ACS
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AMERICAN CHEMICAL SOCIETY
CHEMICAL SAFETY SUMMIT
October 13–15, 2022
Washington, DC

Executive Summary and Recommendations from the 2022 ACS Presidential Safety Summit

The fourth ACS Presidential Safety Summit was held on October 13–15, 2022, at ACS headquarters in Washington, DC. Co-organized by the ACS Committee on Chemical Safety (CCS) and the ACS Office of Safety Programs, the summit brought together 39 participants from industry, academia, national laboratories, graduate students and postdoctoral scholars, and ACS staff members. Three guiding questions focused discussions on articulating and communicating industry needs and expectations related to laboratory safety for new Ph.D. hires in research and development (R&D).

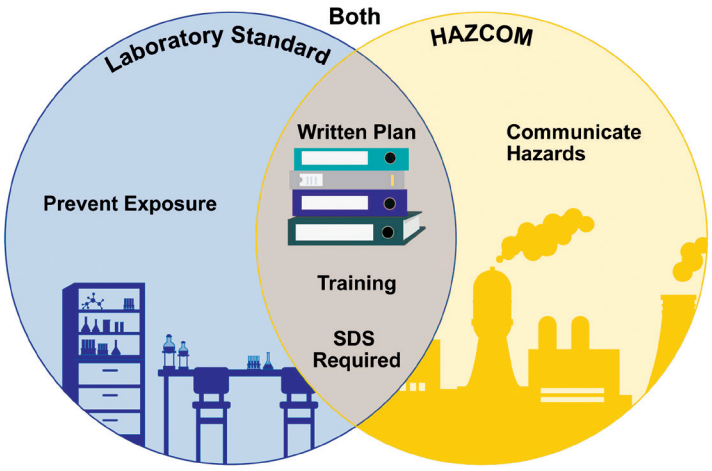
Question 1: What laboratory safety competencies (knowledge, skills, and attitudes) do new Ph.D. hires need to reduce the time for onboarding in industrial R&D laboratories where chemicals are used?

To prepare to address this question, summit participants reviewed survey responses from a select group of industrial safety professionals. The survey questions were designed to determine what safety expectations industrial employers have for their new Ph.D. hires. The framework of Recognize hazards, Assess risks, Minimize risks, Prepare for emergencies (the RAMP model) was used to organize the survey questions.

The discussion of the survey results during the summit highlighted the specific safety knowledge, skills, and attitudes that were most desired in new Ph.D. hires.

These included:

- Awareness and appreciation of regulations from various federal agencies (OSHA, EPA, and FDA) affecting laboratories where chemicals are used.



- Ability to recognize hazards.
- Ability to locate and apply authoritative chemical safety information.
- Ability to implement the RAMP model by
  - Conducting risk assessments,
  - Applying the hierarchy of controls,
  - Selecting and using personal protective equipment (PPE),
  - Recognizing when a Management of Change procedure is needed,
  - Recognizing off-normal conditions,
  - Learning from near-misses and incidents, and
  - Applying ionizing and non-ionizing radiation safety practices.

Human factors[1] were also identified as ways to reduce time for onboarding. These included:

- Leadership skills that include prioritizing safety,
- Cultural acknowledgment in the context of safety,
- Safety mindset,
- Communication and listening skills, and
- Willingness to learn and adapt.

[1]As used here, "human factors" include those safety categories and items that can affect the performance of an individual, including risk perception, attitude, technical and non-technical skills, and competence.

Question 2: Building on the successes of recent initiatives, what additional opportunities are there for industry and ACS to respond to industry's needs and expectations related to laboratory safety for new Ph.D. hires in R&D?

To inform this discussion, participants were provided with information on the current landscape in chemical safety education, the materials that have been created at ACS, and the grassroots organizations known as Laboratory Safety Teams (LSTs) that graduate students are creating throughout the country. In response to the second question, the summit participants emphasized that ACS has a unique opportunity to build more connections between academia and industry. If chemical safety education is included in collaborative initiatives between ACS and industry, undergraduate and graduate chemistry students will be better prepared to work safely in industrial R&D laboratories.

Suggestions for other collaborative projects between academia and industry that ACS might catalyze included:

- Collaborative development of safety education and training opportunities that meet industry standards and expectations,
- Highlighting industry expectations through ACS webinars, symposia, and other communications,
- Enhancing safety expectations in the *ACS Guidelines for Bachelor's Degree Programs,* and
- Encouraging and supporting Laboratory Safety Teams (LSTs) in graduate programs to reflect industry expectations.

Question 3: How do we broaden and continue the summit conversations?

During the last part of the summit, potential next steps and partners were considered. Disseminating information through symposia, papers, webinars, and workshops will be a key first step in continuing the conversation and pursuing collaborative initiatives. Participants identified potential actionable strategies in four areas:

- Advancing safety education and training activities,
- Conveying safety expectations,
- Connecting industry and academia, and
- Engaging influential stakeholders in chemical safety.

Strengthening safety education and training of Ph.D. students requires the collective efforts of many stakeholders. Those interested in pursuing actionable strategies should contact safety@acs.org.

REPORT

Since 2018, the ACS Committee on Chemical Safety (CCS) and the ACS Office of Safety Programs have partnered to organize ACS Presidential Safety Summits to connect existing ACS safety activities and develop a cohesive strategy to advance chemical safety. The summits have included ACS stakeholders and external subject-matter experts to initiate Society-wide conversations about safety. The desired outcome of each summit is to deliver actionable strategies for safety projects that maximize the impact of ACS efforts and resources through synergistic and focused collaborations.

