Safety in the laboratory

WILEY

MilliporeSigma

Contents

Imprint

Boschstr. 12, 69469 Weinheim, Germany
Email: info@wiley-vch.de
Editor-in-Chief: Dr. Christina Poggel

Safety in the Laboratory

Anyone working in a laboratory must familiarize themselves with rules and precautions for working safely. This includes awareness of potential risks associated with the handling of hazardous substances, knowledge of exposure and accident hazards and how they occur, best practices for the prevention of laboratory accidents, how to behave in case of exposure to hazardous substances, and many more aspects.

At institutes and companies, there are usually regular mandatory training sessions for this purpose, at which extensive information material is made available. In addition, laboratory safety is the subject of several health and safety regulations and guidelines in various countries. In day-to-day laboratory work, it is often not easy to keep track of all guidelines and the many aspects that are important for working safely.

This eBook is designed to give you a quick overview of important safety rules for chemical laboratories in an easy-to-digest way. Links to additional online resources for every topic are given in the purple boxes. Furthermore, you can find short video clips and expert presentations in the last part of this eBook.

The eBook begins with an overview of the different types of hazards and a guide for the correct labeling of chemicals and solvents on pages 4 and 5.

In the second part of this eBook, best practices for the handling of hazardous substances are described. Learn about the chemical resistance of commonly used gloves, the classes of hazardous substances and how they can be stored together, the fire and explosion triangle, as well as the substitution of hazardous substances, and more.

On page 12, you will find information about laboratory accidents at a glance, as well as information on how to deal with spills and how to clear them away safely.

Finally, this eBook concludes with a series of video clips and expert presentations to further expand your knowledge about laboratory safety.

1 Fundamentals of hazards

1.1 Types of hazards

The laboratory contains hazards that fall into four general classes:

Biological **Chemical** **Physical** **Radiological**

A hazard is any material, condition, or action that may result in physical harm or impairment to employees.

Hazard management is challenging due to the complexity of the work and the diversity of the hazards.

Risk is related to:

- Exposure levels
- Duration of exposure
- Toxicity or pathogenicity of the hazardous material
- Safety controls present
- Other factors such as health or age of the laboratory worker

Risk is reduced by:

- Minimizing exposure
- Storing only small quantities of the hazardous material
- Storing hazardous materials in appropriate containers
- Substituting highly toxic or dangerous chemicals for less hazardous materials where possible

Biological hazards

Biological hazards include infectious agents such as bacteria, parasites, fungi, and viruses that may be transmitted through contaminated body secretions, tissue, or other materials.

All clinical specimens are potentially infectious. The isolation and culture of pathogenic microorganisms increases the risk.

Chemical hazards

Chemical hazards include all chemicals that may be toxic or irritating. These include solids, liquids, and gases such as mercury, acetone, xylene, stains, and formaldehyde.

Risk and severity is influenced by:

- Exposure (dose)
- Route of exposure (i.e., inhalation, ingestion, absorption)
- Chemical properties of the compound
- Susceptibility of the individual
- Duration of exposure

- Laboratory chemicals are labeled and described by their hazard classification, such as irritant, corrosive, flammable (gas, liquid, solid), poison (toxic), or carcinogen.
- Reactive chemicals must be segregated for storage.
- Poisons or toxic compounds can cause acute or chronic symptoms when ingested, inhaled, or absorbed through the skin and can affect the nervous, respiratory, or reproductive systems.
- Carcinogens may cause malignant neoplasms in humans or animals long after exposure.
- Use of highly toxic chemicals or carcinogens should be restricted, and they should be handled only in a designated area by well-trained personnel.
- When possible, disposable PPE should be used. A chemical hygiene plan (required for all laboratories) details the specific safety measures.
- When exposure monitoring is required, a trained industrial hygienist can measure the chemical level to determine whether the level exceeds the permissible exposure limit (PEL).
- PELs represent the maximum concentration of a chemical to which an employee may be exposed (either short term, or over a workday or workweek).

Physical hazards

Physical hazards include:

- Ergonomic issues
- Fire
- Electrical hazards
- Noise levels
- Equipment
- Accidents (e.g., slipping, falling, and lifting)
- UV light exposure
- Compressed gases

Accidents often occur from workspace overcrowding, poor lighting, poor maintenance, and lack of attention by the employee.

Accidents should be investigated to identify the cause and correct the problem.

