Eye and face protection	• Goggles • Face shield	 
Safety facilities	• Emergency shower • Eye wash • Fume hood • Reagent cabinet (general, sealed, exhaust)	  

- Guidelines on wearing personal protective equipment when handling chemical substances
  - Eye protection

① Wear as you would a pair of glasses. For safety goggles, adjust straps accordingly.

② Wear safety goggles over your glasses.

③ Prescription safety glasses can be ordered (lenses must be plastic).

④ Lenses and general glasses are prohibited.

Instructions and Precautions for Eye Protection

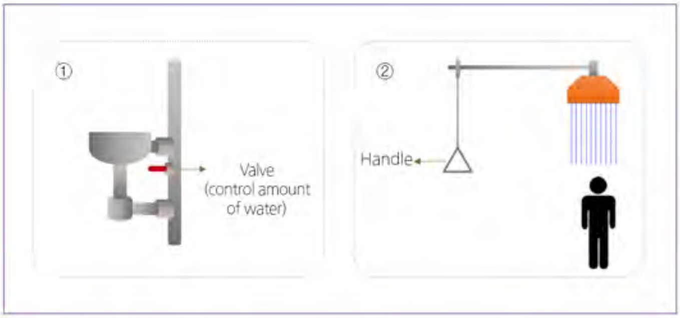
- Emergency shower

① When using for the first time, open the valve and pull the handle.

② Check that the water is clean, and take a shower (in the event of fire).

③ In the event of chemical spills, remove contaminated clothing before getting in the shower.

④ Close the valve after use.



Instructions and Precautions for Emergency Shower

– Eyewash

① Use the eyewash if chemical substances have entered your eyes.

② Turn or press the part labeled (A) for three seconds to remove impurities that may have accumulated due to lack of use.

③ Check that the water is clean. Move your face towards the eyewash and flush your eyes for at least 15 minutes.

④ Close the valve after use.

- Minimize exposure to chemical substances
  - Wear a lab coat and thick pants that cover your knees.
  - Do not wear shoes that expose your toes, sandals, or clogs.

- Understanding of GHS/MSDS
  - Be aware of physical/chemical properties and hazards (e.g. corrosiveness, flammability, reactivity, toxicity, etc.).
  - Consult with the supplier or other experts when handling a substance for the first time.

- Get permission from the safety manager of principal investigator before conducting experiments involving harmful substances.

- Wash face, hands, and arms with soap at the end of the experiment.

- Separate storage
  - Toxic substances must be stored separately from other reagents in cabinets with locking mechanisms.
  - Floor marking should be used to keep a safe distance between different types of chemical substances.

- Storing in sealed containers
  - Seal all lids to prevent leakage of chemical substances.
  - Exercise caution when handling highly acidic solutions as they may release harmful vapor when exposed to moist air.

- Designation of managers
  - Reagents stored in the reagent cabinet must be clearly marked. Introduction of new reagents or use of existing reagents must be recorded.
  - The manager must ensure that the actual remaining amount of harmful substances is consistent with the records.

3.4.3. References and Websites for Chemical Safety

National Science and Technology Human Resources Development Center, Standard Textbook for Safety in Laboratory - Chemical/Gas Safety (http://www.kird.re.kr/front/portal/pr/PublishData.jsp?sv={e2}xjiJn_ImKA0oInZaVyiWKa3ctdGg==)

Online resources for MSDS
- Korea Occupational Safety & Health Agency (KOSHA) Unified Search: http://msds.kosha.or.kr/
- MSDS Portal Site: http://ilpi.com/msds/
- MSDS Solutions 3E company : http://www.msds.com/
- PubChem US National Institutes of Health : http://pubchem.ncbi.nlm.nih.gov/
- Sigma, Aldrich (Chemical Manufacturers and Suppliers) : http://www.sigmaaldrich.com/
- Japan Advanced Information Center of Safety and Health : http://www.jaish.gr.jp/
- Canada' National Occupational Health and Safety Resource : http://ccinfoweb.ccohs.ca/msds/search.html

Information on physical hazards (explosive materials, etc.)
- Hazard information provided by National Emergency Management Agency (http://hazmat.nema.go.kr/index.jsp)
- HSDB (Http://toxnet.nim.nih.gov/cgi-bin/sis/htmlgen?HSDB)
- ILO-ICSC (http://www.ilo.org/public/elglish/protection/safework/cis/products/icsc/dtasht/index.htm)

Information on health hazards (acutely toxic substances)
- Organization for Economic Co-operation and Development (OECD) SIDS (http://www.chem.unep.ch/irptc/sids/oecdsids/sidspub.html)
- European Chemicals Agency (ECHA) IUCLID (http://www.ecb.jrc.ec.Europa.eu/esis/)
- National Library of Medicine (NLM) HSDB (http://www.toxnet/nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB)
- International Agency for Research on Cancer (IARC) Monographs Site (http://monographs.iarc.fr/)

Information on environmental hazards (substances hazardous to the aquatic environment)
- WHO IPCS (http://www.inchem.org/pages/ehc.html)
- ECOTOX (http://cfpub.epa.gov/ecotox/quick_query/html)
- ECB IUCLID (http://ecb.jrc.ec.Europa.eu/esis/)

5. Fire Safety

Fires are most likely to occur in laboratories dealing with chemical substances, but can also be caused by electric leakage and overheating of devices. Fires resulting from chemicals can lead to explosions, which are associated with a high number of human casualties and significant loss of property. Extra cautions must be exercised in laboratories, and all researchers should be aware of how to use firefighting facilities. Principal investigators or safety managers should purchase fire extinguishers suited to the type of fire most likely to occur, and use them for the intended purpose.

Extinguisher	Classification of fire	Examples of materials
Class A	Ordinary combustible materials	Office supplies, cloth, paper, rubber, plastic
Class B	Combustible liquids	Oil, lubricant, tar, paint, lacquer, gas
Class C	Energized electrical equipment	Depends on material conductivity
Class D	Combustible metals	Magnesium, titanium, zircon, lithium, sodium, potassium

3.5.1. Main Causes of Fire Safety Accidents

Many fires in laboratories are caused by chemical products and overloading of heating devices. Researchers should avoid using multi-outlets, and make sure that electrical wires are not squashed by desks, chairs, or other heavy objects. The use of personal heaters or cooking can also result in fires.

Fire Emergency Response

- Step 1: Alert others, and use a fire extinguisher if fire is in the early stage.
- Step 2: Activate the fire alarm, and report the fire to 119 and the control room.
- Step 3: Shut doors to prevent the fire and smoke from spreading.
- Step 4: Evacuate to a safe place.

"Do not use elevators"

Extinguisher Manual(PASS)

1. Pull the pin. This will allow you to discharge the extinguisher.
2. Aim at the base of the fire.
3. Squeeze the top handle or lever.
4. Sweep from side to side until the fire is completely out.
5. Keep an eye on the area in case it re-ignites.