The 2022 ACS Safety Summit, designated as a Presidential Event by Dr. Angela Wilson, 2022 ACS President, took place on October 13–15, 2022, in Washington, DC. The summit goals were as follows:

- Understand industry's needs and expectations related to laboratory safety for new Ph.D. hires in research and development (R&D).
- Identify potential ACS–industry collaborations to further safety education for Ph.D. chemistry students.
- Develop a plan to communicate industry's needs and expectations throughout the chemistry enterprise.

Dr. H. N. Cheng (2022 ACS Immediate Past-President) joined the summit in person, and Dr. Angela Wilson (2022 ACS President) addressed the summit participants virtually. The 39 summit participants included industrial employees, safety professionals, postdoctoral researchers, graduate students active in Laboratory Safety Teams (LSTs) at their universities, educators specializing in graduate and undergraduate education in the chemical sciences, and ACS staff members (Appendix 1). Many participants were also members of ACS divisions and committees.

The summit discussions were framed by guiding questions centered around emerging opportunities in chemical safety that ACS can lead and influence. These guiding questions were inspired by the previous three safety summits, when participants from industry advocated that ACS should actively increase its involvement in encouraging Ph.D. programs to better prepare chemists for industrial careers – specifically by improving their chemical safety competencies. Data show that most chemistry and chemical engineering graduates are employed by industry.[1, 2]

Industrial employees noted that as new hires come on board, companies can spend up to a year on safety training before a new chemist is considered "safe" to work in their R&D laboratories. In the words of one participant from industry at a previous summit, "What is common to all companies is that a new Ph.D. generally represents a safety risk to themselves, to their co-workers, and to the company." Despite much anecdotal discussion about a lack of safety preparation for industrial careers, a literature search did not reveal any data regarding the gap between employers' expectations and new hire competencies, and so this topic emerged as an opportunity for a deeper examination at a safety summit.

In preparation for the 2022 ACS Safety Summit, a small working group created a survey designed to gather the data needed to better understand industry's needs and expectations related to chemical safety for new Ph.D. hires in R&D laboratories. A list of 29 safety expectations was created based on *Employer Safety Awareness Expectations for New Hires,* a document by ACS Corporation Associates (CA) and the CCS.[3]

[1]Survey of Doctorate Recipients; National Science Foundation, National Center for Science and Engineering Statistics, 2017. https://ncsesdata.nsf.gov/doctoratework/2017/

[2]Marchant, S.; Marchant, C. ChemCensus; American Chemical Society: Washington, DC, 2015.

[3]https://www.acs.org/content/dam/acsorg/about/governance/committees/chemicalsafety/Employer-Expectations-2014.pdf

The list of safety expectations was reviewed by individuals from several ACS partner groups[4] and revised as needed based on their feedback. For each of the 29 safety expectations, the following two questions were asked:

1. When it comes to the expectations of Ph.D. new hires, would you consider the following safety expectations as "must have", "should have", "nice to have", "not expected to have", or "not applicable"?
2. On average, how frequently do Ph.D. new hires have to apply each of the following safety expectations within the first year of employment?

The survey was distributed in early 2022 to about 9740 people. Screening questions were added to limit respondents to only those individuals who either managed or contributed to the safety onboarding of new Ph.D. hires in industrial settings. A total of 173 responses meeting this criterion were received. The survey demographics and findings are included in Appendix 2.

The Summit Agenda is included in Appendix 3. At the summit, discussions were guided by three questions:

- What laboratory safety competencies (knowledge, skills, and attitudes) do new Ph.D. hires need to reduce the time for onboarding in industrial R&D laboratories where chemicals are used?
- Building on the successes of recent initiatives, what additional opportunities are there for industry and ACS to respond to industry's needs and expectations related to laboratory safety for new Ph.D. hires in R&D?
- How do we broaden and continue the summit conversations?

Summit Findings

Question 1: What laboratory safety competencies (knowledge, skills, and attitudes) do new Ph.D. hires need to reduce the time for onboarding in industrial R&D laboratories where chemicals are used?

Responses from the survey were ranked by importance and frequency of use for the 29 safety expectations. Discussions related to safety competencies were therefore based on the survey results (Appendix 2). The summit participants were asked to reflect on their experiences and identify their top five competencies that would reduce the time needed to onboard a newly hired Ph.D. chemist. Their responses went beyond those stated in the survey. They included specific safety knowledge and skills, as well as human factors[5].

[4]The Committee on Chemical Safety (CCS), the Division of Chemical Health and Safety (CHAS), the ACS Green Chemistry Institute, the ACS Division of Small Chemical Businesses (SCB), and the ACS Committee on Corporation Associates (CA).

[5]As used here, "human factors" include those safety categories and items that can affect the performance of an individual, including risk perception, attitude, technical and non-technical skills, and competence.

Specific safety knowledge and skills emphasized by industrial partners included:

- Awareness and understanding of various federal regulations (Occupational Safety and Health Administration (OSHA), Environmental Protection Agency (EPA), and Food and Drug Administration (FDA)) related to chemical safety in the context of chemical research.
- Ability to recognize hazards.
- Ability to locate and apply safety information.
- Ability to implement the RAMP model[6], including:
  - conducting risk assessments,
  - applying the hierarchy of controls,
  - selecting and using personal protective equipment (PPE),
  - recognizing when a Management of Change procedure is needed,
  - recognizing off-normal conditions,
  - learning from near-misses and incidents, and
  - applying ionizing and non-ionizing radiation safety practices.

Human factors:

- Leadership skills that include prioritizing safety
- Cultural acknowledgment in the context of safety
- Safety mindset
- Communication and listening skills
- Willingness to learn and adapt.

