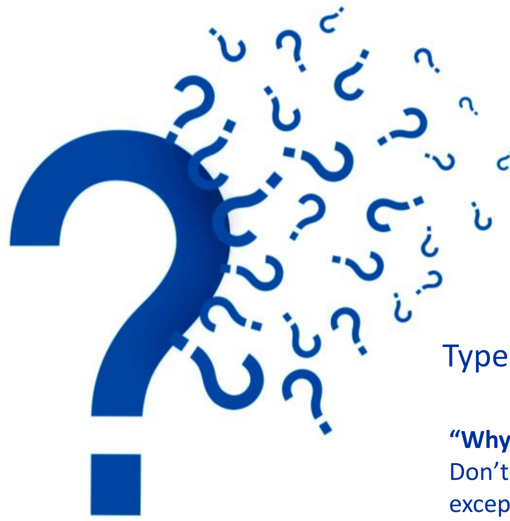
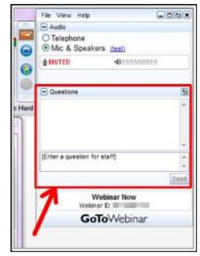
Have Questions?

ACS Chemistry for Life®





Type them into questions box!

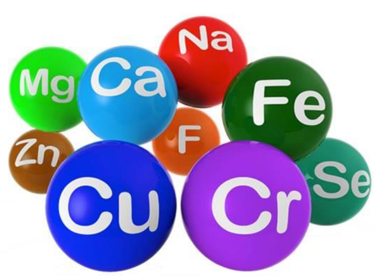
"Why am I muted?"
Don't worry. Everyone is muted except the presenter and host. Thank you and enjoy the show.

Contact ACS Webinars ® at acswebinars@acs.org

ACS Webinars® CLICK • WATCH • LEARN • DISCUSS

ACS Chemistry for Life®

Have you discovered the missing element?



http://bit.ly/benefitsACS

Find the many benefits of ACS membership!

ACS Webinars
CLICK • WATCH • LEARN • DISCUSS

ACS Chemistry for Life®

Benefits of ACS Membership

c&en CHEMICAL & ENGINEERING NEWS

Chemical & Engineering News (C&EN)
The preeminent weekly news source.

ACS Presentations on Demand™ YOUR SOURCE FOR RECORDED MEETING CONTENT

NEW! Free Access to ACS Presentations on Demand®
ACS Member only access to over 1,000 presentation recordings from recent ACS meetings and select events.

NEW! ACS Career Navigator
Your source for leadership development, professional education, career services, and much more.

http://bit.ly/benefitsACS

Let's get Social…post, tweet, and link to ACS Webinars during today's broadcast!

ACS Chemistry for Life®

facebook.com/acswebinars

@acswebinars

LinkedIn: Search for "acswebinars" and connect!

How has ACS Webinars® benefited you?

http://bit.ly/SelfFulfillment

ACS Chemistry for Life®

"Darren offered a refreshing perspective on how to act as a scientist. It was a nice reminder to find positives in a negative situation. I also liked how Darren challenged the audience to be open to art (and other fields), and not to be a closed-off scientist."

Fan of the Week

Kevin Kempton
Research Associate
Innophos, Inc., ACS member for 3 years strong!

Be a featured fan on an upcoming webinar! Write to us @ acswebinars@acs.org

5

ACS Webinars® CLICK • WATCH • LEARN • DISCUSS

ACS Chemistry for Life®

6

ACS Webinars
CLICK • WATCH • LEARN • DISCUSS

ACS Chemistry for Life®

Learn from the best and brightest minds in chemistry! Hundreds of webinars presented by subject matter experts in the chemical enterprise.

Recordings are available to current ACS members after the Live broadcast date via an invitation email. **www.acs.org/acswebinars**

Broadcasts of ACS Webinars® continue to be available to the general public LIVE every Thursday at 2pm ET!

www.acs.org/acswebinars 7

ACS Chemistry for Life®

ChemIDP.org

Nanomaterial Design Guided by the Principles of Green Chemistry

ACS Chemistry for Life®

Thursday, May 18 @ 2-3pm ET

How can green chemistry be applied to nanotechnology to achieve the high performance needed for advanced applications while preventing or reducing health and environmental impacts? Join James Hutchison from the University of Oregon as he discusses the foundations for greener nanotechnology and presents a case study that uses nanomaterial product innovation guided by green chemistry.

Register Now!

What You Will Learn

- The opportunity to achieve a net environmental benefit by bringing together green chemistry with nanoscience
- The role that green chemistry plays in designing high performance nanomaterials and efficient nanomaterial production
- How green chemistry and nanoscience can be used together to develop innovative new products with environmental benefits

ACS Webinars®

Experts

James Hutchison
University of Oregon

Joe Fortunak
Howard University

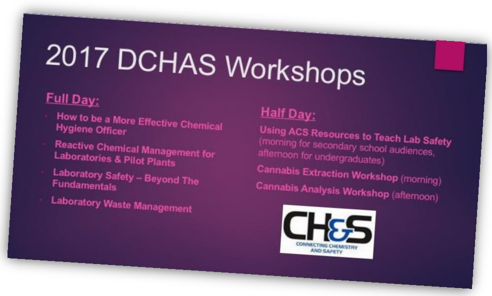
Co-Produced With

ACS Green Chemistry Institute®

http://bit.ly/GreenNano

Join the ACS Chemical Health and Safety Division!

ACS Chemistry for Life®



The division is dedicated to supporting the efforts of chemical manufacturers, industrial and academic researchers, and science teachers at all levels to work for a safe and healthful work environment. Through our technical symposia, the Division's Journal, the ***Journal of Chemical Health and Safety***, our **workshops** and our **DCHAS-L listserv**, we provide a forum for scholarly health and safety research, advice and counsel from an experienced group, and support for health and safety efforts in industry and academia.

https://dchas.org

Upcoming ACS Webinars
www.acs.org/acswebinars

ACS Chemistry for Life®

Thursday, May 18, 2017

Nanomaterial Design Guided by the Principles of Green Chemistry

Co-produced with the ACS Green Chemistry Institute

James Hutchison, Lokey-Harrington Chair in Chemistry, University of Oregon

Joe Fortunak, Professor of Chemsitry, Howard University

Thursday, May 25, 2017

Anti-Infectives: *Rational Approaches to the Design and Optimization*

Co-produced with the ACS Division of Medicinal Chemistry and the AAPS

Jason Sello, Associate Professor of Chemistry, Brown University

Courtney Aldrich, Associate Professor, Department of Medicinal Chemistry, University of Minnesota and Editor-in-Chief of *ACS Infectious Diseases*