3.5.2. General Rules for Fire Safety

General Rules for Fire Safety

(1) Know safety rules before conducting experiments, and always wear appropriate personal protective equipment.
(2) Be aware of locations of emergency exits and fire extinguishers, fire hydrants, and alarm pull stations.
(3) If a fire breaks out, check the evacuation route and emergency contact.
(4) For burns, rinse the affected area and place in cold water.
(5) If clothing catches fire, cover your eyes and face with your hands, and roll on the floor or wrap yourself in a blanket.
(6) Turn off switches and unplug electrical devices that are not in use.
(7) Open windows for air to circulate before turning on the gas.
(8) When using burners, adjust the air flow to get blue flames
(9) Use fire extinguishers, fire hydrants and other firefighting equipment to contain the fire before it spreads.
(10) Alert others in a loud voice, and activate the alarm pull station.
(11) Do not try to contain the fire on your own. Promptly leave the building.
(12) When reporting a fire, provide accurate information on the location and type of fire.
(13) Participate in emergency evacuation drills.
(14) Maintain a low posture when passing a smoke-filled area (stay in a position that keeps you 30 to 60 cm above ground).

3.5.3. References and Websites for Fire Safety

Standard Laboratory Safety, Ministry of Science and Technology, 2006
Laboratory Health and Safety Guide, KIST, 2008
Manual for Laboratory Inspection Items and Improvement Methods, Support Center for Laboratory Safety, 2012
Laboratory Safety for Persons Engaged in Research Activities, Ministry of Education, Science and Technology, National Research Foundation of Korea, 2012
Laboratory Safety Rules - 1. Fire Safety (http://blog.naver.com/PostView.nhn?blogId=allestage&logNo=220469767979&parentCategoryNo=&categoryNo=&viewDate=&isShowPopularPosts=false&from=postView)

6. Gas Safety

At most labs, a number of researchers including unskilled researchers often handle a small amount of gas in a variety of types. Poor storage and transportation of gas, damaged containers, faulty installation, and mishandling may result in a fatal gas accident (e.g. explosion, poisoning, suffocation, burn). **Extra caution** must be exercised when handling gases because of their fast diffusion and colorless/ odorless properties, Researchers must also be **familiar with related laws**[3].

Classification	Description
Explosion	Caused by leakage of explosive gases (acetylene, hydrogen, LPG, LNG, ammonia, etc.)
Gas poisoning	Caused by leakage of toxic gases (chlorine, hydrogen chloride, carbon monoxide, sulfur dioxide, ammonia, phosgene, etc.)
Suffocation	Caused by lack of oxygen in air due to high amounts of asphyxiating gas (carbon dioxide, etc.)
Low-temperature burns	Burns caused by physical contact with low-temperature liquefied gas (liquefied nitrogen, etc.)

*** Proper handling of liquefied nitrogen**

- Wear appropriate personal protective equipment (including face shield and safety goggles).
- Use a proper storage vessel designed to control internal pressure.
- Do not fill up the entire vessel.
- Do not dispose in sealed spaces or frequently accessed areas. Ensure that the gas can evaporate without causing any harm (paved road ×, gravel or soil ○).

3.6.1. Main Causes of Gas Accidents

3) Related laws: High Pressure Gas Safety Control Act, Safety Control and Business of Liquefied Petroleum Gas Act, Urban Gas Business Act, etc.

Gas accidents are usually caused by human negligence, namely poor installation of gas pipes/valves, inadequate management of combustion devices, and faulty gas products. The main causes of gas accidents in laboratories are given below.

Classification	Main Cause	Solution
Machine	Inadequate installation of gas cylinders, use of old gas pipes and valves	Enforce safety in design and manufacturing Enforce safety inspections and improve facilities
Media	Problems in management and storage of gas storage cylinders	Enforce and observe safety rules
Man	Problems in using gas	Provide training and practice sessions before/after experiments
Media	Working in area with poor ventilation	Improve working environment
Management	Lack of safety education and supervision	Improve working environment and train managers

3.6.2. General Rules for Gas Safety

General Rules for Gas Safety

(1) Check labels on high pressure gas cylinders, and read GHS/MSDS to understand gas characteristics and accidental release measures.
(2) High pressure gas cylinders must be firmly fixed to a wall or pillar using a fixing device or chains.
(3) Separate cylinders being used from empty cylinders or those not in use.
(4) Lock the valve for gas cylinders not in use. Leave the safety cap in place when storing to protect the valve in case of tipping or falling.
(5) Store high pressure gas cylinders below 40℃, and use in well-ventilated areas.
(6) When replacing gas, ensure that some pressure remains in the cylinder to prevent air from flowing in. Check for leakage, and always put on the safety cap after replacing.
(7) Before using the gas, check for leakage and ensure that the regulator is working properly.

(8) Install flame arrestors for flammable gas and prevent flames from mixing with oxygen.
(9) Exercise caution when opening the valve of regulators as a sudden increase in gas flow may result in frictional heating or static electricity.
(10) Store flammable, oxidizing and toxic gases separately to prevent explosions or at least 3 meters apart with firewalls in between.
(11) Do not store corrosive substances, flammable substances (oil, LPG, etc) and sources of ignition in areas designated for gas storage.
(12) Place pyrophoric/toxic gas cylinders in a well-ventilated area or in cabinets accessible only to authorized persons.
(13) Perform regular inspections and check expiry of refilling dates. If cylinders are nearing or have passed the expiry date, contact the manufacturer for pick-up and disposal.
(14) When transporting high pressure gas cylinders, wear personal protective equipment such as gloves, safety goggles, and safety shoes.
(15) When transporting flammable substances, prepare fire extinguishers and wear personal protective equipment.
(16) Before transporting gas cylinders, remove regulators, lock valves and leave on safety caps.
(17) Before using regulators, be aware of how to properly use each component. Use appropriate equipment when connecting gas cylinders to regulators. Remember that flammable gas and non-flammable gas outlets are threaded in opposite directions.

3.6.3. References and Websites for Gas Safety

Korea Gas Safety Corporation Website (http://www.kgs.or.kr/kgsmain/index.do)
Gas Safety Training Website (http://www.kgs.or.kr/kgsmain/index.do)
How to Wear and Use Protective Equipment, Korea Occupational Safety & Health Agency, 2004
Standard Laboratory Safety, Ministry of Science and Technology, 2006
Laboratory Health and Safety Guide, KIST, 2008
Laboratory Safety Management Manual, Ministry of Education, Science and Technology, 2008
Case Studies of Domestic/International Laboratory Accidents, Ministry of Education, Science and Technology, 2011
Case Studies of Laboratory Safety Accidents, Ministry of Education, Science and Technology, 2012
Occupational Safety and Health Manual, Ministry of Education and Korea Research Institute for Vocational Education & Training, 2013
Standard Teaching Material on Laboratory Safety, Chemical/Gas Safety, National Science and Technology Human Resources Development Center, 2015

7. Biological Safety

Recently, research activities have continuously increased and become significantly complicated and diverse in reflection of the development of the bioengineering industry and convergent research.

Biological laboratories refer to laboratories that conduct experiments involving Living Modified Organisms (LMOs), high-risk pathogens, biological agents, and toxins. Such laboratories must adhere to the following rules and report or obtain approval for their facilities.

