Safety in the Lab

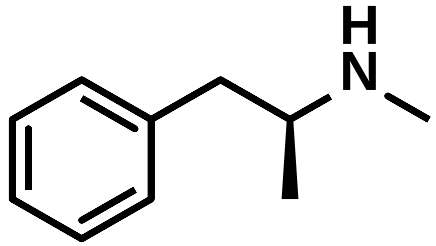
Things you may have never thought about but now you will

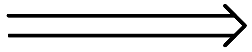
(and otherwise it is a repetition…)

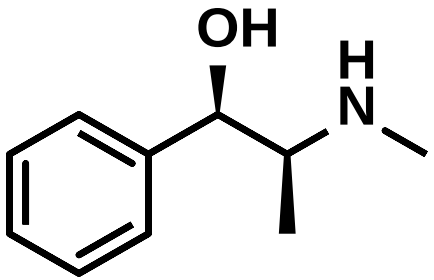
Menu of Today

- How to prepare before you do an experiment in the lab
- Illustrative examples of lab accidents and lessons learned
- What could possibly go wrong in a lab (also for biology oriented people)?

Breaking Bad: how not to make chemical compounds…







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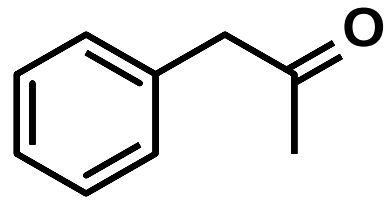


Crystal meth production from pseudo ephedrine or via reductive amination of P2P

The century of the fume hood!

- **No exposure to fumes**
- **Volatiles are diluted and removed (explosion / fire danger decreases)**
- **Leakages (chemicals / water) are contained**

All chemical reactions / purifications and preparation of solutions using organic solvents must be done in a fume hood

NFPA rating system

All chemical compunds must be treated as potentially dangerous (either on short or on long term)

Chemwatch Hazard Ratings

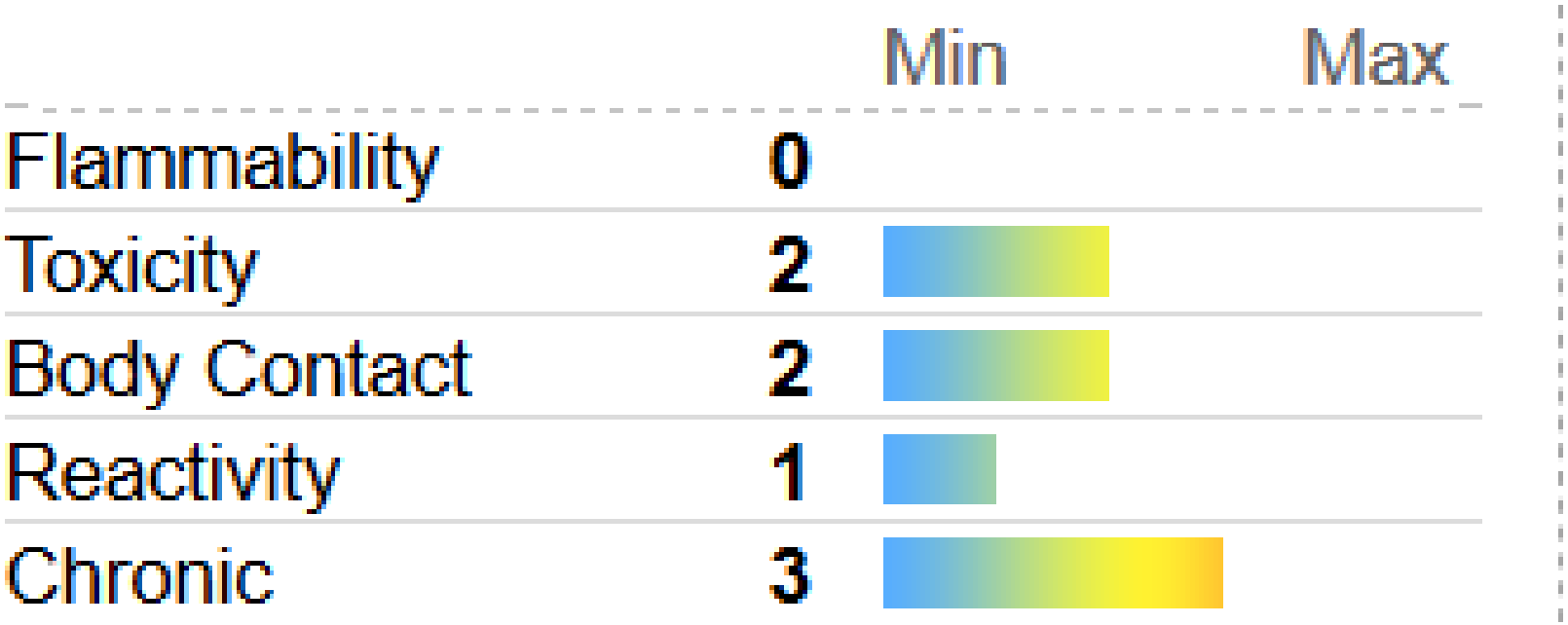
Hazard Category	Hazard Rating	Hazard Level	Colour Code	Nature of Hazard Substance
Flammability Toxicity Body Contact Reactivity Chronic	0/Min	Non	Grey	Non Hazardous Substance
	1	Low	Blue	Low Hazardous Substance
	2	Moderate	Yellow	Moderate Hazardous Substance
	3	High	Orange	Highly Hazardous Substance
	4	Extreme	Red	Extremely Hazardous Substance