During further discussion in small groups, additional thoughts were captured. These focused on assessing safety competencies (knowledge, skills, and attitudes), sharing effective practices related to safety education and training, and promoting safety as an important component of chemistry education. The participants agreed that assessing safety knowledge, skills, and attitudes acquired during Ph.D. preparation is difficult because there is not sufficient guidance on what basic safety competencies are expected.

Question 2: Building on the successes of recent initiatives, what additional opportunities are there for industry and ACS to respond to industry's needs and expectations related to laboratory safety for new Ph.D. hires in R&D?

The summit participants emphasized that ACS has a unique opportunity to build more connections between academia and industry. Collaborative initiatives between ACS and industry that are focused on the development of a number of competencies (including safety) would help students to be better prepared for industrial jobs.

One of the recommendations was to provide more programs and collaborative projects that bring together industrial and academic partners. For example, a collaborative project to clearly identify the safety competencies needed for work in industrial R&D laboratories would be valuable. Although the industry employees emphasized that safety onboarding would always be a responsibility of the industrial employers and cannot be delegated to academia, the project could identify which safety competencies could be developed in academia. Newly hired chemists with a strong conceptual safety knowledge, relevant training, and a safety mindset would be more likely to successfully adapt to industry cultures where safety is a priority.

[6]Recognize hazards, Assess risks, Minimize risks, Prepare for emergencies

Suggestions for other collaborative projects between academia and industry that ACS might catalyze included:

- Collaboratively developing safety education and training opportunities that meet industry standards and expectations,
- Highlighting industry expectations through ACS webinars, symposia, and other communications,
- Enhancing safety expectations in the *ACS Guidelines for Bachelor's Degree Programs*[7], and
- Encouraging and supporting Laboratory Safety Teams (LSTs) in graduate programs to reflect industry expectations.

Industrial members applauded ACS for including chemical safety in its values and investing in initiatives to produce authoritative resources, such as the *Guidelines for Chemical Laboratory Safety in Academic Institutions*[8], *Safety in Academic Chemistry Laboratories*[9], and the free online course *Foundations of Chemical Safety and Risk Management*[10]. They shared the following additional recommendations for ACS safety-related programs and activities:

- Continue using surveys to learn more about safety education and training.
- Develop offerings that engage students with ACS safety programs and resources.
- Expand adoption of ACS safety resources within curricula for both undergraduate and graduate programs.
- Develop incentives for universities to improve safety practices for graduate students.

Question 3: How do we broaden and continue the summit conversations?

During the last part of the summit, participants identified potential influencers and organizations to engage in growing advocacy for strengthening safety education of chemistry students. These included:

Industry influencers:

- State and federal agencies, such as OSHA and EPA
- Industrial environmental health and safety departments
- ACS Corporation Associates
- Safety role models
- Public relations departments
- Investors
- Customers

Academic influencers:

- Environmental health and safety offices
- Laboratory Safety Team representatives
- Funding agencies
- Publishers
- Administrators
- High-profile academic scientists (Kavli, Nobel laureates, etc.)
- "Top 20" universities

Professional and trade organizations:

- ACS Division of Chemical Health and Safety (CHAS)
- American Chemistry Council (ACC)
- American Fuel and Petrochemical Manufacturers (AFPM)
- American Institute of Chemical Engineers (AIChE)
- Campus Safety, Health, and Environmental Management Association (CSHEMA)
- National Association of Scientific Materials Managers (NAOSMM)
- National Registry of Certified Chemists (NRCC)
- Society of Chemical Manufacturers and Affiliates (SOCMA)

[7]2023 ACS Guidelines for Bachelor's Degree Programs. Section 7: Creating a Safety Culture. https://www.acs.org/education/policies/acs-approval-program/guidelines.html

[8]https://www.acs.org/content/dam/acsorg/about/governance/committees/chemicalsafety/publications/acs-safety-guidelines-academic.pdf

[9]https://www.acs.org/content/dam/acsorg/about/governance/committees/chemicalsafety/publications/safety-in-academic-chemistry-laboratories-students.pdf

[10]https://institute.acs.org/foundations-chemical-safety.html

Other influencers:

- ACS awardees
- *Chemical & Engineering News*
- Upper management
- Safety committees
- Insurance underwriters
- Human resources departments
- Employee resource groups
- National laboratories
- University partnerships/external technical collaborations

The participants acknowledged that disseminating the summit findings will require additional assistance from subject-matter experts and specialty groups. They would not only be able to offer guidance but may also have a wider circle of influence and assist in the dissemination of information from this summit.

The summit participants also identified potential partners for strengthening education and training and for creating and disseminating new resources on specific safety-related topics. Specific ideas for engaging these groups were not discussed. The topics and potential partners identified are shown in Table 1.

Table 1. Additional Safety Topics and Potential Partners Identified at the 2022 ACS Safety Summit

Radiation Safety	• Radiation safety officers at universities • Nuclear Regulatory Commission (NRC) • National laboratories • International Atomic Energy Commission (IAEC) • ACS units: Division of Nuclear Chemistry, CHAS, ACS Center for Lab Safety, and ACS Publications
Regulations	• Regulatory agencies • Curriculum developers • Higher education administration • Environmental health and safety departments • ACS units: CCS, Green Chemistry Institute (GCI), CHAS, and ACS Center for Lab Safety
Assessments	• ACS units: ACS Examinations Institute, CHED, CHAS, and CCS
Safety Information	• Chemistry departments • International Union of Pure and Applied Chemistry (IUPAC) • ACS units: ACS Chemical Abstracts Service (CAS), ACS Publications, CCS, and GCI
Safety Leadership	• Campus Diversity, Equity, Inclusion, and Respect (DEIR) units • Graduate student Laboratory Safety Teams • International agencies • Universities • ACS units: Office of DEIR, CCS, CHAS, GCI, ACS student chapters

Actionable Strategies

The summit participants offered many specific suggestions for potential actionable strategies related to the safety preparation of chemists for industrial careers. Participants applauded ACS for its efforts to build communities and create offerings that empower and equip chemistry educators and practitioners with the competencies needed to practice safer chemistry. They encouraged ACS to continue those activities and expand them. New activities will need to be evaluated and assessed based on the personnel and costs needed to implement them. Some potential strategies and actions are provided in Table 2.