Radiation hazards

Any laboratory that performs tests using radioactive materials needs to meet the requirements of the U.S. Nuclear Regulatory Commission (NRC). The implementation of a radiation safety program and control plan can minimize the occupational exposure to ionizing radiation.

Risk from ionizing radiation is related to:

- The type of radiation emitted
- The quantity of radioactive material present
- The source of exposure (i.e., internal or external)

Engineering and work practice controls are essential to minimizing the risk. Time, distance, and shielding should be considered. The goal is to minimize the length of exposure, maintain the greatest distance between the radioactive material and the worker, and use an effective shield (i.e., lead, Plexiglas).

1.2 Classification and labeling

Warning signs and labels within a laboratory are designed to provide a universal policy to alert visitors and employees to potential hazards. A warning labeling system should be implemented to identify contaminated objects or hazardous materials.

Containers of hazardous reagents, radionuclides, chemicals, and waste must be labeled with the chemical name and appropriate hazard label (e.g., flammable, corrosive, carcinogen, irritant).

With the introduction of the *Globally Harmonized System of Classification and Labelling of Chemicals (GHS)* an internationally comprehensible system for hazard communication has been provided.

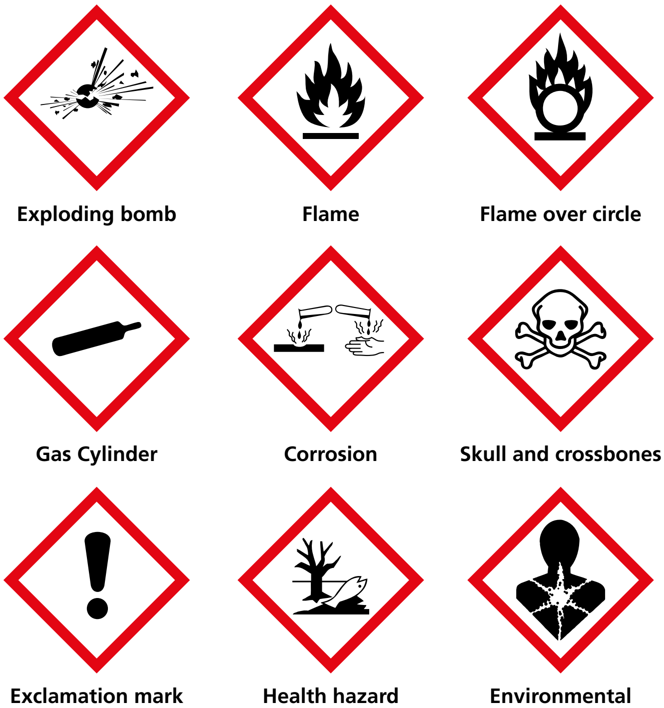
Further information

On this poster you can find an overview of the classes of health hazards and categories.

All hazard and precautionary statements are provided here.

Find out more about the GHS here.

Hazard pictograms



2 Handling of hazards

2.1 Applicable legislation

In the US, controlled substances are regulated by the Drug Enforcement Administration.

Within the EU, REACH is a regulation that applies to all chemical substances. It was adopted to improve the protection of human health and the environment from the risks that can be posed by chemicals. REACH impacts a wide range of companies, including manufacturers, importers, and downstream users of chemicals.

By law, Material Safety Data Sheets (MSDSs) must be readily available.

All laboratories should have a Chemical Hygiene Plan (29CFR Part 1910.1450). Institutional safety officers should be consulted as to its implementation.

- Certain chemicals cannot be easily or safely mixed and should be separated into general hazard classes and stored appropriately.
- Facilities should be appropriate for working with hazardous chemicals. In particular, hazardous chemicals should be handled only in chemical fume hoods, not in laminar flow cabinets. Fume hoods should be checked periodically.
- Laboratories should also be equipped with safety showers and eye-wash facilities (tested periodically). Other safety equipment may be required depending on materials handled.
- Researchers should be trained in the proper procedures for handling hazardous chemicals as well as other laboratory operations.
- Order hazardous chemicals only in quantities that are likely to be used in a reasonable time.
- Substitute alcohol-filled thermometers for mercury-filled thermometers.
- Before starting work, know the physical and chemical hazards of the reagents used. Wear appropriate protective clothing and have a plan for dealing with spills or accidents.
- In the case of larger spills, the area should be evacuated and help should be sought from those experienced in and equipped for dealing with spills—e.g., the institutional Safety Officer.