https://jr.chemwatch.net/chemwatch.web/home

Chemwatch Hazard Ratings

Chloroform:

CHEMWATCH HAZARD RATINGS



https://jr.chemwatch.net/chemwatch.web/home

Additional safety measures (obligated and optional)

Gloves

Safety goggles

Labcoat

Safety shields

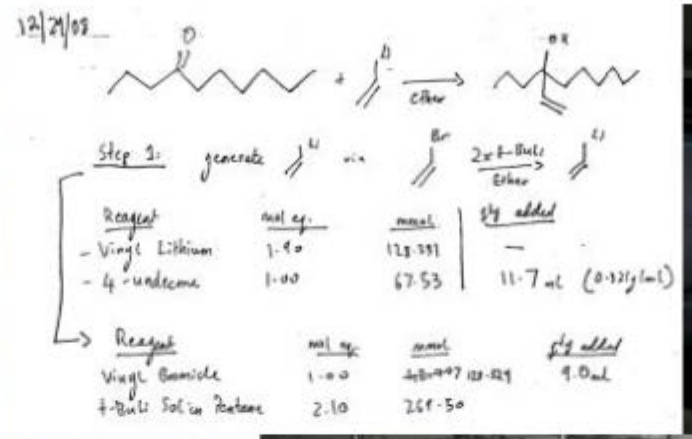
Respatory masks

Additional safety measures: not a good idea

In the lab: boring clothes are better!

Importance of wearing a labcoat: UCLA December 2008

Sheharbano Sangji



Importance of wearing a labcoat: UCLA December 2008

- UCLA 2008: A young research assistant was conducting an experiment with a pyrophoric *t*-butyllithium solution. She wasn't wearing a protective lab coat when the chemical burst into flames, severely burning her over nearly half of her body. She died from her injuries 18 days later.
- 2009: Her supervisor faced criminal prosecution. A settlement was announced that allowed him to escape a trial in 2018.
- Following the tragic accident Laboratory Safety Practices were re-evaluated and safety awareness was increased, trainings were given to students, and more safety checks were done.

Patrick Harran

Safely working with chemicals means:

- **Identify dangers of solvents / compounds you work with**
- **Identify safety measures you need to take (which gloves, additional measures needed?)**
- **Identify how to deal with the waste after the reaction**
- **Know what to do when something goes wrong**

Why do we use gloves?

- To keep hands clean of grease etc
- To protect against solid chemicals
- To protect agains solvents / liquid chemicals
- Because they cheer up my day

The ideal universal glove that protects you against every chemical there is and is nice and flexible and comfortable to wear -- that glove doesn't exist

@TU/e

Neoprene rubber glove

Latex glove

Nitrile glove

Norfoil glove

Facts on latex gloves

solvent	Type 1	Type 2	Type 4
aceton	Immediately leaks	Immediately leaks	Immediately leaks
acetonitril	Immediately leaks	Immediately leaks	Immediately leaks
chloroform	Immediately leaks	Immediately leaks	Immediately leaks
DCM	Immediately leaks	Immediately leaks	Immediately leaks
Diethyl ether	Immediately leaks	Immediately leaks	Immediately leaks
Heptane/hexane	Immediately leaks	Immediately leaks	Immediately leaks
toluene	Immediately leaks	Immediately leaks	Immediately leaks
alcohols	Immediately leaks	Immediately leaks	Immediately leaks

Increasing type: increasing thickness

Facts on nitril gloves

solvent	evo	eco	light
aceton	Immediately leaks	Immediately leaks	Immediately leaks
acetonitril	Immediately leaks	Immediately leaks	Immediately leaks
chloroform	**4**	Immediately leaks	Immediately leaks
DCM	Immediately leaks	Immediately leaks	Immediately leaks
Diethyl ether	Immediately leaks	Immediately leaks	Immediately leaks
Heptane/hexane	**1**	Only recommended for spatters	Only recommended for spatters
toluene	Immediately leaks	Immediately leaks	Immediately leaks
alcohols	**1-6**	Only recommended for spatters	Only recommended for spatters