Table 2. Actionable Strategies Identified at the 2022 ACS Safety Summit

Advance Safety Education and Training Activities	• Schedule symposia, papers, and/or poster sessions at conferences. • Offer webinars, seminars, and/or workshops. • Develop a safety boot camp for principal investigators. • Develop a safety course that focuses on "safety fluency" targeted towards teaching/learning assistants. • Promote connections between risk-based safety and green chemistry. • Include safety criteria in the ACS approval of programs.[11] • Promote "safety champions" in articles and publications.
Convey Safety Expectations	• Develop a validated list of safety competencies and industry expectations.
Connect Industry and Academia	• Establish mechanisms for industry to communicate their expectations to academia. • Offer industrial sabbaticals for students and faculty. • Create more industrial internship programs for students. • Connect industrial members with faculty to arrange industrial tours. • Initiate a mentorship program, which could result in industries adopting a laboratory or LST. • Seek industry recognition of the *Foundations of Chemical Safety and Risk Management* online course. • Ask industry to provide examples of their safety training programs, and consider developing additional courses.
Engage Influential Stakeholders in Chemical Safety	• Engage the following stakeholders is chemical safety initiatives: ▸ professional organizations ▸ regulatory agencies ▸ ACS units ▸ funding agencies (NSF, NIH, DOE, etc.) ▸ accrediting bodies. • Seek funding (grants) for safety projects, such as LSTs, in graduate programs.

[11]This is well under way. 2023 ACS Guidelines for Bachelor's Degree Programs. Section 7: Creating a Safety Culture. https://www.acs.org/education/policies/acs-approval-program/guidelines.html (accessed Jan 30, 2023).

Post-Summit Activities
Disseminating information through symposia, papers, webinars, and workshops will be a key first step in continuing the conversation and pursuing collaborative initiatives.

Strengthening safety education and training of Ph.D. students requires the collective efforts of many stakeholders. Those interested in pursuing actionable strategies should contact safety@acs.org.

Appendix 1: Demographics of the Summit Participants

This list is provided in the report to show the range of expertise and experience at the 2022 ACS Safety Summit. Participants were selected based on their current or past employment or experience with industrial chemical safety or chemical education, as well as their engagement with ACS. They did not attend the summit in an official capacity for their employer or speak on behalf of the companies or institutions that are listed here.

Representatives from Industry

BASF
Sion Power Corporation
Chevron Phillips Chemical Co.
Dow Chemical Company
Dow Benelux B.V.
Boehringer Ingelheim
Georgia-Pacific
MilliporeSigma

Representatives from Organizations, Firms, or Institutions

Professional Analysis and Consulting Inc.
University of California Center for Laboratory Safety
Campus Safety, Health, and Environmental Management Association (CSHEMA)
Green Chemistry & Commerce Council
Sandia National Laboratory, U.S. Department of Energy's National Nuclear Security Administration (DOE-NNSA)
Savannah River National Laboratory, DOE
University of North Carolina System
Auburn University
Virginia Commonwealth University
Harvard Medical School
Southern Illinois University Edwardsville
Rowan University
University of Connecticut
University of Minnesota
Michigan Technological University

Some participants were also members of the following ACS committees:

Corporation Associates (CA)
Chemical Safety (CCS)
Professional Training (CPT)
Technician Affairs (CTA)
Minority Affairs (CMA)
Analytical Reagents (CAR)

Participants were also members of one or more of the following ACS divisions:

Chemical Education (CHED)
Chemical Health and Safety (CHAS)
Chemical Information (CINF)
Industrial and Engineering Chemistry (I&EC)
Medicinal Chemistry (MEDI)
Organic Chemistry (ORGN)
Small Chemical Businesses (SCHB)
Biological Chemistry (BIOL)
Physical Chemistry (PHYS)
Gay and Transgender Chemists and Allies Subdivision

Participants from ACS Staff Members and Other ACS Units

Graduate Student and Postdoctoral Scholars Advisory Board (GSPSAB)
Center for Lab Safety
ACS Strategy
Green Chemistry Institute
Journal of Chemical Health & Safety
Division of Scientific Advancement

Appendix 2: Survey of Industry's Needs and Expectations Related to Laboratory Safety for New Ph.D. Hires in R&D

Survey Design

The survey was designed to ask about 29 KSAs (knowledge, skills, and attitudes) related to chemical safety. For each KSA, two questions were asked:

1. When it comes to the expectations of Ph.D. new hires, would you consider the following safety expectations as "must have", "should have", "nice to have", "not expected to have", or "not applicable"?
2. On average, how frequently do Ph.D. new hires have to apply each of the following safety expectations within the first year of employment?