2.2 PPE – Personal protective equipment

Protective equipment should include eye protection, a lab coat, and gloves. In certain circumstances other items of protective equipment may be necessary (e.g., a face shield).

Different types of gloves exhibit different resistance properties. No gloves resist all chemicals, and no gloves resist any chemicals indefinitely.

Disposable gloves generally offer extremely marginal protection from chemical hazards.

Select gloves carefully and always look for evidence that they will protect against the materials being used. Inspect all gloves before every use and never reuse disposable gloves. Clean reusable gloves after each use and dry carefully inside and out.

Solvents: Chemical resistance of commonly used gloves[a,b]

Abbreviations: VG, very good; G, good; F, fair; P, poor (do not use)

Chemical	Neoprene gloves	Latex gloves	Butyl gloves	Nitrile gloves
Acetic acid	VG	VG	VG	VG
*Acetone	G	VG	VG	P
*Amyl acetate	F	P	F	P
Aniline	G	F	F	P
*Benzene	P	P	P	F
Butyl acetate	G	F	F	P
Butyl alcohol	VG	VG	VG	VG
Carbon disulfide	F	F	F	F
*Carbon tetrachloride	F	P	P	G
*Chlorobenzene	F	P	F	P
*Chloroform	G	P	P	E
Cyclohexanol	G	F	G	VG
*Dibutyl phthalate	G	P	G	G
Diisobutyl ketone	P	F	G	P
Dimethylformamide	F	F	G	G
Dioctyl phthalate	G	P	F	VG
*Ethyl acetate	G	F	G	F
Ethyl alcohol	VG	VG	VG	VG
*Ethyl ether	VG	G	VG	G
*Ethylene dichloride	F	P	F	P
Ethylene glycol	VG	VG	VG	VG
Formaldehyde	VG	VG	VG	VG
*Furfural	G	G	G	G
Glycerin	VG	VG	VG	VG
Hexane	F	P	P	G
Hydrochloric acid	VG	G	G	G
Ketones	G	VG	VG	P
Lactic acid (85%)	VG	VG	VG	VG
Methyl alcohol	VG	VG	VG	VG

Chemical	Neoprene gloves	Latex gloves	Butyl gloves	Nitrile gloves
Methylamine	F	F	G	G
Methyl bromide	G	F	G	F
*Methyl ethyl ketone	G	G	VG	P
*Methyl isobutylketone	F	F	VG	P
Monoethanolamine	VG	G	VG	VG
Morpholine	VG	VG	VG	G
Naphthalene	G	F	F	G
Naphthas, aliphatic	VG	F	F	VG
Naphthas, aromatic	G	P	P	G
*Nitric acid	G	F	F	F
Nitric acid, red and white fuming	P	P	P	P
Nitropropane (95.5%)	F	P	F	F
Oleic acid	VG	F	G	VG
Palmitic acid	VG	VG	VG	VG
Perchloroethylene	F	P	P	G
Phenol	VG	F	G	F
Phosphoric acid	VG	G	VG	VG
Propyl acetate	G	F	G	F
i-Propyl alcohol	VG	VG	VG	VG
n-Propyl alcohol	VG	VG	VG	VG
Sulfuric acid	G	G	G	G
Tetrahydrofuran	P	F	F	F
*Toluene	F	P	P	F
*Trichloroethylene	F	F	P	G
Triethanolamine	VG	G	G	VG
Turpentine	G	F	F	VG
*Xylene	P	P	P	F

a Performance varies with glove thickness and duration of contact. An asterisk indicates limited use.
b Adapted from the July 8, 1998, version of the DOE OSH Technical Reference Chapter 5 (APPENDIX C at https://www.cpp.edu/~psbeauchamp/pdf/424_glove_safety.pdf). For more information also see Forsberg and Keith (1999).

2.3 Storage of chemicals in safety cabinets

The table below applies to smaller quantities of different chemicals and will help to reduce the risk of accidents. There are no exceptions for explosive substances, gases, organic peroxides, self-reactive substances, and radioactive substances.

The storage table for small quantities shows, by means of GHS-pictograms, combinations of products that may be stored together (+) or not (-).

You can learn more about the safe storage of chemicals on this poster.