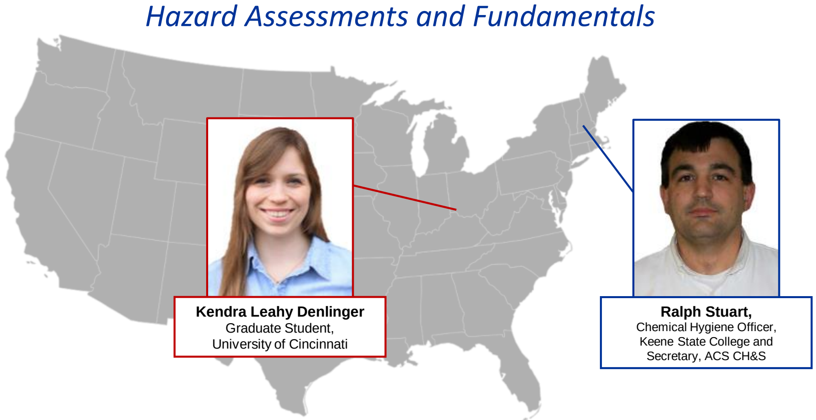
Contact ACS Webinars ® at acswebinars@acs.org

11

ACS Webinars CLICK • WATCH • LEARN • DISCUSS

ACS Chemistry for Life®

Creating a 21st Century Chemical Research Laboratory: *Hazard Assessments and Fundamentals*



Slides available now! Recordings are an exclusive ACS member benefit.

www.acs.org/acswebinars

This ACS Webinar is co-produced by the ACS Division of Chemical Health and Safety and the ACS Green Chemistry Institute

12

CREATING A 21ST CENTURY CHEMICAL RESEARCH LABORATORY:
HAZARD ASSESSMENTS AND FUNDAMENTALS

Dr. Kendra Leahy Denlinger
University of Cincinnati

Ralph Stuart, CIH, CCHO
Chemical Hygiene Officer, Keene State College
Secretary, Division of Chemical Health and Safety,
American Chemical Society

CINCINNATI

Keene STATE COLLEGE

MAY 11, 2017

SAFETY WITHIN THE ACS VISION

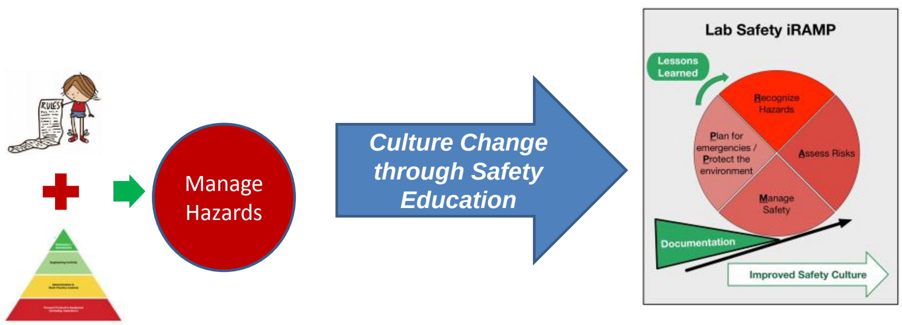
ACS Chemistry for Life®

Strategic Plan for 2017 and beyond

14

MOVING LAB SAFETY INTO THE 21ST CENTURY

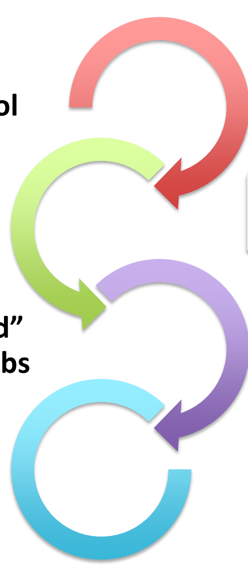
Lab Safety involves both Technical and Cultural Skills



20th Century:
Selecting Controls
Based on Rules, guided by
Chemical Intuition

21st Century:
a Safety System based
on documented
Risk Assessment

TECHNICAL CHEMICAL SAFETY RESOURCES



High school

- NFPA 45 requirements for instructional and educational labs, 2015

Undergraduate teaching labs

- *Safety in Academic Chemistry Laboratories, 8th edition*, 2017

"Mentored" research labs

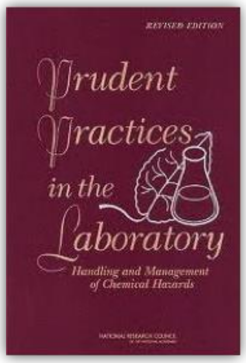
- *Laboratory Safety for Chemistry Students, 2nd Edition*, 2016

Research laboratories

- *Prudent Practices*, 2011
- ***Identifying and Evaluating Hazards in Research Laboratories, 2016***
- PubChem Laboratory Chemical Safety Summaries, 2016
- Pistoia Chemical Safety Library, 2017

RESEARCH RISK ASSESSMENT RESOURCES

National Research Council, 2011



ACS
(at the behest of the CSB)
PDF Version 2013

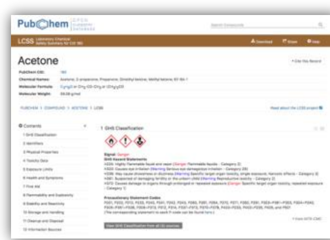
Web Version, 2016

OTHER KEY TECHNICAL TOOLS

National Library of Medicine's Pubchem

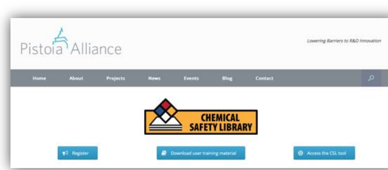
Laboratory Chemical Safety Summaries (2015)

- Safety information on 103,000 chemicals
- Includes SDS-style information as well as specific reaction information between chemicals



Pistoia Alliance Chemical Safety Library (2017)

- Information on specific lab scale chemical incidents
- Access is free upon registrantion and reporting of incidents is encouraged.



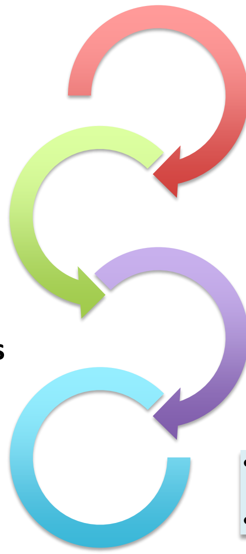
CULTURAL LAB SAFETY RESOURCES

High school

Undergraduate education labs

"Mentored" research labs

Research lab work



- *Guidelines for Chemical Lab Safety in Secondary Schools*, 2016

- *Creating Safety Cultures in Academic Institutions* from ACS, 2013
- *Laboratory Safety Guidelines*, ACS Committee on Professional Training, 2015

- *A Guide to Implementing a Safety Culture in our Universities* from the APLU, 2016
- ACS *Safety Guidelines for the Chemistry Professional* 2017

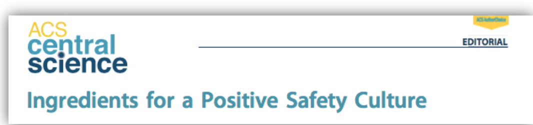
- *Safe Science* from the National Research Council, 2014
- *ACS journals policy*, 2016

19

KEY RESEARCH SAFETY CULTURE RESOURCES

National Research Council, 2014

ACS, 2016


ACS central science
EDITORIAL
Ingredients for a Positive Safety Culture


Home > Volume 94 Issue 48 > ACS journals enact new safety policy

Volume 94 Issue 48 | p. 7 | News of The Week
Issue Date: December 5, 2016 | Web Date: December 1, 2016

ACS journals enact new safety policy

Authors to be required to address novel or significant hazards

By Jyllian Kemsley

20

Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT

Which hazard MOST concerns you?