Classification	Act	Abbreviation
Laboratory safety	Act on the Establishment of Safe Laboratory Environment	Laboratory Safety Act
Biological safety and security	Transboundary Movement of Living Modified Organisms Act	LMO Act
	Biotechnology Support Act	-
	Infectious Disease Control and Prevention Act	Infectious Disease Prevention Act
	Act on the Control of the Manufacture, Export and Import, etc., of Specific Chemicals and Chemical Agents for the Prohibition of Chemical and Biological Weapons	Chemical and Biological Weapons Act
	Act on the Prevention of Livestock Epidemics	
	Aquatic Life Disease Control Act	
	Act on the Preservation, Management and Use of Agro-Fishery Bioresources	Agro-Fishery Bioresources Act
	Act on Securing, Management, and Use of Maritime and Fisheries Genetic Resources	Maritime and Fisheries Genetic Resources Act
Bioethics	Bioethics and Safety Act	Bioethics Act

Classification	Act	Abbreviation
Animal ethics	Animal Protection Act	-
	Laboratory Animal Act	-
Biological resources	Act on the Acquisition, Management, and Utilization of Biological Research Resources	Biological Research Resources Act
Wastes	Wastes Control Act	-
Other	Foreign Trade Act	-
	Occupational Safety and Health Act	-

Biosafety levels are determined depending on the degree of risk of organisms and the content of research; labs must be established and managed for each level.

Level	Description	Report/ Approval
Level 1	• A laboratory that develops or uses LMOs not known to consistently cause disease in immunocompetent adult humans • A laboratory that develops or uses LMOs that present minimal potential hazard to laboratory personnel and the environment	Report
Level 2	• A laboratory that develops or uses LMOs that may cause disease in humans that is easily treatable • A laboratory that develops or uses LMOs that cause mild and recoverable harm even if released to the environment	Report
Level 3	• A laboratory that develops or uses LMOs that may cause disease in humans with severe symptoms but that is treatable • A laboratory that develops or uses LMOs that cause significant but recoverable harm if released to the environment	Approval
Level 4	• A laboratory that develops or uses LMOs that may cause fatal disease in humans • A laboratory that develops or uses LMOs that cause severe and non-recoverable harm if released to the environment	Approval

LMO for Experiment/Research

■ Article 24 (Identification) of LMO Act, Article 2-10 (Identification) of Integrated Notice
A person who develops, produces or imports LMOs shall identify the matters prescribed below on the receptacles, packages, or import invoice thereof.

① Name, type, purpose and characteristics of LMO

- Name : B6SJL-Tg (SOD1*G93A) 1Gur/JStock#002726
- Type : MICE
- Purpose : Experiment/research

② Precautions for safe handling of LMO

- Must be transported using a separate means of transportation
- Must not be exposed to persons and external surroundings
- Personal protective equipment required when handling
- Must not be handled by unauthorized persons

③ Name, address and phone number of LMO developer, manufacturer, exporter and importer

- Exporter: Jackson Lab. USA 1-800-422-6423
- Importer: 000 Bio 000-000-0000

④ Basis for classification as LMO

- A living organism with modified genes

⑤ Use of LMO for release into the environment

- NA (Only used within the designated research facility for experiment/research purposes)

3.7.1. General Safety Rules for Biological Laboratories

Biological laboratories can be categorized into general biological laboratories, mass culture laboratories, animal laboratories, plant laboratories, and insect laboratories (Article 6 of Guidelines for Research Involving Recombinant DNA). This section presents general safety rules for biological laboratories. For more details, refer to the Guidelines for Research Involving Recombinant DNA and the National Lab Safety Education System.

Biosafety rules prevent infections and accidents in biological laboratories by serving as a reference for the establishment of safe laboratory facilities, hazard assessment, and appropriate biosafety management. Below is a list of general safety rules.

General Rules for Biological Safety

- Strictly observe all laws and safety rules related to biological safety.
- Researchers who handle pathogenic microorganisms or infectious substances must be aware of associated hazards.
- To ensure safe handling of biological resources, researchers must receive training on precautionary measures and experimental techniques.
- Appropriate personal protective equipment must be worn in laboratories, and removed when exiting.
- Eating, storing food, smoking, and applying makeup are prohibited in laboratories.
- LMO research facilities can be accessed only by authorized persons.
- LMO research facilities must be equipped with high pressure autoclaves.
- Biological waste products and waste water must be autoclaved using appropriate equipment.
- Infectious substances and pathogenic materials should be handled only in biosafety cabinets.
- Researchers must know how to use equipment and be familiar with related techniques.
- Records must be maintained on date of receipt, type, quantity, date handled, manager, and amount remaining. Biological resources must be periodically inspected to ensure consistency with records.

3.7.2. References and Websites for Biological Safety

National Lab Safety Education System (http://edu.labs.go.kr/MainHome.do?cmd=indexMain)

Konkuk University Guidelines on Biological Safety in Laboratories

Case Studies on Laboratory Accidents Within and Outside Korea, Ministry of Science and ICT, 2015

Emergency Response Manual for LMOs Used in Research/Experiments, 2014

Standard Teaching Material on Laboratory Safety, Biological Safety, National Research Safety Headquarters, 2017

8. Emergency Response Guide for Safety Accidents

Due to the lack of adequate response to accidents, laboratories have seen unnecessary casualties and sustained significant loss of experimental facilities. The emergency response guidelines provided below for different types of accidents can help to minimize damage.

According to the Laboratory Accident Response Manual (Sep. 2014) distributed by the Ministry of Science and ICT, the actions to be taken at each stage are as follows. Persons engaged in research activities, who are usually the first witnesses to an accident, play a key role in emergency response and reporting. Please read the emergency response guide for the type of accident associated with your area of research, and participate in emergency drills so that you will be better prepared for possible accidents in the future.

Stage	Responsibilities	Supervisor
Occurrence of laboratory accident		
Report of accident	**ㅇ First witness→principal investigator→safety department (laboratory safety manager)→head of research entity**	**ㅇ Laboratory safety personnel**
Accident response	**ㅇ Formation of laboratory accident response team if required ㅇ Implementation of accident control measures ㅇ Implementation of emergency measures by principal investigator**	**ㅇ Laboratory safety personnel**
Accident investigation	ㅇ Identification of cause and determination of extent of damage	ㅇ Safety department
Establishment and implementation of preventive measures	ㅇ Establishment of accident prevention measures by laboratory safety manager and reporting to the head of research entity ㅇ Implementation of preventive measures by principal investigator	ㅇ Safety department ㅇ Principal investigator
Follow-up	ㅇ Follow-up to implemented preventive measures and update of safety management plans based on accident analysis	ㅇ Head of research entity ㅇ Safety department

In the event of a fire, explosion or injury in the laboratory, victims must be taken to a hospital for medical treatment. Provided below are guidelines for the various types of accidents.

Laboratory Emergency Response Guide

- Clothing on fire: Do not run. Remove clothes, roll on floor, or wrap with a blanket or lab coat to smother flames. A fire extinguisher may be used away from the victim's head. Use the emergency shower if the fire is caused by an organic solvent that does not mix with water.
- Thermal burns: Flush with running water for **at least 15 minutes,** and seek medical attention at a nearby hospital.
- Chemical burns: Flush immediately with water or use the emergency shower for **at least 15 minutes** and seek medical attention at a nearby hospital (remove contaminated clothes before showering)
- Chemicals in the eyes: Immediately flush using the eye wash for **at least 15 minutes**, and seek medical attention at a nearby hospital.
- Inhalation of toxic fumes: Move to a well-ventilated area, and take deep breaths while seated or lying down. Seek medical attention at a nearby hospital if large amounts have been inhaled.
- Cuts: Clean with ethanol, stop bleeding using a clean bandage or cloth, and seek medical attention at a nearby hospital.
- Fire or explosion: Evacuate all students from the laboratory. Seek medical attention at a nearby hospital. Put out fire using a fire extinguisher. Call 119 if the fire is too large.