	[GHS02 blue]	[GHS02 yellow]	[GHS02 green]	[GHS02 pink]	[GHS03]	[GHS06]	[GHS05]	[GHS08]	[GHS09]	[GHS07]	none
[GHS02 blue]	+	+	–	–	–	–	+	+	+	+	+
[GHS02 yellow]	+	+	+	+	–	+	+	+	+	+	+
[GHS02 green]	–	+	+	+	–	–	+	+	+	+	+
[GHS02 pink]	–	+	+	+	–	–	–	–	–	–	–
[GHS03]	–	–	–	–	+	+	+	+	+	+	+
[GHS06]	+	+	–	–	+	+	–	+	+	+	+
[GHS05]	+	+	+	–	+	–	+	+	+	+	+
[GHS08]	+	+	+	–	+	+	+	+	+	+	+
[GHS09]	+	+	+	–	+	+	+	+	+	+	+
[GHS07]	+	+	+	–	+	+	+	+	+	+	+
none	+	+	+	–	+	+	+	+	+	+	+

- Blue: Flammable liquids and aerosols (H 222, H 223, H224, H 225 or H 226)
- Yellow: Flammable solids (H 228)
- Pink: Substances liable to spontaneous combustion (H 250, H 251 or H 252)
- Green: Substances that form flammable gases in contact with water (H 260 or 261)

Technical rules for hazardous substances (TRGS):

TRGS 510 provides knowledge relating to the storage of hazardous substances in non-stationary containers including the following (handling) activities:

1. Storage and removal from storage facility
2. Transport inside the warehouse
3. Removal of released hazardous substances

TRGS 510 has been extensively revised in recent years.

2.4 Solvents and electrostatics

If flammable liquids (e.g., solvents) are to be used, the container (10L and more) must be properly earthed according to valid safety regulations to avoid explosion and fire risks. Appropriate measures must be taken to discharge static electricity.

1 General warnings and safety instructions must be observed

2 All components (e.g., container and withdrawal system) must be grounded separately in accordance with the applicable safety regulations

3 Grounding clamps must have metallic contact with both the container and the withdrawal system, and a safe ground connection

4 The grounding of the container and the grounding of the withdrawal system must be installed before opening the container

5 The user must always wear conductive personal protective equipment, especially shoes and gloves, to avoid electrostatic charges. Therefore, the user must always wear conductive personal protective equipment, especially shoes and gloves

6 The floor has to be conductive when working with flammable chemicals

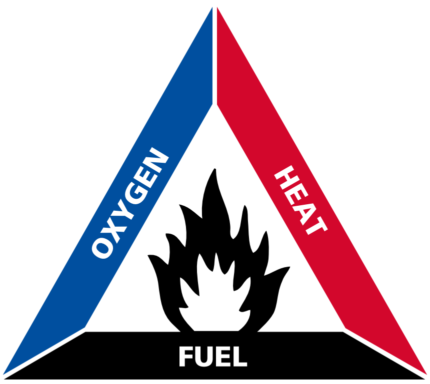
7 Sampling vessels made of insulating material with a volume greater than 1 liter should not be used

8 Before using organic solvents, the user must ensure that there are no additional ignition hazards caused by process-specific parameters, such as increased ignitability of the substances due to changed environmental conditions or when sampling in combination with highly charge-generating processes

The fire and explosion triangle

Oxidizer

Planned introduction of air, inadvertent introduction of oxygen, release of hydrocarbons into air, weathered fluids, oxidizers



Ignition source

Heat, electricity, static electricity, friction, chemical reactions, spontaneous combustion, dieseling, pyrophors, sudden decompression, catalytic reactions

Heavy and light gases, hydrocarbon liquids and vapors, vapors of chemicals / lubricants / solvents, frac oils, flammable materials

Removing at least one of the components avoids the fire / explosion

2.5 Safe handling

Handling hazardous materials improperly can result in gases, vapors, or splashes, or result in the release of materials.

Containers should only be stored up to a height at which they can be set down and removed safely. As a rule, this is above approximately 175 cm / 5 ft 9 in for any container that cannot be carried in one hand.

Breakable containers must be supported at the base when they are being carried, and should only be transported into other rooms using aids that ensure safe holding and carrying.

Transferring or transporting large quantities can be particularly dangerous.

Emptied containers that held hazardous materials should be cleaned before disposal or re-use.

For more information on safe handling, consult the Working Safely in Laboratories guidelines.