- Chemicals of known reactivity
- Chemicals of known toxicity
- Environmentally hazardous chemicals
- Chemicals of unknown toxicity

21

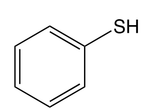
A LESSON IN LAB SAFETY

GHS Label elements, including precautionary statements

Pictogram 

Signal word	Danger
Hazard statement(s)	
H226	Flammable liquid and vapour.
H300 + H310 + H330	Fatal if swallowed, in contact with skin or if inhaled
H315	Causes skin irritation.

:h - T32808



$LC_{50} \leq$ 2.0 mg/L

H319	Causes serious eye irritation.
H335	May cause respiratory irritation.
H361	Suspected of damaging fertility or the unborn child.
H371	May cause damage to organs (Nervous system) if swallowed.
H372	Causes damage to organs (Kidney) through prolonged or repeated exposure if swallowed.
H410	Very toxic to aquatic life with long lasting effects.

https://ehs.unl.edu/sop/s-health_hazards_haz_assessment_risk_min.pdf

22

A LESSON IN LAB SAFETY

Mack Lab Safety Form for Ordering Toxic Chemicals

It is mandatory to fill out this form if the chemical you are ordering is labeled with any of the following HCS Pictograms:

Chemical name:

Chemical structure:

Using the MSDS or SDS for this chemical, list ALL of the potential human health hazards, including routes of exposure (ex. Inhalation, skin contact, ingestion, etc.).

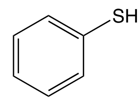
Provide a detailed explanation of why this chemical is essential to your research.

For each of the human health hazards you listed above, explain them in more detail here using the table below, adding more rows if necessary. Some of this can be obtained from the MSDS or SDS, but some will need to be obtained from other sources.

Hazard Statement	LD_{50} or LC_{50}	First Aid Measures	Symptoms of exposure	Pathophysiology (what does it affect in your body?)

What alternatives to this chemical are available? Why can these not be substituted for this chemical?

Now that the possible consequences of using this chemical have been described, please explain how the benefits to your research outweigh the potential costs to our health.



$LC_{50} \leq 2.0$ mg/L

Hazard Assessment | Fundamentals | Ways to Conduct Assessments | Tools

Safety in the laboratory requires a full team effort to be successful. When everyone in the laboratory understands how to identify hazards, assess risk, and select the appropriate control measures to eliminate a hazard or minimize risk, accidents, injuries and near misses can be reduced.

https://www.acs.org/hazardassessment

HAZARD VS. RISK

fundamentals of hazard assessment | scoping and assembling your team | ways to conduct hazard assessments | tools

KNOW THE DIFFERENCE BETWEEN A HAZARD AND A RISK

"Hazard" and "risk" are NOT the same.

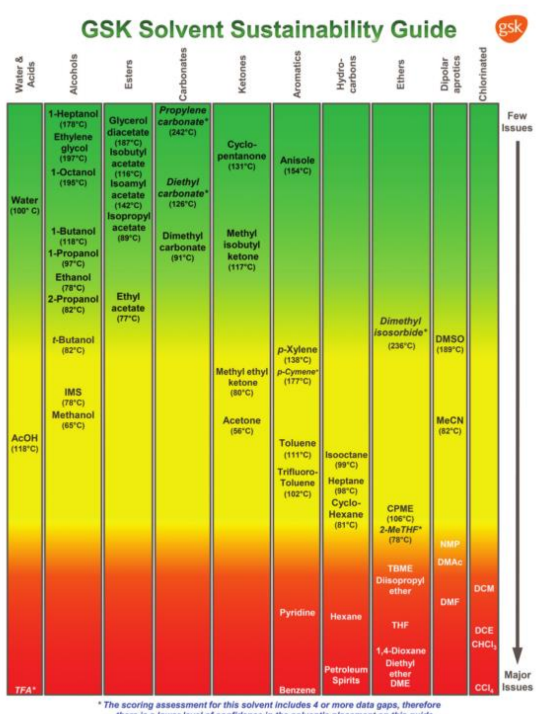
Hazard

- A hazard causes harm.
- A hazard can be eliminated, but not reduced.

Risk

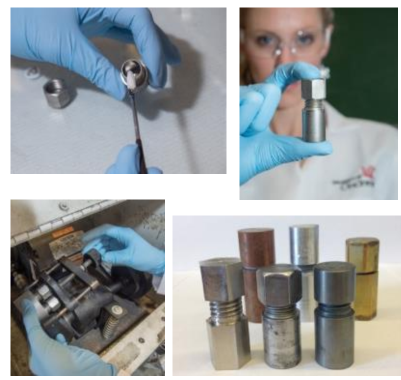
- Risk is the probability that a hazard will cause harm.
- Risk associated with a hazard can be reduced.

Risk = hazard x exposure



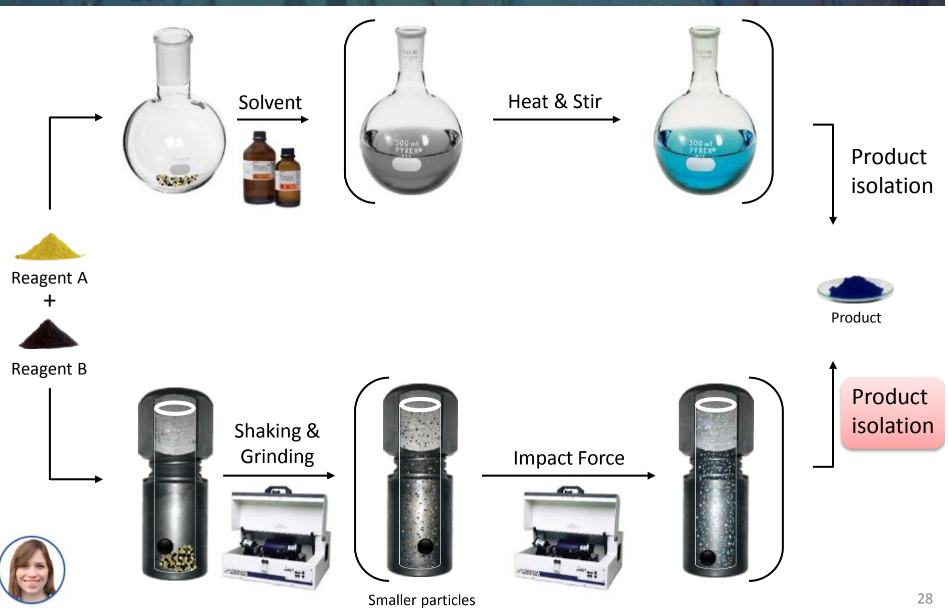
Alder, C. et. al. "Updating and further expanding GSK's solvent sustainability guide." *Green Chemistry*, **2016**, *4*, 1166-1169.