3.8.1. Emergency Response Guide for General Safety Accidents

(1) Burns

Classification	Laboratory (Principal investigator, persons engaged in research activities)
Accident prevention and preparedness	• Use and observe safety signs • Wear personal protective equipment before conducting experiments
Accident response	• Stop using equipment and survey the scene. Move the victim to a safe place and perform appropriate emergency measures. • Brush off solids before flushing with water if the chemical is in solid form. • For minor burns, place the affected area in cold water or against a cold cloth to relieve pain. • For serious burns, cover the affected area with a clean, wet cloth to prevent infections. Seek medical attention at a hospital. • Do not touch the affected area or break blisters. Cover with gauze to prevent secondary infections.
Accident recovery	• Preserve the scene to investigate the cause of the accident. Keep the surroundings organized to prevent secondary accidents. • Inform the victim's family and follow up as necessary.
	• Establish and implement measures for damage recovery and prevention

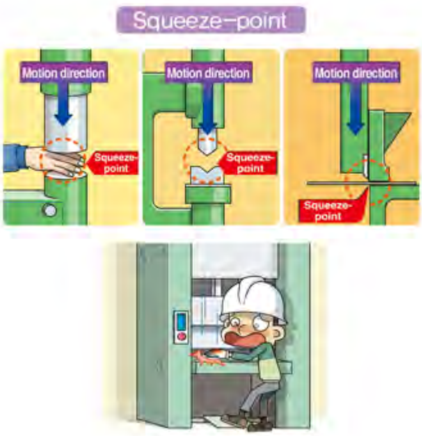
(2) Injury and bleeding

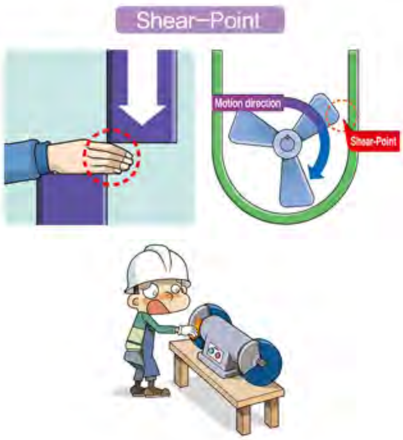
Classification	Laboratory (Principal investigator, persons engaged in research activities)
Accident prevention and preparedness	• Use and observe safety signs • Wear personal protective equipment before conducting experiments
Accident response	• Survey the scene. Move the victim to a safe place and perform appropriate emergency measures. • For cuts, stop bleeding before disinfecting the area. Wrap minor cuts with band-aids. For larger cuts, wrap in bandage and elevate the injured area above the heart. • For grazes, flush under running water before disinfecting. • For bruises, apply ice or cold packs. If the victim is unable to move the injured area, seek medical attention at a hospital to check for sprain or fracture. • Stop bleeding and perform other emergency measures.
Accident recovery	• Preserve the scene to investigate the cause of the accident. Keep the surroundings organized to prevent secondary accidents. • Inform the victim's family and follow up as necessary.
	• Establish and implement measures for damage recovery and prevention.

3.8.2. Emergency Response Guide for Mechanical Safety Accidents

(1) Machine jamming and amputation

Classification	Laboratory (Principal investigator, persons engaged in research activities)
Accident prevention and preparedness	• Install safety devices for machines (protective cover, emergency stop button, etc.) • Establish protective measures for all machines • Wear appropriate personal protective equipment when using machines
Accident response	• Shut down the equipment without causing further harm. • Survey the scene. Move the victim to a safe place and perform appropriate emergency measures. • In the event of a finger or toe amputation, apply pressure using layers of clean cloth or gauze to stop bleeding. • Clean the amputated finger or toe, and place it in a plastic bag filled with ice. Immediately seek medical attention at a hospital specializing in replantation.
Accident recovery	• Preserve the scene to investigate the cause of the accident. Keep the surroundings organized to prevent secondary accidents. • Inform the victim's family and follow up as necessary.
	• Establish and implement measures for damage recovery and prevention.





3.8.3. Emergency Response Guide for Electrical Safety Accidents

(1) Electrocution

Classification	Laboratory (Principal investigator, persons engaged in research activities)
Accident prevention and preparedness	• Use safety signs warning against high voltage and electric shock. • Do not handle electrical equipment when hands are wet. • Consult experts for repair of electrical devices. • Do not use non-standard or uncertified electrical products. • Wear appropriate personal protective equipment depending on experiments. • Maintain a safe distance when conducting electrical experiments. • Always ground electrical devices.
Accident response	• Wear insulated gloves, and turn off the source of electricity. • Use an insulated material (dry wooden pole, plastic stick, etc.) to move the source of shock away from the victim. Do not come into contact with the victim. • Check the victim (consciousness, breathing, pulse, bleeding, etc.) and perform appropriate emergency measures (CPR). • Report to a hospital if necessary.
Accident recovery	• Preserve the scene to investigate the cause of the accident. Keep the surroundings organized to prevent secondary accidents. • Inform the victim's family and follow up as necessary.
	• Establish and implement measures for damage recovery and prevention.

(2) Electrical fire

Classification	Laboratory (Principal investigator, persons engaged in research activities)
Accident prevention and preparedness	• Do not use multi-outlets that exceed the permitted capacity. • Do not handle electrical equipment when hands are wet. • Consult experts for repair of electrical devices. • Do not place flammable objects near electric heaters. • Always ground electrical devices.

Classification	Laboratory (Principal investigator, persons engaged in research activities)
Accident response	• Turn off the source of electricity. • Perform emergency measures on victims who have inhaled smoke or suffered burns. • Avoid spraying water on devices as it may lead to electrocution. • If possible, use fire extinguishers with a class C rating. • Report to a relevant organization (fire station, hospital, etc.) if necessary.
Accident recovery	• Preserve the scene to investigate the cause of the accident. Keep the surroundings organized to prevent secondary accidents. • Inform the victim's family and follow up as necessary.
	• Establish and implement measures for damage recovery and prevention.

3.8.4. Emergency Response Guide for Chemical Safety Accidents

(1) Chemical leak/exposure

Classification	Emergency response for persons engaged in research activities
Accident prevention and preparedness	• Keep MSDS/GHS readily available, and provide related training. • Store chemical substances according to properties.
Accident response	• Inform all persons engaged in research activities of the accident. • Report the accident (location, type and amount of chemical, casualties, etc.) to the safety department (and to a fire station or hospital if necessary). • Wash the affected area with clean water for at least 20 minutes. • Do not wash if contaminated with water-reactive materials. • If the level of risk is negligible, clean up the scene and dispose of materials under the supervision of the safety department.
Accident recovery	• Preserve the scene to investigate the cause of the accident. Keep the surroundings organized to prevent secondary accidents. • Inform the victim's family and follow-up as necessary.
	• Establish and implement measures for damage recovery and prevention.