2.6. Lab hoods

Hoods used for contaminant control are classified into three broad categories:

- **Enclosures** (prevent release of contaminants by enclosing the process or source of generation and transporting them out of the laboratory in the exhaust air stream)
- **Exterior hoods** (used when the process or source cannot be enclosed)
- **Receiving hoods** (take advantage of the process or source generation that results in air movement in a specific direction)

Guidelines for hood selection

Complete enclosure is the best way to contain the contaminants and prevent escape. This needs to be balanced with the need for laboratory workers to access the process and space, and for energy conservation.

Shelves inside hoods

This is not encouraged, but if allowed, should be done carefully. Shelves should not affect airflow within the hood. Ideally, a performance test should be conducted to determine the effect of the shelf on hood containment.

Important features of constant-volume bypass chemical fume hoods

To correct the several deficiencies of the old-fashioned fume cupboard, the following features are found in modern, efficient bypass chemical fume hoods:

1. Bottom and side airfoils around the open face produce nearly turbulence-free airflow into the hood.
2. A mechanism to minimize excessive velocities (300 fpm, 1.5 m/s) when the total opening is 15 cm / 6 in or less. This may be accomplished by an air bypass at the hood or by switching the fan to a lower speed.

2.7 Disposal

Waste should be segregated according to institutional requirements.

For example, into solid, aqueous, non-chlorinated organic, and chlorinated organic material, and should always be disposed of in accordance with all applicable federal, state, and local regulations.

Protocols for the disposal and decontamination of some hazardous chemicals commonly encountered in laboratories can be found here.

3 Substitution of hazardous substances

Where possible, it is always preferable to use less hazardous substances.

Substitution with a chemically similar product can have a significant advantage, as the changes to established formulations and technology may be minimal. However, a similar product may share the profile of hazardous characteristics of the restricted substance.

Properties that contribute to hazard and risk for human health and the environment

There are some potentially serious hazards that are manageable without exceptional measures (flammability, pyrophoricity, and explosivity).

Engineering controls can protect against exposure to highly toxic substances. However, some hazards are sufficiently concerning that authorization may be needed.

Indicators of problems in achieving safe use can include:

For health:

- Very toxic substances
- Carcinogens, mutagens, or reproductive toxins

For the environment:

- Highly bio-accumulative substances
- Highly persistent substances
- Substances with severe ecotoxicological effects

Uses that cannot be controlled completely include:

- Industrial uses that are not completely enclosed (most uses outside the top end of the chemicals sector).
- Substances or preparations used by professionals outside of the chemical industry or other major industries.
- The public (chemical substances can be found in many products, such as detergents, and cleaners).
- Substances found in articles such as batteries or ink cartridges, furniture, toys, and electrical goods.
- Waste (for example electrical equipment, recycled paper, and plastic goods at the end of their lives).

TRGS 600 specifies requirements of the Ordinance on Hazardous Substances (GefStoffV). If the technical rules with the TRGS are observed, then it can be assumed that corresponding requirements of the Ordinance are fulfilled.

TRGS 600 has been completely revised in recent years, and it is worth familiarizing with the updates.

Assessment of alternatives – replacement of use

Legislation such as the REACH Regulation and the Carcinogens Directive necessitate consideration of the replacement of the most hazardous substances with more acceptable alternatives.

In addition, there are economic benefits to the substitution of hazardous substances for 'green' alternatives.

'Off the shelf' substitution is rarely possible, and the new research and development needed for substitution is costly and time-consuming.

What is an alternative?

An alternative is not necessarily the replacement of one substance by another.

When considering a replacement of a substance there will inevitably be consequences for the whole application.

Therefore, a valid alternative is one which represents an overall improvement. For example, the introduction of a less toxic substance may be of little benefit if it requires a very dangerous process to manufacture it.

Analysis of alternatives

Some general areas of consideration can be identified:

- Acceptability of a substance in respect of health and environmental safety.
- Substitution may necessitate a change in the whole formulation, usually for physicochemical reasons.
- Substitution may require technology change, even for relatively simple cases.
- Technical performance is likely to change with substitution, so new performance specifications will be required.

The analysis of alternatives requires consideration of the relative strengths and weaknesses of a replacement technology compared to another.

Considerations should include:

- Is there a regulatory need now, or will there be in future?
- Will there be a technology change?
- With a new technology, customers and/or suppliers will need to be involved. Will research and development work be needed?
- Will there be training needs?
- Will there be costs associated with establishing the regulatory acceptance of the new technology?