Sample

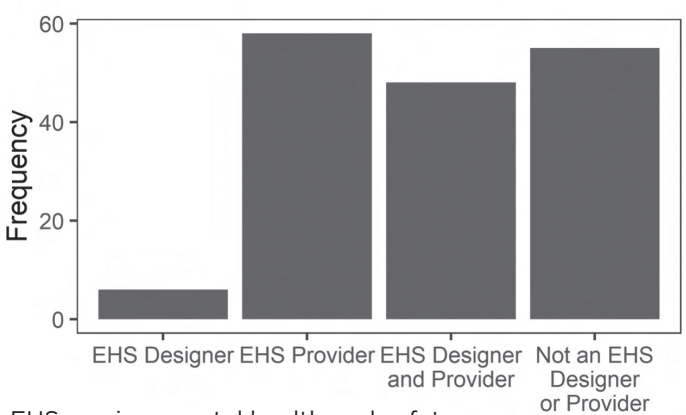
The following is taken from the original ACS report:

This survey was fielded from February 16 to March 11, 2022, via email and upon request to approximately 9742 people. A total of 173 people met the criterion* and passed the screener (226 people did not pass the screener). The approximate response rate is 4.1%, and the margin of error is ±7%.

*Individuals who either managed or contributed to the safety onboarding of new Ph.D. hires in industrial settings.

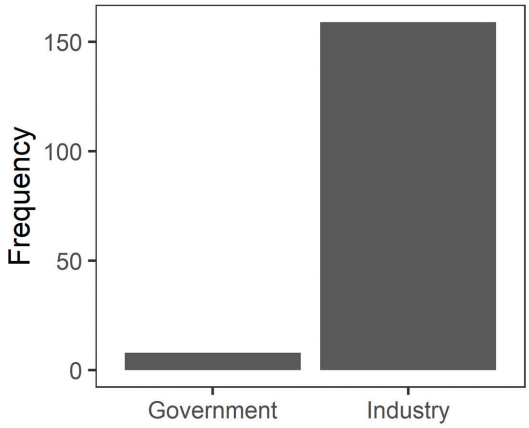
Key Demographics of Participants:

EHS Designer or Provider

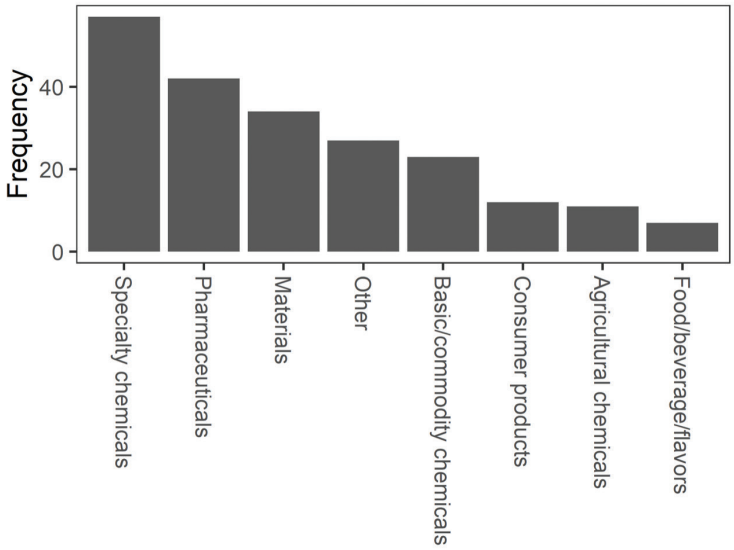


EHS: environmental health and safety

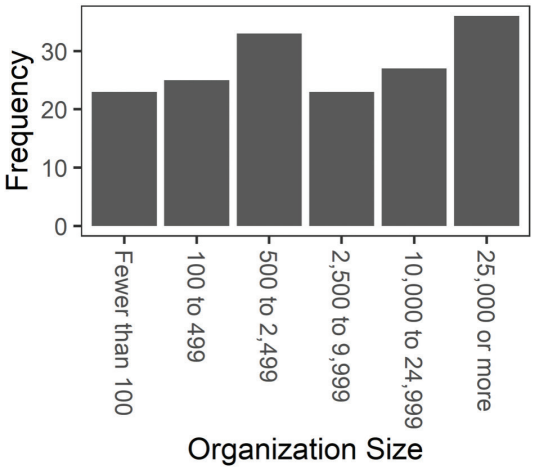
Sector Distribution of Respondents



Industry Type



Organization Size

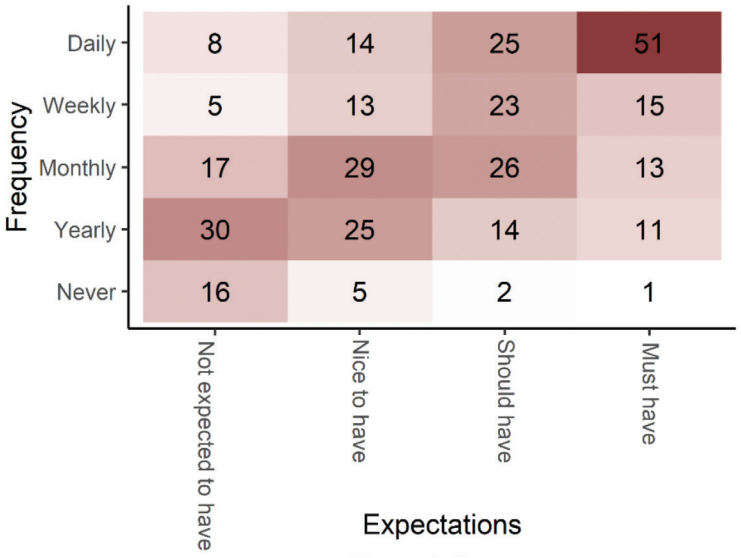


Full Text Questions

Label	Question
R1	Identify common laboratory and reaction hazards such as corrosivity, pressure, vacuum, laser, noise.
R2	Understand the Globally Harmonized System of Classification and Labelling of Chemicals (GHS).
R3	Use safety information from authoritative and publicly available sources, including federal and international agencies, such as Safety Data Sheets, PubChem Laboratory Chemical Safety Summary, Bretherick's Handbook of Reactive Chemical Hazards.
R4	Understand standard exposure and toxicology terminology and parameters, such as PEL, TLV, LC_{50}, LD_{50}, IDLH, etc.
R5	Determine chemical compatibilities and unique hazards associated with mixtures and reactive chemistry.
R6	Understand how to use restricted substances lists (RSLs) and manufacturing restricted substances lists (MRSLs).
R7	Recognize impacts throughout the chemical life cycle, spanning design, manufacturing, use, and end of life, as applied to sustainability, environmental, and health hazard considerations, such as persistence, toxicity (human and eco), bioaccumulation potential, etc.
R8	Recognize the applicability of OSHA lab safety regulations on laboratory operations.
R9	Identify all byproducts, incompatibilities, and the need for waste separation.
A1	Know how to apply risk assessment to laboratory processes using appropriate tools, such as "What-If", "HAZOP", HAZID, "Process Hazard Analysis", etc.
A2	Recognize off-normal conditions that might require more detailed assessment and additional controls.
A3	Recognize when Management of Change (MoC) might be necessary based on risk assessment assumptions and parameters.
A4	Provide safety leadership to lab/research team, for example, leading risk assessment teams.
A5	Assess environmental, safety, health, and sustainability hazards and risks through the use of appropriate metrics, such as Life Cycle Assessment (LCA), Process Mass Intensity (PMI), etc. across the chemical life cycle.
M1	Handle materials using best practices of laboratory safety, for example, flammable liquids, corrosive liquids and solids, toxic materials, low-level radioactive material, and biological materials.
M2	Properly use a laboratory chemical hood, including recognizing when the hood is malfunctioning.
M3	Properly use electrical equipment, such as extension cords, power strips, power supplies, etc.
M4	Recognize when to use PPE and appropriately select it.
M5	Implement equipment-related risk controls, such as flow-rate controls, temperature controls, and inspecting equipment for defects, etc.
M6	Prepare standard operating procedures (SOPs).
M7	Manage chemical storage using accepted practices, such as inventory control and hazard separation.
M8	Eliminate or minimize laboratory wastes and environmental emissions by appropriately selecting chemicals and chemical processes.
P1	Implement appropriate spill control and response procedures, for example, determine chemical compatibility of common absorbents used as spill cleanup materials.
P2	Determine when a chemical release is too large to handle safely on your own.
P3	Demonstrate the appropriate use of a safety shower and eye wash station in response to a chemical splash.
P4	Know what to do in the event of a laboratory fire, including evacuating or using an appropriate fire extinguisher.
P5	Ensure lab safety equipment is functioning and up to date, for example, spill kits, fire extinguishers, eye wash-safety shower stations, etc.
P6	Be prepared to investigate and familiarize oneself with the company's emergency response plan.
P7	Be prepared to learn from incidents and near misses to communicate with the team in accordance with company protocols.

Expectations versus Frequency

Because the survey asks about both expectations of Ph.D. new hires at the time of employment and the frequency with which new hires will act based on those expectations in the first year of employment, we have two variables to consider. First, we might like to know the degree to which expectations and frequency of use are correlated. Although there is a moderate correlation between the two, it seems reasonable to expect that some things happen infrequently but are expected to be well-known/adopted. For simplicity, the remainder of this report focuses on expectations that industry and government chemists have for Ph.D. new hires, not the frequency at which those expectations are applied in the first year of employment.