(2) Chemical fire/explosion

Classification	Laboratory (Principal investigator, persons engaged in research activities)
Accident prevention and preparedness	• Keep MSDS/GHS readily available, and provide related training. • Store chemical substances according to properties. • Designate a shelter area to proceed to in case of explosion.
Accident response	• Inform all persons engaged in research activities of the accident. • If the level of risk is negligible, put out the fire. • Spray water while keeping a safe distance to prevent further damage. • Do not use water if the fire is due to water-reactive materials. • Wear personal protective equipment to prevent the inhalation of harmful gases or products of combustion. • Wash the affected area with clean water for at least 20 minutes. • If the fire is difficult to control, proceed to the designated shelter area.
Accident recovery	• Preserve the scene to investigate the cause of the accident. Keep the surroundings organized to prevent secondary accidents. • Inform the victim's family and follow up as necessary.
	• Establish and implement measures for damage recovery and prevention.

3.8.5. Emergency Response Guide for Fire Safety Accidents

(1) Emergency evacuation

Classification	Emergency response for persons engaged in research activities
Accident prevention and preparedness	• Keep the laboratory well-organized, and store flammable substances separately. • Participate regularly in fire safety training, and inspect fire safety facilities.
Accident response	• Activate the alarm pull station in the corridor, and notify others of the accident. • Report the fire to the safety department (safety team or operations control center). • If the fire is difficult to control, shut the door to the laboratory and safely evacuate (report the fire to the principal investigator). • Use a handkerchief to cover your mouth and nose. Crawl towards an exit away from the spread of fire. • If clothing is on fire, use the emergency shower in the corridor, or roll on the floor with your arms across your chest to smother flames. • If you are not familiar with using the fire extinguisher, do not attempt to put out the fire. Report the fire and evacuate.

Classification	Emergency response for persons engaged in research activities
Accident recovery	• Preserve the scene to investigate the cause of the accident. Keep the surroundings organized to prevent secondary accidents. • Inform the victim's family and follow up as necessary.
	• Establish and implement measures for damage recovery and prevention.

(2) Fire

Classification	Laboratory (Principal investigator, persons engaged in research activities)
Accident prevention and preparedness	• Conduct fire drills. Be aware of locations of emergency exits and fire extinguishers. • Know the different classes of fire extinguishers and how to use them.
Accident response	• Shout to alert others, and activate the alarm pull station (call 119). • Close the door to the scene of the fire, and evacuate all persons in the building. • Shut all doors when exiting to delay the spread of fire. • Identify the type of fire, and use appropriate fire extinguishers. • If casualties are present, administer emergency oxygen and wait for an ambulance.
Accident recovery	• Preserve the scene to investigate the cause of the accident. Keep the surroundings organized to prevent secondary accidents. • Inform the victim's family and follow up as necessary.
	• Establish and implement measures for damage recovery and prevention.

3.8.6. Emergency Response Guide for Gas Safety Accidents

(1) Flammable gas leak/explosion

Classification	Laboratory (Principal investigator, persons engaged in research activities)
Accident prevention and preparedness	• Place flammable gas cylinders in a well-ventilated area outside the building. • Install and manage flammable gas detectors. • Install gas cylinder fixing devices. • Perform regular inspections for gas leaks.
Accident response	• Inform persons in the building of the leak and advise them to evacuate. • Shut the valve and ventilate the area to prevent the leak from spreading. • Immediately evacuate if the leak is too large to contain.
Accident recovery	• Preserve the scene to investigate the cause of the accident. Keep the surroundings organized to prevent secondary accidents. • Inform the victim's family and follow-up as necessary.
	• Establish and implement measures for damage recovery and prevention.

(2) Toxic gas leak

Classification	Laboratory (Principal investigator, persons engaged in research activities)
Accident prevention and preparedness	• Store toxic gas cylinders outside the building or in appropriate cabinets. • Keep respiratory protection readily available. • Install and manage toxic gas detectors and neutralizing equipment. • Perform regular inspections for gas leaks.
Accident response	• Inform persons in the building of the leak and advise them to evacuate. • Wear personal protective equipment (gas mask) matched to the hazard. • Shut the valve to prevent the leak from spreading. • Move victims who have inhaled toxic gases to a well-ventilated area. • Immediately evacuate if the leak is too large to contain. • Shut doors and fire doors when evacuating to prevent the leak from spreading.
Accident recovery	• Preserve the scene to investigate the cause of the accident. Keep the surroundings organized to prevent secondary accidents. • Inform the victim's family and follow up as necessary.
	• Establish and implement measures for damage recovery and prevention.

Standard Textbook for Safety in Laboratory

New Persons Engaged in Research Activities

CHAPTER

4

Examples of Safety Violations

1. General safety issues
2. Mechanical safety issues
3. Electricity safety issues
4. Chemical safety issues
5. Fire safety issues
6. Gas safety issues
7. Biological safety issues

CHAPTER 4 New Persons Engaged in Research Activities

Examples of Safety Violations

Common safety violations are provided below to enhance your understanding of laboratory safety. Check that such violations are not occurring in your laboratory, and follow the suggestions for improvement.

Putting safety off to tomorrow causes an accident today.

1. General safety issues

Photo	Problem	Correction	Note
	Poor documentation in daily inspection report	• Write daily inspection report using standard form • Obtain signatures from safety managers (professors)	

Photo	Problem	Correction	Note
	Poor accessibility to or lack of laboratory safety guidelines and emergency contact numbers	• Post guidelines in an area easily visible by all research personnel and visitors	
	Poor accessibility to or lack of laboratory safety guidelines and emergency contact numbers	• Wear laboratory safety access card (back of ID)	
	Storage of temporary bed in laboratory	• Remove temporary bed/sofa from laboratory	
	Eating in the laboratory	• No eating • Remove coffee, drinks, and snacks from laboratory (to be consumed in seminar room or lounge)	
	Poor storage of personal protective equipment	• Store lab coats in designated area (closet) • Dispose of personal protective equipment (gloves) after experiments • Remove gloves before exiting	

Photo	Problem	Correction	Note
	Research personnel not dressed in proper lab attire	• Wear proper lab attire • Do not wear earphones • Wear safety shoes that cover the entire foot when working with machines • Wear lab coat when entering common equipment room	
	Risk of objects falling from high shelves	• Remove reagents and other objects from high shelves	
	Storing unnecessary objects below the emergency shower	• Remove objects from below the emergency shower	
	Disorganized laboratory environment	• Keep evacuation routes free of obstacles	
	Storing reagents and food in the same refrigerator	• Do not store food in reagent refrigerator • Do not use refrigerator for food storage	
	Dryer accident due to absence of research personnel during experiment	• Post special safety guidelines in laboratory • Receive on-site guidance on accident prevention during laboratory safety inspection	

2. Mechanical safety issues

Photo	Problem	Correction	Note
	No roller protective device	• Install protective device and block nip points	
	Inadequate safety gap for grinding machine	• Adjust position of grinding blades	
	No indication of safety area	• Maintain sufficient gap between equipment and tables, and mark out safety areas	
	No replacement of old laboratory equipment	• Check the state of equipment and replace if necessary	• Check recommended period of use, inspection date, and frequency of replacement