HIGH-SPEED BALL MILLING



27

BALL MILLING VS. SOLUTION



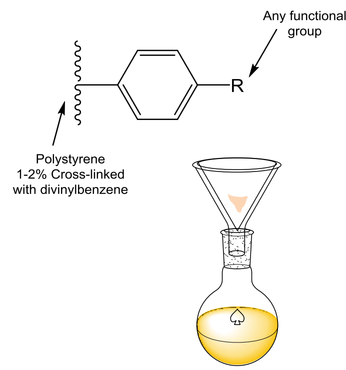
28

CHROMATOGRAPHY

Table 5.8 **Column Chromatography Materials**

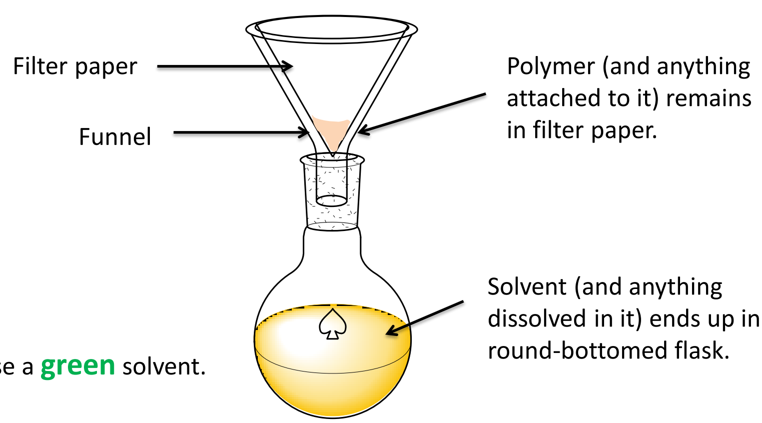
Stationary Phase		**Moving Phase**	
Alumina	↑ *Increasing*	Water	↑ *Increasing*
Silicic acid	*adsorption*	Methanol	*solvation*
Magnesium sulfate	*of polar*	Ethanol	*of polar*
Cellulose paper	*materials*	Acetone	*materials*
		Ethyl acetate	
		Diethyl ether	
		Methylene chloride	
		Cyclohexane	
		Pentane	

Functionalized polymer resins



Mayo, Dana W.; Pike, Ronald M.; Forbes, David C. *Microscale Organic Laboratory*. United States: John Wiley & Sons, Inc., 2011. Print.

FUNCTIONALIZED POLYMER RESINS

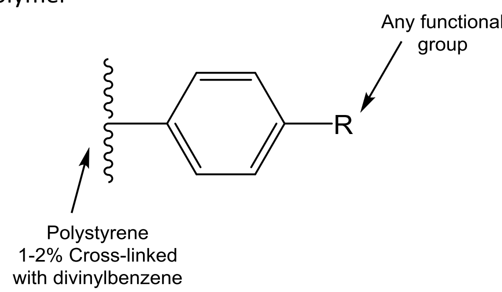


Choose a **green** solvent.

WHAT SHOULD BE ATTACHED?

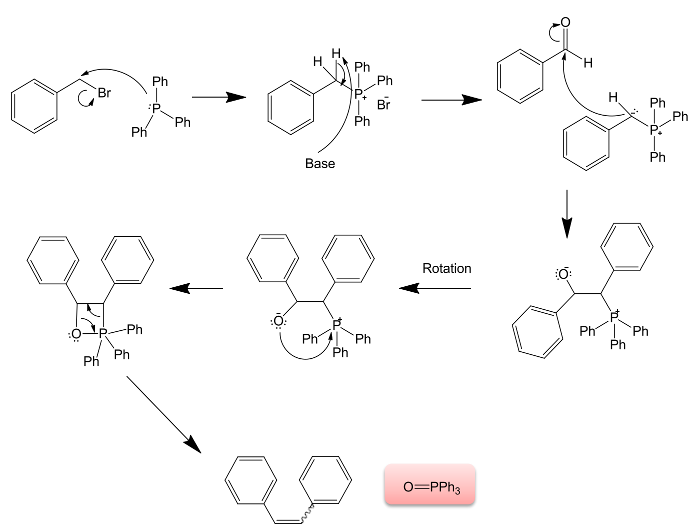
Design the reaction so that:

- A **product** is attached to the polymer
- A **byproduct** is attached to the polymer
- A **catalyst** is attached to the polymer

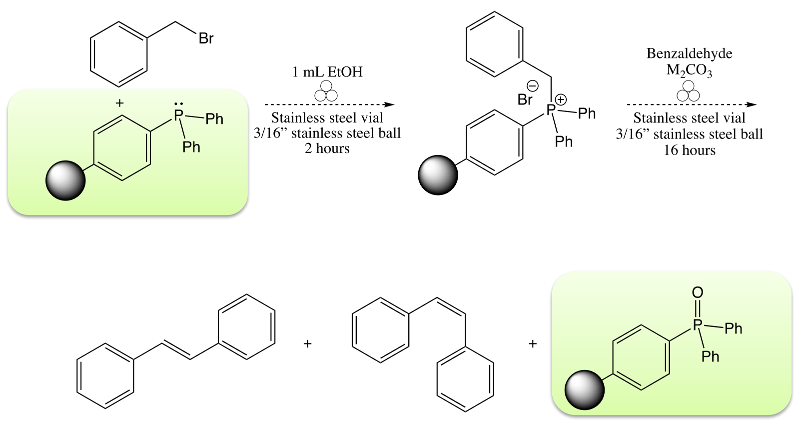


WITTIG REACTION

- 1950's
- Nobel Prize awarded in 1970's
- Harmful organic solvents
- Very strong bases (*n*-BuLi)



WITTIG REACTION WITH POLYMER RESIN



33

Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT

Have you developed Green Chemistry alternatives for specific reactions in your lab work?

- Yes, we have developed a full set of GC alternatives
- Yes, we have developed some GC alternatives
- Yes, we have developed a few GC alternatives
- No, we have not developed any GC alternatives yet

34

Determine the Scope

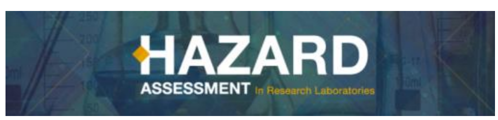
Collect Appropriate Background Information

The analysis team will need appropriate background information, including:

- Equipment diagrams
- A list describing common hazards associated with chemicals and gases
- A list of the equipment's chemical and gas compositions, operating pressures, flow rates, run times, and other applicable parameters
- Potential health and physical hazards of equipment (e.g., ionizing or nonionizing radiation, high temperature, high voltage, or mechanical pinch points)
- Equipment safety features (e.g., interlocks)
- Physical access to equipment, as necessary/possible

Safety Data Sheets can include a lot of this information.