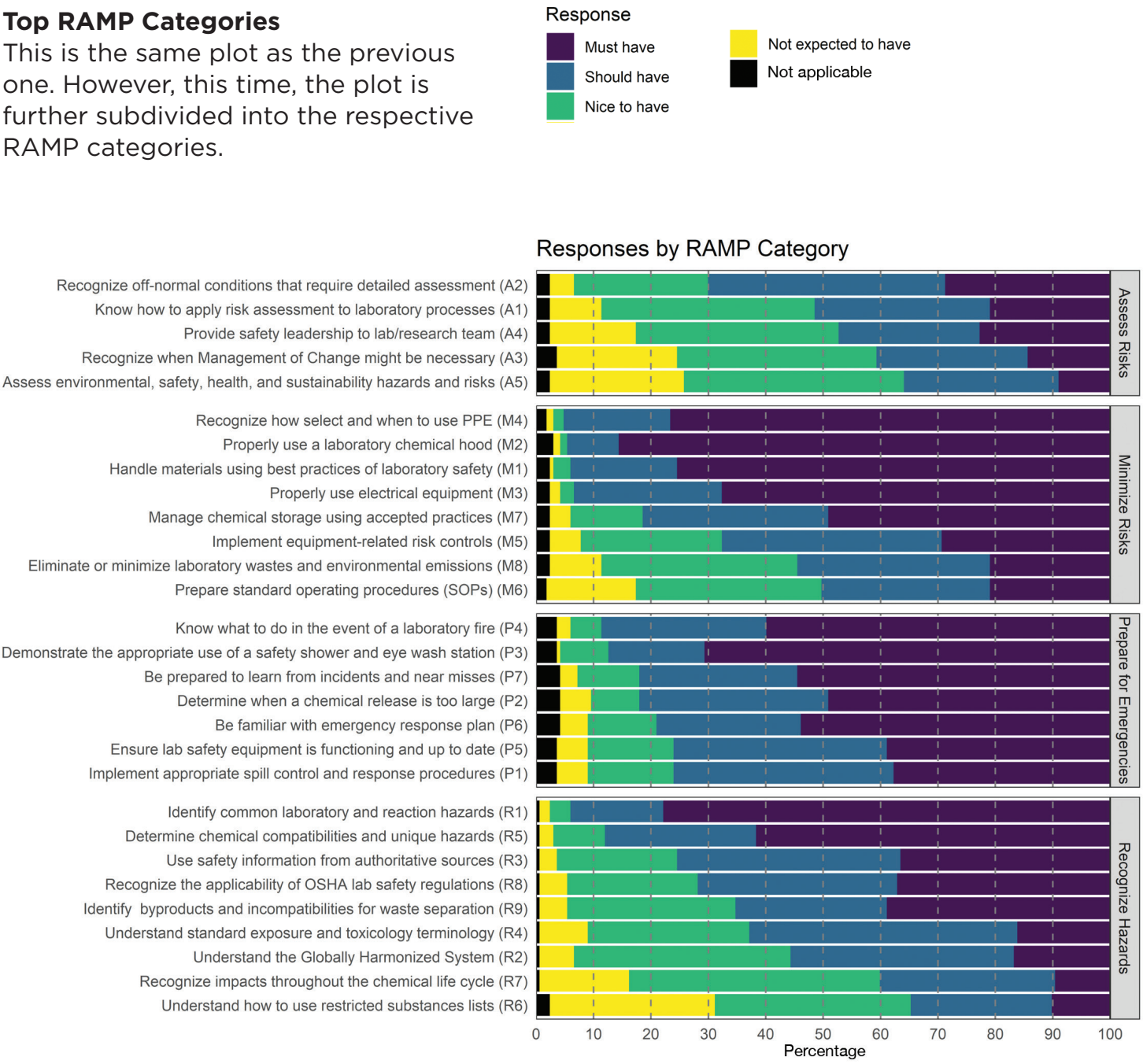


Top "Must Have" and "Should Have" Expectations

Here are the results of the survey for each item considering that "must have" (purple) and "should have" (blue) are likely to have similar desirability. Thus, the vertical axis is ordered by the combined total of "must have" and "should have", to reflect the uncertain nature of these similar terms.

Top RAMP Categories

This is the same plot as the previous one. However, this time, the plot is further subdivided into the respective RAMP categories.



Suggested analyses and discussions:

- What specific items resonate with you?
- What would you add to the list?

Qualitative Comments

At the end of the survey, participants were asked whether they had any comments related to safety preparations in the workplace. A total of 50 comments were received in this manner and were categorized according to the following themes.

Theme	Examples of Comments	Mentions*
Theme 1. Importance of safety training, procedures, and requirements (on-boarding and ongoing routines)	"Our expectation is that they get the training (usually on their first day of work) and utilize and add to the safety culture throughout their career." "Chemical Safety in industry is a requirement and is not optional. Chemists need to know chemical safety, period. If you don't handle chemicals safely, you will be fired."	**23**
Theme 2. Protocols, policies, processes, and regulatory aspects	"...identifying, sharing, and learning from near-misses and unsafe conditions, and (3) Management of Change, which is absolutely critical." "Since the company is new, we are generally increasing our standards and practices. And developing new procedures and SOPs as new chemistry is done."	**15**
Theme 3. Corporate culture (team and risk orientation, for example)	"Ensure to incorporate safety analysis sections in writing all new standard operating procedures for new methods. These should include all aspects of protection: Mechanical, Energy, Chemical ..." "Risk Assessments are a large part of safety in the R&D environment. Being able to understand the concepts, techniques and mitigation are important parts of their job."	**14**
Theme 4. Specific safety expectations	"The biggest issue I have had with new Ph.D. hires is **consistent and appropriate use of PPE**." "Some of the safety items, such as **demonstrating safety showers and eyewashes** in an emergency, and **evacuation procedures**..."	**12**
Theme 5. Attitudes, behaviors, and housekeeping	"An appreciation of safety and how to keep the individual, teammates, and the community safe is a critical aspect of every role at our company." "In addition to the safety requirements, the safety-related behaviors are important in the laboratory."	**11**

*A single comment may contain more than one theme, so the totals do not add to 50.

Theme 6. General lack of safety training among recently graduated Ph.D. hires	"I think that newly-minted PhDs typically are not sufficiently trained in risk- or behavior-based safety (vs. just compliance)..." "Universities do a TERRIBLE job of preparing Ph.D. graduates for working in industry, as far as safety practices are concerned!"	**10**
Theme 7. Expectation of general safety awareness	"Some new hired PhDs run, eat, drink, do not properly label chemicals, wear headphones or earphones that block the alert sounds..." "If a chemist is unaware of many of the items you had listed, then they become a hazard to themselves and all around."	**7**
Theme 8. Suggestions for the future	"Thank you - in many ways, you have given me pause for thought, and possible addition to my expectations list. I would love to see this final survey and I am interested in finding more resources to step up our expectations of 1-year employees - if we aren't going to get this out of the schools, how do we tackle it in our own training programs?"	**1**