3. Electricity safety issues

Photo	Problem	Correction	Note
	Use of ungrounded power outlet	• Use grounded power outlets to prevent harm to humans in the event of short circuit	
	Disorganized wires	• Use molding to keep electrical wires organized and prevent physical damage	
	Fire caused by short circuit	• Inspect fire prevention equipment and laboratory safety • Enforce laboratory safety education	

4. Chemical safety issues

Photo	Problem	Correction	Note
	Storing mass amounts of reagents in fume hood	• Keep fume hood organized (do not pile up reagents) • Remove objects from below fume hood	
	Storing reagents for a long period	• Dispose of reagents	
	Poor storage of flammable reagents	• Store in safety cabinet	
	Lack of fall prevention bar in reagent shelf	• Install fall prevention bar	
	Poor organization of experimental waste	• Affix labels (acid, alkali, organic, inorganic) • Affix waste processing request forms	
	Storing of corrosive reagents in wrong cabinet	• Store only flammable substances in cabinet for flammable substances • Store corrosive reagents in separate cabinet	

Photo	Problem	Correction	Note
	Keeping of list of reagents	• Enter in reagent management program • Print out and store in binder	
	Poor organization of fume hood	• Organize and clean fume hood	

5. Fire safety issues

Photo	Problem	Correction	Note
	Placing of unnecessary objects in front of fire hydrant and distribution board	· Remove unnecessary objects	
	Use of personal heater	· Remove personal heater	
	Inadequate pressurization of fire extinguisher	· Check that the extinguisher is properly pressurized · Replace if not in the normal range	
	Placing of equipment in corridor and blocking of evacuation route	· Keep evacuation route free of obstacles by removing equipment and unnecessary objects	

6. Gas safety issues

Photo	Problem	Correction	Note
	Lack of protective cap on high pressure gas tanks	• Install protective cap	
	Use of gas tanks that have passed the expiry date	• Return to manufacture or dispose of according to instructions	
	Lack of overload prevention device	• Install fixing device	
	Inadequate bending of high pressure gas tanks	• Use cable ties and clamps	

7. Biological safety issues

Photo	Problem	Correction	Note
	No indication of starting date on medical waste container	• Enter first date of using medical waste container and observe recommended storage period	
	Placing of flower pots in laboratory	• Remove flower pot	
	No indication of starting date on sharps waste container	• Enter starting date and other required information	
	Lack of cover for medical waste	• Install medical waste cover and keep marked	
	Mixing of medical waste and general waste	• Do not mix general waste with medical waste	

Standard Textbook for Safety in Laboratory

New Persons Engaged in Research Activities

Appendix

Appendix 1 Case of safety education for new persons engaged in research activities

※ The checklist below is used for new research personnel at another institute.

Institutions governed by the Act on the Establishment of Safe Laboratory Environment must provide training to new participants in research activities. To help institutions offer efficient and practical safety training, it is worth referring to the orientation checklists used in the United States and among universities in Korea. Equivalent to lab safety orientation or site safety orientation in the United States, the Lab Safety Checklist for New Trainees, which has been in force at KAIST since March 2015, allows lab managers or lab safety managers to train new participants in research activities by going through checklists together or assessing the understanding of essential matters after completion of lab safety training. This checklist is designed to allow new researchers to check basic matters on safety management that they have to be substantially familiar with. Please modify the checklist as required in consideration of the institution's characteristics and circumstances. Checklists reviewed by individuals may be aggregately managed by the safety-related department or compiled into a lab safety binder for each research lab.

- Trainer: Advisor or lab representative (senior researcher or higher)
- Trainee: New research personnel

Check "✓" in the "check" column for items that have been fully explained, or in the NA column if not applicable.

Laboratory Safety Orientation Checklist

1. Personal Particulars

Department:	Building Name/Room No.:
Name:	Student No./Personal ID:
Date (MM-DD):	Advisor/Principal Investigator:

2. Orientation Checklist

Check	NA	① Emergency response
☐	☐	1. Location of fire extinguishers, fire hydrants, and fire alarm switches (Extinguisher: _____, Hydrants and alarms: _____)
☐	☐	2. Location of closest emergency exist and evacuation route
☐	☐	3. Location and contact number of emergency assembly area ( )
☐	☐	4. Emergency response procedures and contact number of emergency operations center (- - or)
☐	☐	5. Understanding of Emergency Guide and its location (_____)
☐	☐	6. Location of medicine and first aid kit (_____)
☐	☐	7. Use and location of emergency shower and eyewash (_____)
☐	☐	8. Use and location of chemical adsorbent and spill kit (_____)

Check	NA	② Laboratory Safety Management
☐	☐	1. Registration of members and use of laboratory safety management system
☐	☐	2. Requirements for safety education and instructions for completion (online safety education and group education)
☐	☐	3. Writing of daily inspection reports (online registration in laboratory safety management system)
☐	☐	4. Use and location of laboratory safety management handbook ( )
☐	☐	5. Understanding of legal provisions of chemical substances (gas, hazards, etc.) and biological materials (import, report, designated amount, etc.)
☐	☐	6. Use and storage of Material Safety Data Sheet (MSDS) ( )
☐	☐	7. Use of safety labels (laboratory safety signs, chemical warning labels, hazardous equipment labels, etc.)

Check	NA	③ Personal Protective Equipment
☐	☐	1. Wearing of proper lab attire (gown, safety goggles, shoes that completely cover the foot, etc.)
☐	☐	2. Type and size of lab coat (Type: □ General □ Flame-resistant / Size:)
☐	☐	3. Use and storage of personal protective gear (safety goggles, gloves, etc.) ( )

Check	NA	④ Laboratory Wastes
☐	☐	1. Understanding of laboratory waste processing manual
☐	☐	2. Disposal procedures for chemical waste and biological waste

Check	NA	⑤ Other
☐	☐	1. Use of key equipment (fume hood, vacuum chamber, oven, centrifugal separator, laser, crane, etc.) and safety procedures
☐	☐	2. Other matters necessary for laboratory safety

Terms related to laboratory safety

Appendix 2

- **AC**: Electricity with differences in phase.
- **Accident investigation**: A series of actions taken to identify the cause of an accident and to determine the extent of damage, including data collection, interviewing of relevant personnel, and on-site surveys.
- **Accident response**: A series of actions taken in the event of an accident, including emergency treatment, damage control, and accident scene preservation.
- **Accident**: An unexpected event that causes harm to humans or objects.
- **Adherent**: Different structures that stick together but can be easily detached.
- **Arc**: Electrical discharge produced when a gas between two different electrodes is converted to a conductive medium.
- **Base metal**: Metal used for base metal welding or gas cutting.
- **Bearing**: Device that supports rotation around a fixed axis or straight line movement.
- **Biosafety manager**: A person who ensures the observance of biosafety guidelines within an institute, conducts biosafety training and safety inspections, reports biosafety accidents, and collects information on biosafety.
- **Body current**: Current that flows through the human body following

electrocution.

◎ **Body resistance**: Resistance in the electrocution circuit that changes according to bodily conditions and the environment.