Increasing right: decreasing thickness

Permeation time: 1: > 10 min 6: > 480 min

Overview of gloves

	Intended use	(+) / (-)
Nitril 	Incidental contact (disposable) Extended contact (thicker reusable glove) **Excellent general use glove** *excellent wet and dry grip, excellent puncture, abrasion and snag resistance*	(+) protects from bases, oils, many solvents, greases and animal fats (-) **avoid ketones, aromatic, chlorinated solvents** (xylene, toluene, DCM, $CHCl_3$, ...)
Latex 	Incidental contact (disposable) *highly flexible*	(+) cheap (+) Good for biological and water-based materials. (-) ***may cause allergic reactions-*** (-) Poor for organic solvents; **offers little chemical protection**
Neoprene 	Extended contact (non disposable) *excellent mobility and flexibility also at low temperatures*	(-) **Poor for halogenated and aromatic hydrocarbons** (+) resists many oils, acids, caustics, peroxides, hydrocarbons and solvents (phenol, ethyl glycol, aniline,...)
Viton 	Extended use (non disposable) *Good resistance to cuts and abrasions.*	(+) Good for chlorinated and aromatic solvents and acids (-) **Poor for ketones** (-) very expensive (100 euro / pair)

Overview of gloves

	Intended use	(+) / (-)
Polyvinylalcohol (PVA) 	Specific use *resists snags, punctures, abrasions and cuts*	(+) Good for aromatic and chlorinated solvents, esters and most ketones (-) Water-soluble: degrades if exposed to water-based solutions .
Butyl 	Extended contact *excellent dexterity and flexibility*	(+) resistance against aldehydes, ketones, esters and concentrated mineral acids (+) protection against gasses (HCN, chlorine) (-) relatively poor resistance to mineral solutions (-) fairly expensive
Polyvinylchloride (PVC) 	Specific use *excellent abrasion resistance*	(+) good resistance to many acids, caustics ,bases, fats, oils and alcohols (-) not recommended for ketones, poor for most organic solvents. *less resistant to punctures*
Norfoil 	Extended contact	(+) Good for most hazardous chemicals. (-) Poor fit *Dexterity can be partially regained by using a heavier weight Nitrile glove over the Norfoil/Silver Shield glove.*

What glove shall I wear today??

Check MSDS!!

Most of the times: no gloves are recommended to avoid a false sense of safety!!
Check what to do in case you spill on your skin!!
What to do in case of mixtures of chemicals??

Benzene

Skin Contact	If skin contact occurs: ▸ Immediately remove all contaminated clothing, including footwear. ▸ Flush skin and hair with running water (and soap if available). ▸ Seek medical attention in event of irritation.

Trifluoromethanesulfonic acid:

Hands/feet protection	▸ Elbow length PVC gloves ▸ When handling corrosive liquids, wear trousers or overalls outside of boots, to avoid spills entering boots. The selection of suitable gloves does not only depend on the material, but also on further marks of quality which var manufacturer. Where the chemical is a preparation of several substances, the resistance of the glove material can n advance and has therefore to be checked prior to the application. The exact break through time for substances has to be obtained from the manufacturer of the protective gloves and. when making a final choice. Personal hygiene is a key element of effective hand care. ▸ Neoprene gloves

Working with chemicals: what can possibly go wrong?

Sodium azide

CHEMWATCH HAZARD RATINGS

	Min	Max
Flammability	0	
Toxicity	4	
Body Contact	4	
Reactivity	2	
Chronic	0	

Potassium cyanide

CHEMWATCH HAZARD RATINGS

	Min	Max
Flammability	0	
Toxicity	4	
Body Contact	4	
Reactivity	1	
Chronic	0	

Benzene

CHEMWATCH HAZARD RATINGS

	Min	Max
Flammability	3	
Toxicity	0	
Body Contact	2	
Reactivity	1	
Chronic	4	

Working with chemicals: what can possibly go wrong?

MINI SDS

BENZENE

INGREDIENTS	CAS NO	%	8HR OEL
benzene	71-43-2	99.9	3,25 mg/m3

GHS

DG

UN No: **1114**
DG Class: **3**
Subsidiary Risk: **Not Applicable**
Packing Group: **II**

HEALTH HAZARD INFORMATION

Signal word:	**Danger**	
Hazard statement(s):	**H225**	Highly flammable liquid and vapour.
	H340	May cause genetic defects.
	H372 **	Causes damage to organs through prolonged or repeated exposure.
	H315	Causes skin irritation.
	H319	Causes serious eye irritation.
	H304	May be fatal if swallowed and enters airways.