35



Assemble Your Team

Everyone should be involved in hazard assessment, regardless of experience level or title in the lab.

Everyone is responsible for familiarizing themselves with appropriate controls for the hazards discovered in the lab.

Everyone is responsible for participating in hazard analyses (checklists, Job Hazard Analysis, and What-if Analysis) and the updating of the lab's Standard Operating Procedures. This is also a good time to review accidents, incidents, and near misses and collectively brainstorm ways to prevent these events in the future.

More experienced members of the team should lead risk assessment activities and assign risk ratings to the materials and processes in your lab.

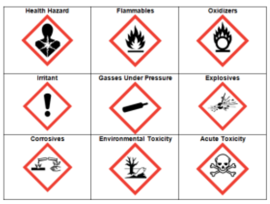
Learn about the roles and responsibilities of various people in the lab.

36

HAZARD ASSESSMENT In Research Laboratories

CONDUCTING A HAZARD ASSESSMENT

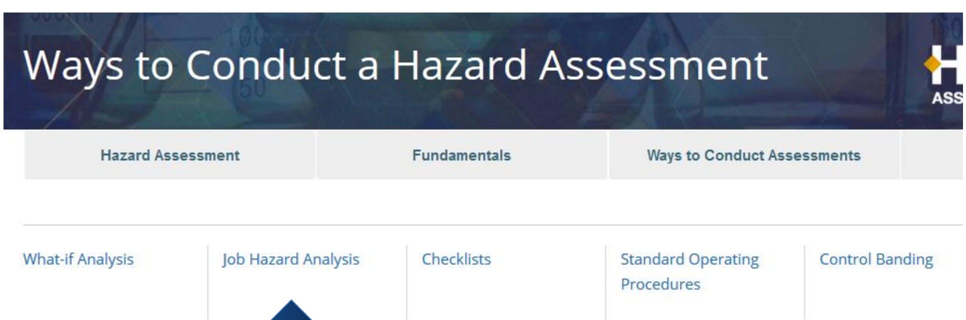
Identify hazards → Analyze risks → Select controls



37

fundamentals of hazard assessment | scoping and assembling your team | ways to conduct hazard assessments | tools

Identify hazards → Analyze risks → Select controls



38

fundamentals of hazard assessment | scoping and assembling your team | ways to conduct hazard assessments | tools

Identify hazards → **Analyze risks** → Select controls

Calculate Risks Using Probability of Occurrence and Severity of Consequences Scaling

Many risk assessments use "probability of occurrence" and "severity of consequences" scales to rate risks associated with laboratory experiments. They are comprehensive assessment tools and provide greater differentiation of risks based on actual laboratory operations.

Using this kind of scaling, laboratory hazard risk rating is calculated as follows:

Risk Rating (RR) = Probability of Occurrence (OV) x Severity of Consequences Value (CV)

As the formula indicates, the higher the assessed probability of occurrence and severity of consequences, the greater the risk rating will be.

39

fundamentals of hazard assessment | scoping and assembling your team | ways to conduct hazard assessments | tools

Identify hazards → **Analyze risks** → Select controls

Probability of Occurrence with Standard Linear Scaling

Occurrence Value (OV)		Probability of Occurrence	
Rating	**Value**	**Percent**	**Description**
Not Present	0	0%	Item/operation is not present in laboratory.
Rare	1	1–10%	Rare
Possible	2	10–50%	Possible
Likely	3	50–90%	Likely
Almost Certain to Certain	4	90–100%	Almost Certain to Certain

Severity of Consequences, Weighted Value Scale

Consequence Value (CV)		Impact to...				
Rating	Value	Personnel Safety	Resources	Work Performance	Property Damage	Reputation
No Risk	1	No injuries	No impact	No delays	Minor	No impact
Minor	5	Minor injuries	Moderate impact	Modest delays	Moderate	Potential damage
Moderate	10	Moderate to life impacting injuries	Additional resources required	Significant delays	Substantial	Damaged
High	20	Life threatening injuries from single exposure	Institutional resources required	Major operational disruptions	Severe	Loss of confidence

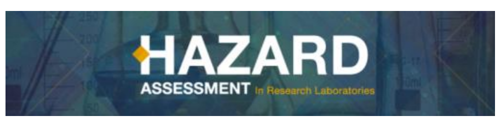
high probability x no consequences = 4
low probability x life threatening consequences = 20

40

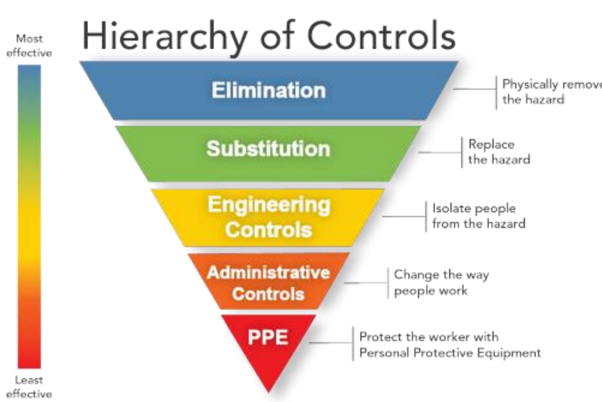
fundamentals of hazard assessment | scoping and assembling your team | ways to conduct hazard assessments | tools