Appendix 3: 2022 ACS Presidential Safety Summit Agenda

Friday, October 14, 2022	
Time	**Details**
8:30 am	**WELCOME AND OPENING REMARKS** Tom Connelly, ACS CEO, and Angela Wilson, 2022 ACS President
8:45 am	**INTRODUCTIONS** Kirk Hunter, 2021 Chair, Committee on Chemical Safety
9:10 am	**SUMMIT OVERVIEW** Sammye Sigmann, 2022 Chair, Committee on Chemical Safety • Summit goals - **Goal 1:** understand industry's needs and expectations related to laboratory safety for new Ph.D. hires in R&D - **Goal 2:** identify potential ACS/industry collaborations to further safety education for Ph.D. chemistry students - **Goal 3:** develop a plan to communicate industry needs and expectations throughout the chemistry community • Summit agenda • Summit norms/ground rules
	Part 1: Shaping 21st Century Safety Education
9:20 am	**PRESENTATION — Shifting the Paradigm in Safety Education** Sammye Sigmann, 2022 Chair, Committee on Chemical Safety **LARGE GROUP DISCUSSION** *Discussion Moderator:* Al Ribes, 2022 ACS Chemical Safety Summit Organizing Committee From your perspective, what shifts have you observed in the past several years related to chemical safety? **SUMMARY OF KEY POINTS**
9:50 am	**BREAK**
10:05 am	**PRESENTATION — Using the Language of Safety Preparation** Sammye Sigmann, 2022 Chair, Committee on Chemical Safety Sue Wiediger, 2022 Chair, Division of Chemical Education Safety Committee **LARGE GROUP DISCUSSION** Why is it important to differentiate these terms? **SUMMARY OF KEY POINTS**

Friday, October 14, 2022	
Time	**Details**
10:25 am	**PRESENTATION — Graduate scholars' perspectives** *Presenters:* Julian Bobb, Virginia Commonwealth University; Brady Bresnahan, University of Minnesota; Caroline Donaghy, University of Connecticut; and Monica Nyansa, Michigan Technological University Attachment: • Starting and Sustaining a Laboratory Safety Team (LST) **LARGE GROUP DISCUSSION** *Discussion Moderator:* Imke Schroeder, 2022 ACS Chemical Safety Summit Organizing Committee What new information or insights do you have about graduate scholars' perspectives? **SUMMARY OF KEY POINTS**
11:10 am	**PANEL DISCUSSION — Industry Perspectives on Readiness of New Hires** *Moderators:* P. Kalyani Martinelango and Al Ribes, 2022 ACS Chemical Safety Summit Organizing Committee *Panelists:* Christopher L. Campion, Sion Power Corporation; Lisa Harlow, BASF; Mary Heuges, MilliporeSigma; and Masud Monwar, Chevron Phillips Chemical Co.
12:10 pm	**LUNCH**
1:10 pm	**PANEL DISCUSSION,** continued **LARGE GROUP DISCUSSION** What new information or insights do you have about industry needs? **SUMMARY OF KEY POINTS**
1:35 pm	**PRESENTATION — Review of the *Safety Expectations of Industrial Employers* Survey Results** *Presenters:* Kirk Hunter and Jordan Harshman, 2022 ACS Chemical Safety Summit Organizing Committee Attachment: • *Safety Expectations of Industrial Employers* Survey Results **BREAK** **LARGE GROUP DISCUSSION** *Discussion Moderator:* Imke Schroeder What specific expectations resonate with you? What would you add to the list? **SUMMARY OF KEY POINTS**

Friday, October 14, 2022	
Time	**Details**
3:10 pm	**GUIDING QUESTION #1** **What lab safety competencies (knowledge, skills, and attitudes) do new Ph.D. hires need to reduce the time for onboarding in industrial R&D laboratories where chemicals are used?** *Session Moderator:* Kirk Hunter Purpose: Small and large group discussions will result in a robust picture of industry expectations and needs. **SMALL GROUP ACTIVITY — Part 1** **GALLERY WALK and LARGE GROUP DISCUSSION** *Discussion Moderator:* Jordan Harshman Do you have any questions for other groups? Where are you seeing similarities? Differences? **BREAK** **SMALL GROUP ACTIVITY — Part 2** **LARGE GROUP DISCUSSION** *Discussion Moderator:* Jordan Harshman What questions and curiosities do you have related to the insights shared by other groups?
5:15 pm	**CLOSING of DAY 1** Sammye Sigmann, 2022 Chair, Committee on Chemical Safety
6:00 pm	**GROUP DINNER**

	Saturday, October 15, 2022
Time	**Details**
8:30 am	**OPENING** Kirk Hunter, 2021 Chair, Committee on Chemical Safety **LARGE GROUP DISCUSSION** What insights did you gain from yesterday's conversations?
Part 2: Supporting the Preparation of Ph.D. Chemists for Work in Industry	
8:55 am	**GUIDING QUESTION #2** **Building on the successes of recent initiatives, what additional opportunities are there for industry and ACS to respond to industry's needs and expectations related to laboratory safety for new Ph.D. hires in R&D?** *Session Moderator:* Jodi Wesemann **SMALL GROUP ACTIVITY** Purpose: These discussions are intended to begin the conversation about how to respond to industry's needs and expectations. **LARGE GROUP DISCUSSION** Which, if any, ideas were identified by more than one group? What are the next steps for those items?
10:10 am	**BREAK**

Saturday, October 15, 2022	
Time	**Details**
Part 3: Communicating 21st Century Safety Education Needs of Industry	
10:25 am	**GUIDING QUESTION #3** **How do we broaden and continue the Summit conversations?** *Session Moderator:* Jodi Wesemann **LARGE GROUP DISCUSSION** Who are the influencers in academia? Who are the influencers in industry? **SMALL GROUP ACTIVITY** Purpose: These discussions are intended to identify specific strategies for engaging and communicating with stakeholders in the chemistry enterprise. **LARGE GROUP DISCUSSION** Which of these strategies can ACS/industry partner on? What are the next steps?
11:35 am	**SUMMARY and CLOSING** Kirk Hunter, 2021 Chair, Committee on Chemical Safety Sammye Sigmann, 2022 Chair, Committee on Chemical Safety
Approx. noon	**BOXED LUNCH DELIVERED** **DEPARTURE**