4 Management of lab accidents

The major accident categories are:

Technical failures
(filters corrupted, centrifuge gasket leaky)

Failure of personal protection
(protection of eyes, skin, and inhalation)

Unsafe procedures
(wrong strains, benchwork, spills, and sharps)

Working in a laboratory is as safe as you make it. It is within your interests and that of your colleagues, institution, and community that you constantly think about the way you handle substances in the laboratory.

How to behave in case of an exposure to hazardous substances

Provide immediate care to the exposed sites:

- Wash wounds and skin with soap and water
- Flush contaminated mucous membranes and conjunctiva sites with water

Report the incident to a supervisor according to institutional policy

Evaluate the risk of exposure:

- Appraise type of substances
- Appraise type of exposure (e.g., inhalation, ingestion, direct contact, or percutaneous inoculation)
- Appraise the volume of material or concentration of microorganisms tested

How to clear away chemical spills SAFELY

Spills happen, and it is important to clear away aggressive or unpleasant liquids quickly and safely.

In case of spillages, use dedicated absorption agents, e.g., Supelco® Chemizorb® absorbents.

All Chemizorb® absorbents are used in a similar way:

1. Cover spilled liquids with sufficient absorbent
2. Use a spatula, spoon, or small shovel to mix the absorbent and spilled liquid
3. Wait until neutralization and absorption processes are complete

Specific usage instructions are provided on each Chemizorb® product label.

The used absorbent should be collected in a polyethylene bag, and sent for disposal in accordance with the company regulations and national guidelines for the hazardous products in question.

Fast-acting Supelco® Chemizorb® absorbents consist of porous mineral or synthetic copolymers that are chemically inert, and capable of absorbing up to 400% of their own weight in liquid.

Find out more about Chemizorb® products here.

Copyright: 10.1128/9781555817282.ch28; J.J. Dunn, D.L. Sewell; Laboratory Safety; In: Clinical Laboratory Management; eds L.S. Garcia et. al.; © 2014 ASM Press

5 Video Clips: Deepen your knowledge about laboratory safety

Safety in the Laboratory – Merck Video Series

In this safety film, you can explore the many aspects important to overall safety in the laboratory setting. This includes packaging, storage and handling of chemicals, the explanation of product labels and Safety Data Sheets, as well as basic lab rules and correct use of personal protective equipment.

Click here to access this video.

Understanding Lab Accidents through a Multidisciplinary Approach

by A Dana Ménard, Ph.D. & C.Psych John Trant, Ph.D. from the University of Windsor

The modern experimental chemistry lab is almost 200 years old. However, despite significant advances in instrumentation, analytical tools, availability of reagents, modern academic labs often seem to embody the purported maxim from von Liebigs' lab, "If you want to become a chemist…you have to ruin your health." This is evident from the continuing spate of preventable deaths and accidents in the academy worldwide.

In this web seminar, the speakers will discuss the state of lab safety research, the challenges to conducting such research, and preliminary data from our Canadian pilot study on accident correlates and reporting practices. The speakers argue that solutions to this problem will require multidisciplinary collaboration to address the human side of the equation.

Click here to access this video.

Safety Connects: How to Maximize Safety when Handling Hazardous Goods
by Annett Schneider, Global Product Manager Safety Products, Merck KGaA

Safety is a serious concern for many laboratory personnel, especially when working with hazardous chemicals. But risks can be minimized – with the right knowledge and tools. This video presents an optimal approach that combines innovative products and packaging with expert support to keep you safe, simplify your work, and help you save resources.

You will learn about the role of safety in the lab, challenges that can occur when handling hazardous goods, and how to improve daily processes to ensure personal safety. Besides accident prevention, the speaker will also cover appropriate emergency procedures in the event of chemical spills and demonstrate reliable cleaning of lab equipment.

[Click here to access this video.]

MilliporeSigma

SAFETY

INSIDE

Trust our safety expertise

We combine ingenious products and packaging solutions with individual support to keep you safe, simplify your lab work, and help you save resources. Discover daily safety, risk prevention and emergency solutions that match your high standards.

Discover more:
SigmaAldrich.com/lab-safety

Integrated safety right from the start
Risk prevention

Tools & products for your
Daily safety

Swift, simple and efficient
Emergency help

The life science business of Merck KGaA, Darmstadt, Germany operates as MilliporeSigma in the U.S. and Canada.

Supelco®
Analytical Products

WILEY

MilliporeSigma