Identify hazards → Analyze risks → Select controls

Job Hazard Analysis Job Location: Rieveschl Hall, UC Laboratory Group: Mack Date: 03/14/2017			
Activity or Job	**Run Wittig reaction**		
Completed By	**Kendra**		
Equipment and Chemicals Required	**Stainless steel vial + cap, o-ring, stainless steel ball, balance, ball mill, glass pipette, rubber pipette bulb, metal spatula, PS-PPh$_2$, benzyl bromide, cesium carbonate, benzaldehyde**		
Work Steps and Tasks *Describe the tasks or steps involved in the work in the order performed*	**Hazards Identified for each Task/Step**	**Risk Level** *Risk Nomogram can be used (see APPENDIX B)*	**Control/Safe Work Procedures for each Task/Step** *Controls to be implemented*
Weigh out benzyl bromide (*l*)	Combustible liquid	1 x 5 = **5**	Do not handle near open flames or sources of ignition
	Causes skin irritation	1 x 5 = **5**	Use PPE; discard contaminated gloves immediately; wash hands upon exiting lab
	Causes serious eye irritation	2 x 10 = **20**	Weigh under snorkel
	May cause respiratory irritation	2 x 5 = **10**	
Weigh out PS-PPh$_2$ (*s*)	Causes skin irritation	1 x 5 = **5**	Use PPE; discard contaminated gloves immediately; wash hands upon exiting lab
	Harmful if swallowed, in contact with skin, or if inhaled	2 x 5 = **10**	Weigh under snorkel; use PPE; discard contaminated gloves immediately; wash hands upon exiting lab
	Causes serious eye irritation	1 x 10 = **10**	
	May cause respiratory irritation	1 x 5 = **5**	
Weigh out cesium carbonate (*s*)	Causes serious eye damage	1 x 10 = **10**	Use PPE; discard contaminated gloves immediately; wash hands upon exiting lab
	May cause respiratory irritation	1 x 5 = **5**	
Weigh out benzaldehyde (*l*)	Combustible liquid	1 x 5 = **5**	Do not handle near open flames or sources of ignition
	Harmful if swallowed or in contact with skin	1 x 5 = **5**	Use PPE; discard contaminated gloves immediately; wash hands upon exiting lab
	Causes skin irritation	1 x 5 = **5**	
	Toxic to aquatic life	-	Do not empty into drains
Clamp vial in ball mill and start ball mill	Caught in ball mill	2 x 5 = **10**	Use care when opening and closing the ball mill
Hazards Checklist [Note: This section can be modified, as needed. See Table D-1: Common Hazards and Descriptions in APPENDIX D.]			
Can someone be exposed to chemicals? Yes	*If so, what is the nature of the chemical hazard?* Ingestion and inhalation hazards; eye and skin irritation		
Can someone slip, trip, or fall? Yes	*Can someone injure someone else?* Yes		
Can someone be caught in anything? Yes	*Can someone strike against or make contact with any physical hazards?* Yes		



Identify hazards → Analyze risks → Select controls



Source: http://www.cdc.gov/niosh/topics/hierarchy

Elimination and Substitution

The San Destin Declaration: 9 Principles of Green Engineering*

1. Engineer processes and products holistically, use systems analysis, and integrate environmental impact assessment tools.
2. Conserve and improve natural ecosystems while protecting human health and well-being.
3. Use life-cycle thinking in all engineering activities.
4. Ensure that all material and energy inputs and outputs are as inherently safe and benign as possible.
5. Minimize depletion of natural resources.
6. Strive to prevent waste.
7. Develop and apply engineering solutions, while being cognizant of local geography, aspirations, and cultures.
8. Create engineering solutions beyond current or dominant technologies; improve, innovate, and invent (technologies) to achieve sustainability.
9. Actively engage communities and stakeholders in development of engineering solutions

*Abraham, M.; Nguyen, N. "Green engineering: Defining principles" – Results from the Sandestin conference. *Environmental Progress* **2004**, *22*, 233-236.DOI: 10.1002/ep.670220410

Meeting was supported by EPA, NSF, DOE (Los Alamos National Lab), and the ACS GCI.

"How can we tell if what we're doing is actually greener?"

Green Chemistry Metrics

Source: ACS Green Chemistry Institute®

43

Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT

How interested are you in a Green Chemistry metrics tool that incorporated job hazard assessment considerations?

- Very interested
- Somewhat Interested
- Neither interested or disinterested
- Somewhat disinterested
- Very disinterested

44

WASTE MINIMIZATION

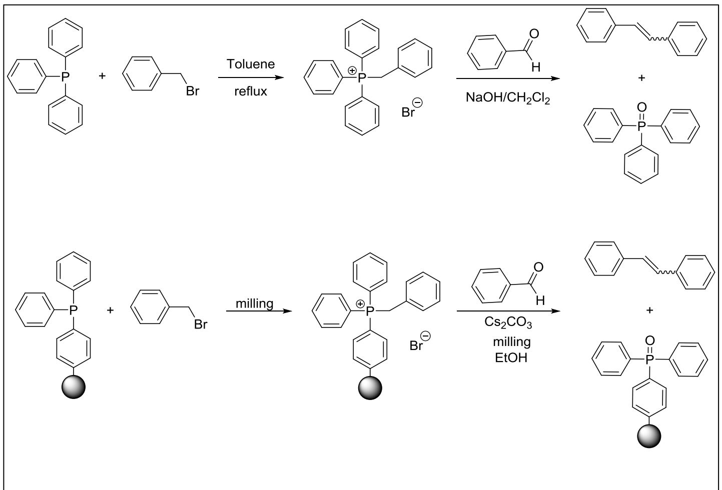


Figure 1. Comparasion of soluion based Wittig (top) against mechanochemical Wittig (botom)

Leahy, Kendra; Mack, Anthony; Mack, James. "An EcoScale Comparison of Mechanochemistry and Solution Based Reactions." *Green Technologies for the Environment*. Obare et. al. ACS Symposium Series; American Chemical Society: Washington, DC, **2014**. 129-137. Print.

MEASURING WASTE MINIMIZATION – THE ECOSCALE

Parameter	Penalty points
1. Yield	(100 – %yield)/2
2. Price of reaction components (to obtain 10 mmol of end product)	
Inexpensive (< $10)	0
Expensive (> $10 and < $50)	3
Very expensive (> $50)	5
3. Safety[a]	
N (dangerous for environment)	5
T (toxic)	5
F (highly flammable)	5
E (explosive)	10
F+ (extremely flammable)	10
T+ (extremely toxic)	10
4. Technical setup	
Common setup	0
Instruments for controlled addition of chemicals[b]	1
Unconventional activation technique[c]	2
Pressure equipment, > 1 atm[d]	3
Any additional special glassware	1
(Inert) gas atmosphere	1
Glove box	3
5. Temperature/time	
Room temperature, < 1 h	0
Room temperature, < 24 h	1
Heating, < 1 h	2
Heating, > 1 h	3
Cooling to 0°C	4
Cooling, < 0°C	5
6. Workup and purification	
None	0
Cooling to room temperature	0
Adding solvent	0
Simple filtration	0
Removal of solvent with bp < 150°C	0
Crystallization and filtration	1
Removal of solvent with bp > 150°C	2
Solid phase extraction	2
Distillation	3
Sublimation	3
Liquid-liquid extraction[e]	3
Classical chromatography	10

Van Aken, Koen; Strekowski, Lucjan; Patiny, Luc. "EcoScale, a semi-quantitative tool to select an organic preparation based on economical and ecological parameters." *Ballstein J. of Org. Chem.* **2006**, *3*.
Leahy, Kendra; Mack, Anthony; Mack, James. "An EcoScale Comparison of Mechanochemistry and Solution Based Reactions." *Green Technologies for the Environment*. Obare et. al. ACS Symposium Series; American Chemical Society: Washington, DC, **2014**. 129-137. Print.