◎ **Brush discharge**: Repetition of phase discharge known as streamer; a type of corona discharge.

◎ **Bushing**: A component placed at the end of a metallic pipe; used to prevent damage to insulating material when electrical wires are inserted or withdrawn.

◎ **Capacitance**: Physical quantity that indicates the capacity of an object to accumulate electric charge; Also referred to as electrostatic capacity.

◎ **Compressed gas**: Gas with a gauge pressure of more than 1 MPa at room temperature or 35℃. Has a critical temperature lower than room temperature, and does not liquefy even if compressed and exists in the gaseous state. e.g.) Oxygen, nitrogen, hydrogen, etc.,

◎ **Corona discharge**: Electrical discharge that occurs with the intensifying of electric field at the terminal end when one or both sides of electrodes have sharp ends.

◎ **Corrosive gas**: A gas that corrodes the material with which it comes into contact. (E.g.) Chlorine, fluorine, sulphur dioxide, hydrogen sulfide, ammonia, hydrogen chloride, ethylene oxide, etc.

◎ **Critical temperature**: Temperature at which a substance cannot be liquefied, regardless of pressure.

◎ **Current transformer**: Equipment used to obtain low current that is proportionate to the high current of AC.

◎ **Danger**: Dangerous elements or situations that may lead to manmade disasters, property loss, environmental damage, or a combination thereof.

◎ **Degradation**: Phenomenon in which material characteristics, including performance and functions, are sequentially degraded due to the effects of heat, light, radiation, oxygen, ozone, water, and microorganisms.

◎ **Dielectric breakdown**: Phenomenon in which insulation resistance undergoes degradation and allows relatively higher current to pass through when the size of the voltage applied to the insulator exceeds a certain level.

- **Disability**: Mental and physical damage that remain and cannot be improved by treatment even if injury or disease exists.
- **Dissolved gas**: Gas that can explode when compressed or liquefied and is used by dissolving in a solvent. e.g.) Acetylene (slightly positive pressure at 15℃)
- **Earth fault current**: Current with hazardous voltage passing through the electrical circuit or casing of a mechanical device due to the deterioration of insulation between the electrical circuit and the earth.
- **Earth leakage circuit breaker**: Device used to prevent risk of electrocution by earth leakage in the electrical line connected to an electric machine.
- **Earthing**: Maintaining of the potential of an electrical device to be the same as that of the earth, that is 0, by connecting the electric circuit or part of electrical devices to the earth with conducting wires.
- **Electric charge**: Quantity of electricity. Expressed in units of Coulomb (C)
- **Electric field**: Quantity that shows the electrical state of each point of the space in which an electrified body is present.
- **Electric motor**: Equipment that converts electric energy into dynamic energy using the force obtained from a magnetic field by a conductor through which current is passed.
- **Electric resistance**: Value that indicates the difficulty in passing current through an object. Expressed in the unit of Ohm (Ω).
- **Electric shock prevention device**: Equipment used to prevent electric shock by lowering the secondary no-load voltage of the welder when there is no spatter during arc welding.
- **Electric shock**: Phenomenon in which current passes through part or all of the body.
- **Electrical insulation**: Prevents the passage of electricity or heat.
- **Electrocution circuit**: Electric circuit formed by electrocution of the body

◎ **Experiment**: Procedures carried out using tools, devices, specimens, materials, and energy to induce changes in an object or phenomenon, and making scientific conclusions based on observations of such changes.

◎ **Explosion threshold**: The range of temperature at which a mixture of natural gas and air explodes. No explosion occurs below or above this range.

◎ **Fail Safe**: Safety measures devised to prevent accidents even in the event of breakdown or failure of a machine or its parts. A design feature or structure implemented to prevent accidents that may occur when workers do not follow recommended procedures.

◎ **Faulty contact**: Phenomenon in which a core wire comes in contact with other core wires in an electrical circuit.

◎ **Fire outbreak**: Fire caused by combining the source of ignition and combustible materials in its vicinity.

◎ **Flammable gas**: Gas that discharges light and heat when ignited after having been mixed with oxygen or air. Examples include methane, ethane, propane and hydrogen. Exists in the gaseous state at room temperature and pressure, but some become liquefied when compressed (E.g. Ethane, propane, etc.). Also refers to gas with a lower explosive limit less than 10%, or with a difference greater than 20% between the lower and upper explosive limits. (E.g.) Methane, ethane, propane, hydrogen, etc.

◎ **Fool Proof**: A human-centered design that prevents accidents even under improper handling or operation of a device. A feature (structure, function, etc.) that makes it difficult for humans to make mistakes. (E.g.: Protective cover of a rotating device, a two-step stop button of an emergency kill switch)

◎ **Freezing current**: When the through-current of the body is increased to this level, the muscles in the passage of the current experience spasms, and the nerves become paralyzed. While there is no direct threat to life, the body is unable to detach itself from the source of the through-current. Also referred to as deadlock current.

◎ **Full-load operation**: Operation of devices and equipment at rated output.

- **Functional insulation**: Insulation that is necessary for the device to perform its intended function.
- **Gaseous discharge**: Discharge occurring in gas.
- **Ground fault current**: Occurrence of accidents due to an insulated live part coming into contact with the earth.
- **Grounding**: Grounding between the electrical circuit and the earth has abnormally dropped, or been bridged by means of arc or conductive material, thereby generating hazardous voltage or passage of current in the electrical circuit or external part of the device. Also referred to as earth leakage.
- **Hazard factor**: Any factor that could cause an accident, such as chemical or physical risk factors.
- **Head of a research entity**: The representative of a university, research institute, etc., or the owner of a relevant laboratory.
- **Hot line**: State of flow of electricity or line with live electricity.
- **Impedance**: The difficulty in passing current through an AC circuit.
- **Inductance**: Quantity that indicates the ratio of the counter electromotive force generated by electromagnetic induction due to changes in current flowing through the circuit. Expressed in units of Henry (H).
- **Instrument transformer**: Device inserted between the instrument and electric circuit to facilitate measurements of high voltage and current.
- **Insulation resistance**: Resistance value induced by the insulator for the current generated when DC voltage has been applied.
- **Insulation**: The shielding and separation of areas surrounding the conducting portion using non-conductors when electricity is passed through electric machines, devices, and electrical wires.
- **Laboratory accident**: A person engaged in research activities suffers a loss in life or body, such as an injury, disease, physical disability, or death, in connection with the research activities in a laboratory, or a situation in which facilities, equipment, etc., in a laboratory are damaged.

◎ **Laboratory safety manager**: A person conducting safety management and prevention of accidents in laboratories. Project Investigator): and guiding a laboratory safety manager for technical matters related to a safe laboratory.

◎ **Laboratory**: All places designed for the purpose of conducting experiments, including laboratories equipped with research equipment.

◎ **Let-go current**: Pain can be felt when the through-current exceeds the threshold of the perception current. The threshold current for which pain can be endured and without threat to life is known as the let-go current. Also known at breakaway current or pain current.

◎ **Live part**: Electrical part to which voltage is applied.

◎ **Load**: Consuming of output energy of a device that generates electrical and mechanical energy.

◎ **Magnetic field**: Spatial domain in which electromagnetic force is exerted on moving electric charges.