MEASURING WASTE MINIMIZATION – THE ECOSCALE

Parameter	Penalty points
1. Yield	(100 – %yield)/2
2. Price of reaction components (to obtain 10 mmol of end product)	
Inexpensive (< $10)	0
Expensive (	
Very exper	
3. Safety[a]	
N (dangerc	
T (toxic)	
F (highly fla	
E (explosiv	
F+ (extrem	
T+ (extren	
4. Technical s	
Common setup	0
Instruments for controlled addition of chemicals[b]	1
Unconventional activation technique[c]	2
Pressure equipment, > 1 atm[d]	3
Any additional special glassware	1
(Inert) gas atmosphere	1
Glove box	3

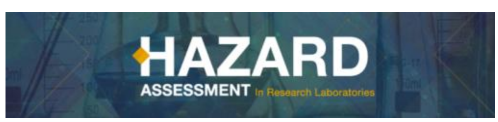
5. Temperature/time	
Room temperature, < 1 h	0
Room temperature, < 24 h	1
Heating, < 1 h	2
	3
	4
	5
	0
	0
	0
	0
	0
	1
Removal of solvent with bp > 150°C	2
Solid phase extraction	2
Distillation	3
Sublimation	3
Liquid-liquid extraction[e]	3
Classical chromatography	10

	Solution		Mechanochemistry	
Total Penalty Points		65		23
EcoScale rating	100-65	35	100-23	77
Overall Assessment		Inadequate		Excellent

Van Aken, Koen; Strekowski, Lucjan; Patiny, Luc. "EcoScale, a semi-quantitative tool to select an organic preparation based on economical and ecological parameters." *Ballstein J. of Org. Chem.* **2006**, *3.*
Leahy, Kendra; Mack, Anthony; Mack, James. "An EcoScale Comparison of Mechanochemistry and Solution Based Reactions." *Green Technologies for the Environment*. Obare et. al. ACS Symposium Series; American Chemical Society: Washington, DC, **2014**. 129-137. Print.

47

48



Common Hazards | Further Reading | Definitions of Hazard Assessment

Examples | Templates

What-If Analysis

- Analysis of a Wolff-Kishner reaction [Word]
- Entering an empty lab without wearing protective glasses [Word]*
- Inert materials and nonchemical effects: nitrogen backfill exceeds atmospheric pressure [Word]*
- Lockout or tagout principle for hazardous energy [Word]*
- Management of change: relocating moisture removal column [Word]*
- Material substitution: Hydrogen mixture replaced with pure hydrogen [Word]*
- Toxic or flammable gas cylinder in a fume hood [Word]
- Using a hotplate with flammable liquid [Word]

Job Hazard Analysis

- Analysis for neutralizing solution of glacial acetic acid, zinc sulfate heptahydrate, potassium chloride, and water [Word]

Checklists

- Chemical hazard assessment for sodium cyanide [Word]

Standard Operating Procedures

- SOPs for new process involving carbon monoxide [Word]
- SOP for use of carbon monoxide to create metal complexes under pressure [Word]

Control Banding

- Approach to establishing chemical safety levels [Word]

Risk Assessment

- Laboratory hazard risk assessment matrix [Word]
- Laboratory process risk assessment matrix [Word]
- Laboratory process risk assessment for a process using a chemical [Word]

fundamentals of hazard assessment | scoping and assembling your team | ways to conduct hazard assessments | tools

Summary

- Risk = hazard x exposure
- Determine scope (use SDS!)
- Assemble your team
- Conduct a hazard assessment
  - Assigning risk ratings
  - Job hazard analysis
- Select controls
- Green engineering principles
- Green chemistry metric: EcoScale

49

Acknowledgments

Advisor: Prof. James Mack

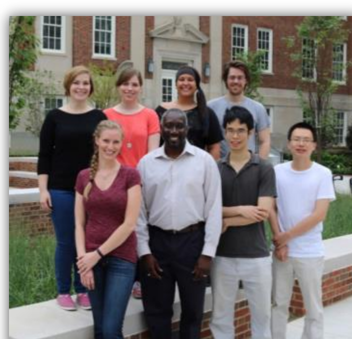
Committee Members:
- Prof. Hairong Guan
- Prof. Neil Ayres

American Chemical Society:
- Ralph Stuart
- Marta Gmurczyk
- Mary Kirchhoff

Mack Group:
- Heather
- Longrui
- Becca
- Cong
- Joel
- Nina

Undergraduates:
- Preston Carr
- Kingsley Benson

Incoming graduate students:
- Rashad Pace
- Nina Trankina



50

Kendra Leahy Denlinger **denlinkm@mail.uc.edu** **leahykr@gmail.com**

51

KEY CHEMICAL SAFETY REFERENCES

Audience	Technical Resources	Cultural Resources
High school and undergraduate teaching labs	*NFPA 45 requirements for instructional and educational labs*, 2015	*Guidelines for Chemical Lab Safety in Secondary Schools*, ACS 2016
Mentored research labs (REU, CURE, similar programs)	*Safety in Academic Chemistry Laboratories*, 8th edition ACS 2017	*Creating Safety Cultures in Academic Institutions* ACS, 2013
Supervised research (graduate school)	*Guidelines for Chemical Lab Safety in Secondary Schools*, ACS 2016	*A Guide to Implementing a Safety Culture in our Universities* APLU, 2016
Research leadership	*Prudent Practices in the Laboratory* National Academies Press 2011 *Hazard Assessment in Research Laboratories* ACS, 2016	*Safe Science* National Academies Press, 2014 *Safety Guidelines for the Chemistry Professional* ACS DCHAS / CCS, 2017

52

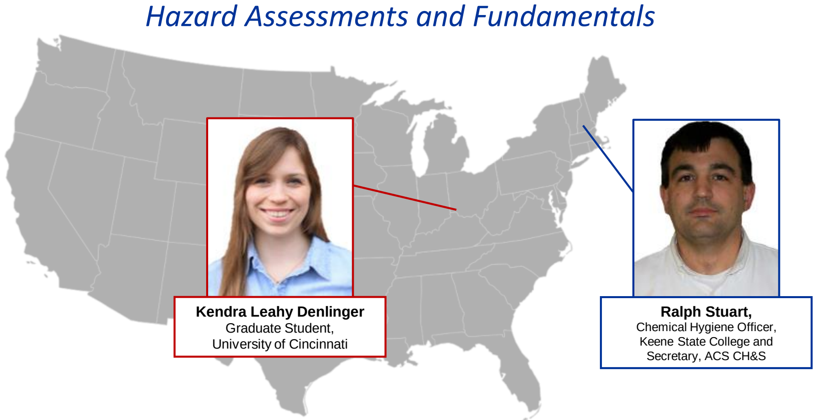
KEY GREEN CHEMISTRY REFERENCES

Audience	Technical Resources
Laboratory Researchers	EcoScale green chemistry metric
	ACS Green Chemistry Institute
	"An EcoScale Comparison of Mechanochemistry and Solution Based Reactions," 2014

ACS Webinars
CLICK • WATCH • LEARN • DISCUSS

ACS Chemistry for Life®

Creating a 21st Century Chemical Research Laboratory:
Hazard Assessments and Fundamentals



Slides available now! Recordings are an exclusive ACS member benefit.

www.acs.org/acswebinars

This ACS Webinar is co-produced by the ACS Division of Chemical Health and Safety and the ACS Green Chemistry Institute

Nanomaterial Design Guided by the Principles of Green Chemistry

ACS Chemistry for Life®

Thursday, May 18 @ 2-3pm ET

How can green chemistry be applied to nanotechnology to achieve the high performance needed for advanced applications while preventing or reducing health and environmental impacts? Join James Hutchison from the University of Oregon as he discusses the foundations for greener nanotechnology and presents a case study that uses nanomaterial product innovation guided by green chemistry.

Register Now!

What You Will Learn

- The opportunity to achieve a net environmental benefit by bringing together green chemistry with nanoscience
- The role that green chemistry plays in designing high performance nanomaterials and efficient nanomaterial production
- How green chemistry and nanoscience can be used together to develop innovative new products with environmental benefits

ACS Webinars® CLICK · WATCH · LEARN · DISCUSS

Experts

James Hutchison
University of Oregon

Joe Fortunak
Howard University

Co-Produced With

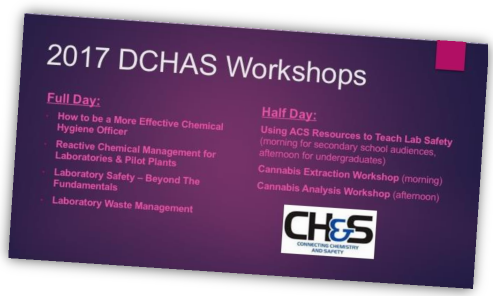
ACS Green Chemistry Institute®

http://bit.ly/GreenNano

55

Join the ACS Chemical Health and Safety Division!

ACS Chemistry for Life®



The division is dedicated to supporting the efforts of chemical manufacturers, industrial and academic researchers, and science teachers at all levels to work for a safe and healthful work environment. Through our technical symposia, the Division's Journal, the ***Journal of Chemical Health and Safety***, our **workshops** and our **DCHAS-L listserv**, we provide a forum for scholarly health and safety research, advice and counsel from an experienced group, and support for health and safety efforts in industry and academia.

https://dchas.org

56

Upcoming ACS Webinars
www.acs.org/acswebinars

ACS Chemistry for Life®

Thursday, May 18, 2017

Nanomaterial Design Guided by the Principles of Green Chemistry
Co-produced with the ACS Green Chemistry Institute

James Hutchison, Lokey-Harrington Chair in Chemistry, University of Oregon
Joe Fortunak, Professor of Chemsitry, Howard University

Thursday, May 25, 2017

Anti-Infectives: *Rational Approaches to the Design and Optimization*
Co-produced with the ACS Division of Medicinal Chemistry and the AAPS

Jason Sello, Associate Professor of Chemistry, Brown University
Courtney Aldrich, Associate Professor, Department of Medicinal Chemistry, University of Minnesota and Editor-in-Chief of *ACS Infectious Diseases*

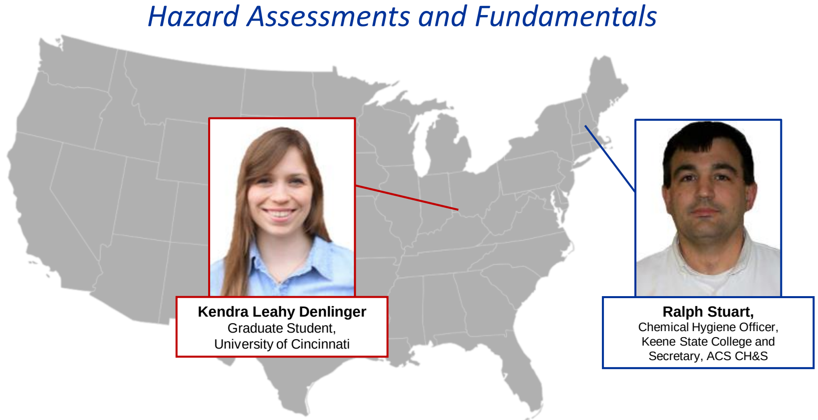
Contact ACS Webinars ® at acswebinars@acs.org

57

ACS Webinars® CLICK • WATCH • LEARN • DISCUSS

ACS Chemistry for Life®

Creating a 21st Century Chemical Research Laboratory:
Hazard Assessments and Fundamentals



Slides available now! Recordings are an exclusive ACS member benefit.
www.acs.org/acswebinars

This ACS Webinar is co-produced by the ACS Division of Chemical Health and Safety and the ACS Green Chemistry Institute

58

THE TAKE HOME MESSAGE

Job Hazard Analyses and Green Chemistry metrics support each other and make for better and safer science. This is because they are both based on clear, careful descriptions of the chemical processes being conducted.

CH&S CONNECTING CHEMISTRY AND SAFETY

ACS Green Chemistry Institute®

59

How has ACS Webinars® benefited you?

http://bit.ly/SelfFulfillment

ACS Chemistry for Life®

"Darren offered a refreshing perspective on how to act as a scientist. It was a nice reminder to find positives in a negative situation. I also liked how Darren challenged the audience to be open to art (and other fields), and not to be a closed-off scientist."

Fan of the Week

Kevin Kempton
Research Associate
Innophos, Inc., ACS member for 3 years strong!

Be a featured fan on an upcoming webinar! Write to us @ acswebinars@acs.org

60

ACS Webinars CLICK • WATCH • LEARN • DISCUSS

ACS Chemistry for Life®

61

ACS Webinars CLICK • WATCH • LEARN • DISCUSS

ACS Chemistry for Life®

Benefits of ACS Membership

Chemical & Engineering News (C&EN)
The preeminent weekly news source.

NEW! Free Access to ACS Presentations on Demand®
ACS Member only access to over 1,000 presentation recordings from recent ACS meetings and select events.

NEW! ACS Career Navigator
Your source for leadership development, professional education, career services, and much more.

http://bit.ly/benefitsACS

62

ACS Webinars
CLICK • WATCH • LEARN • DISCUSS

ACS Chemistry for Life®

ACS Webinars® does not endorse any products or services. The views expressed in this presentation are those of the presenter and do not necessarily reflect the views or policies of the American Chemical Society.

Contact ACS Webinars ® at acswebinars@acs.org

Upcoming ACS Webinars

www.acs.org/acswebinars

ACS Chemistry for Life®

Thursday, May 18, 2017

Nanomaterial Design Guided by the Principles of Green Chemistry

Co-produced with the ACS Green Chemistry Institute

James Hutchison, Lokey-Harrington Chair in Chemistry, University of Oregon

Joe Fortunak, Professor of Chemsitry, Howard University

Thursday, May 25, 2017

Anti-Infectives: *Rational Approaches to the Design and Optimization*

Co-produced with the ACS Division of Medicinal Chemistry and the AAPS

Jason Sello, Associate Professor of Chemistry, Brown University

Courtney Aldrich, Associate Professor, Department of Medicinal Chemistry, University of Minnesota and Editor-in-Chief of *ACS Infectious Diseases*

Contact ACS Webinars ® at acswebinars@acs.org