◎ **Molding**: Components that have been filled into resin and hardened

◎ **Neutral line**: Electrical wire taken out from the neutral point of a power source of multi-phased AC. Generally grounded to the terminal end from which it is drawn out.

◎ **No-load loss**: Refers to the input of an electric motor when operated at the rated voltage, frequency, and speed under no-load condition. That is, the sum of the core loss, mechanical loss, and loss due to existing current.

◎ **No-load**: State in which there is no load.

◎ **Nominal voltage**: Authorized voltage, which may vary from the actual voltage.

◎ **Nonflammable gas**: Gas that does not combust on its own and does not assist in the burning of other substances. Irrelevant with combustion. E.g.) Argon, helium, nitrogen etc.,

◎ **Nontoxic gas**: Gas that does not cause harm to the human body even if existing at a high concentration in air. E.g.) Oxygen, hydrogen, etc.

◎ **Ohm's law**: Intensity of the current is directly proportional to the potential difference between two points and inversely proportional to the electric resistance.

- **Overload**: Load that exceeds the normal value to be borne by an overloaded device or equipment.
- **Oxidizing gas**: Gas necessary for the combustion of fuel, including flammable gas. E.g.) Air, oxygen, chlorine, etc.
- **Partial disconnection**: Disability in which core wires of the circuit are disconnected but become connected intermittently.
- **Perception current**: Minimum amount of current that the body can perceive when current is passed through.
- **Potential gradient**: Value obtained by dividing the potential difference between two points in an electric field by the distance between them. Indicates the intensity of the electric field.
- **Potential**: Locational energy of the unit electric charge within an electric field. Expressed in units of Volt (V).
- **Power distribution**: Electric line that is fed from the power distribution substation to the service line through the high power transformation line, transformer, and low voltage power distribution line.
- **Preliminary risk analysis of hazard factors**: A preliminary analysis of hazard factors conducted before commencing research and development activities.
- **Project investigator**: A person who is responsible for supervising and managing research equipment of a laboratory, affiliated research personnel, and persons engaged in research activities.
- **Protection insulation**: Independent insulation installed on the functional insulation to ensure protection against electrocution caused by dielectric breakdown.
- **Pulse phase**: Phenomenon of appearance of voltage, current, or wave that produces a huge amplitude in a short period of time.
- **Reactance**: The resisting element, other than resistance, that interferes with

current arising from changes in the direction and quantity of AC. Does not apply to DC.

◎ **Refrigerated liquefied gas**: Gas under the pressure of 0.2 MPa at room temperature or 35℃. Has a critical temperature above room temperature. Can be liquefied within a high pressure container, and has vapor pressure corresponding to that temperature. Highly pressurized gas may induce accidents such as rupturing of container and gas eruption. Subject to High Pressure Gas Safety Control Act as such gases have been reported to be the cause of disasters such as gas explosion, ignition, intoxication and suffocation. E.g.) Carbon dioxide, ammonia, chlorine, liquefied petroleum gas (LPG), etc.

◎ **Research laboratory**: A laboratory, a practical room, and a preparation room for experiments equipped with a facility, equipment, and research materials, established by a university, research institute, etc., for research and development activities in the fields of science and technology.

◎ **Researcher**: Researchers, college students, graduate school students, research assistants, etc., engaged in research and development activities in the fields of science and technology in a university, research institute, etc.

◎ **Safe voltage**: Voltage that does not harm the human body even if electrocuted.

◎ **Safety inspection**: An act of inspecting risk factors existing in a laboratory by a person having experience and technology with the naked eye or inspection instruments, etc.

◎ **Serious laboratory accident**: A laboratory accident, the degree of loss or damage by which is serious, as prescribed by Ordinance of the Ministry of Science and ICT.

◎ **Short circuit**: Two points of an electric circuit connected with a conductor having very low electric resistance.

◎ **Short**: Abnormal state of contact when the electric resistance between electric lines has decreased or is absent due to breakdown or negligence.

◎ **Sleeve**: A relatively long cylindrical component wrapped around the external part of the axis of a rotating body. Prevents dangerous situations that may result from coming into contact with or being fed into the rotating body.

◎ **Spatter**: Slag or metallic pellets that are produced and scattered during welding.

◎ **Static eliminator**: Machine that neutralizes static electricity using ionized air.

◎ **Streamer**: Magnetic tape device that continuously operates at high speed.

◎ **Structure**: Pillar or wall of building.

◎ Terms related to toxicity

Acronym	Full Name	Meaning
TLV-TWA (Allowable concentration)	Threshold Limit Value-Time Weighted Average (Allowable concentration)	A concentration of harmful substances that causes no adverse effects on a worker during an 8-hour workday
LD50	Lethal Dose fifty	Dose required to kill half the members of a tested population when orally administered
TDLO	Toxic Dose Low	Lowest dosage of a substance known to have produced signs of toxicity when orally administered
LDLO	Lethal Dose Low	Least amount of drug that can produce death when orally administered
LC50	Lethal Concentration fifty	Dose required to kill half the members of a tested population when inhaled for four hours
TCLO	Toxic Concentration fifty	Lowest dosage of a substance in air known to have produced signs of toxicity
LLO	Lethal Concentration Low	Lowest concentration of a material in air reported to have caused death

◎ **Thorough safety inspection**: An inspection and assessment conducted by a person who meets the standards or qualification requirements prescribed by Presidential Decree for the purpose of detecting any potential danger and establishing measures for the improvement thereof, in order to prevent the occurrence of any accident in a laboratory.

◎ **Threshold concentration**: The threshold concentration at which explosion occurs when arc is introduced to a mixture of combustible gas and air.

◎ **Through current**: Current that passes through a conductor.

◎ **Toxic gas**: Includes ammonia, carbon monoxide, carbon disulfide, chlorine, fluorine, benzene, hydrogen chloride, monosilane, disilane, diborane, hydrogen selenide, and phosphine. Allowable concentration in air is no more than 5,000 parts per million by volume of gas.

◎ **Transformer for power distribution**: Transformer used on power distribution cables of electric power companies to transform high voltage into lower voltage for end users.

◎ **Tree-type**: The branching out of numerous strands in a branch-like configuration.

◎ **Ventricular fibrillation current**: Spasms are induced when the current passing through the heart reaches a certain value. This sends the ventricles into fibrillation and interferes with normal heart beat.

◎ **Voltage in contact**: The potential difference between the earthing point and people or objects in the vicinity when fault current passes through the earthing line and forms a potential gradient in the form of a concentric circle with the highest potential at the earthing point.

◎ **Voltage**: Difference between potentials. Expressed in units of Volt (V).

◎ **Welding rod holder**: Device that tightly holds the terminal end of a welding rod and passes welding current from the cable to the welding rod.

◎ **Zero-sequence current transformer**: A current transformer used to protect the earthing of relatively low transmission current. A type of earth leakage circuit breaker that prevents erroneous operation of earth relay at the neutral point by achieving magnetic balance of the common magnetic circuit for each group.

◎ **Zero-sequence current**: Voltage displayed due to the impedance of the earth.

◎ **Flammable gas**: Includes acetylene, ammonia, hydrogen, hydrogen sulfide, carbon monoxide, methane, butane, and benzene. Refers to gas with a lower explosive limit less than 10%, or w

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