PROPERTIES

Liquid. Does not mix with water. Floats on water.Highly flammable.

EMERGENCY

FIRST AID

Swallowed:	Give water (if conscious). Seek medical advice. Do NOT give milk or oil. Do NOT give alcohol.
Eye:	Wash with running water.
Skin:	Remove contaminated clothing. Wash with soap & water.
Inhaled:	Fresh air. Rest, keep warm.
Advice To Doctor:	Evaluate for respiratory distress. Consider lavage with cuffed tube. NO adrenalin.
Fire Fighting:	Keep containers cool. Foam.
	Eliminate ignition sources. Consider evacuation. Prevent from entering drains. Contain spillage by any me

Working with chemicals: what can possibly go wrong?

PRECAUTIONS FOR USE

Appropriate engineering controls:	Local Exhaust Ventilation recommended.
Glasses:	Consider chemical goggles.
Gloves:	1.PE/EVAL/PE 2.PVA 3.TEFLON
Respirator:	Type A Filter of sufficient capacity. (AS/NZS 1716 & 1715, EN 143:2000 & 149:2001, ANSI Z88 or national equivalent)
Storage and Transportation:	Store in cool, dry, protected area. Restrictions on Storage apply. Refer to Full Report. Take precautionary measures against static discharges. Dispose of this material and its container at hazardous or special waste collection point. Keep locked up. Keep out of reach of children. Keep away from living quarters. Keep container in a well ventilated place. Keep away from food, drink and animal feeding stuffs. Keep away from sources of ignition. No smoking.
Fire/Explosion Hazard:	HIGHLY FLAMMABLE. Vapours/gas heavier than air. Toxic smoke/fumes in a fire. Take precautionary measures against static discharges. Dispose of this material and its container at hazardous or special waste collection point. In case of fire and/or explosion, DO NOT BREATHE FUMES.

FIRST AID

Swallowed:	Give water (if conscious). Seek medical advice. Do NOT give milk or oil. Do NOT give alcohol.
Eye:	Wash with running water.
Skin:	Remove contaminated clothing. Wash with soap & water.
Inhaled:	Fresh air. Rest, keep warm.
Advice To Doctor:	Evaluate for respiratory distress. Consider lavage with cuffed tube. NO adrenalin.
Fire Fighting:	Keep containers cool. Foam.
Spills and Disposal:	Eliminate ignition sources. Consider evacuation. Prevent from entering drains. Contain spillage by any means. Control vapour with water spray/ fog. Absorb with dry agent. Stop leak if safe to do so. Take precautionary measures against static discharges. Dispose of this material and its container at hazardous or special waste collection point. This material and its container must be disposed of in a safe way. To clean the floor and all objects contaminated by this material, use water and detergent.

Exercise: what do you when you perform a new experiment

What do you wear obligatory? What can you absolutely not wear?

Where do you perform the experiment?? How do you prepare??

Discuss which safety measures are absolutely required in your current laboratory, and if and how it differs with another one

If there are significant differences, discuss what the origin could be of these differences

Groups:

1. Anjana Daniel Melissa
2. Linlin Stephen Africa
3. Michela Alis Shreyas
4. Maria Manos Boris new

Azides: explosive, toxic and obnoxious but also very important

NaN_3, starting material for the synthesis of azides, is extremely toxic

- Sodium azide can be absorbed through the skin and is toxic (LD_{50} oral (rats)=27 mg/kg)
- When protonated by water or acidic media, it forms HN_3 (hydrazoic acid)
- HN_3 is a colourless, explosive, smelly, volatile (bp = 37 °C) liquid
- The gas is less dense (lighter) than air, so it will rise
- When you breathe the gas, the cells of the body cannot take up oxygen and die

Always keep chemical waste at high pH to prevent the formation of HN_3

Azides, explosive and toxic

Azides can explode

most azides are explosive substances that decompose with the release of nitrogen through the slightest input of external energy, for example pressure, impact, or heat.
The heavy-metal azides are used, for example, in explosives technology, in which they serve as detonators. The organic azides, particularly methyl azide, often decompose explosively.

Consider the Carbon to Nitrogen Ratio (C/N)

The **number of nitrogen atoms** should not exceed **the number of carbon atoms** in an organic azide. Some azides that have a C/N ratio between 1 and 3 can be synthesized in small quantities, but the azides should be used or quenched as soon as possible. Azides should be stored at -18 °C, and in the absence of light (preferably in plastic amber containers). **Concentrations should not exceed 1 M.**

$$(N_{Carbon} + N_{Oxygen}) / N_{Nitrogen} \geq 3$$

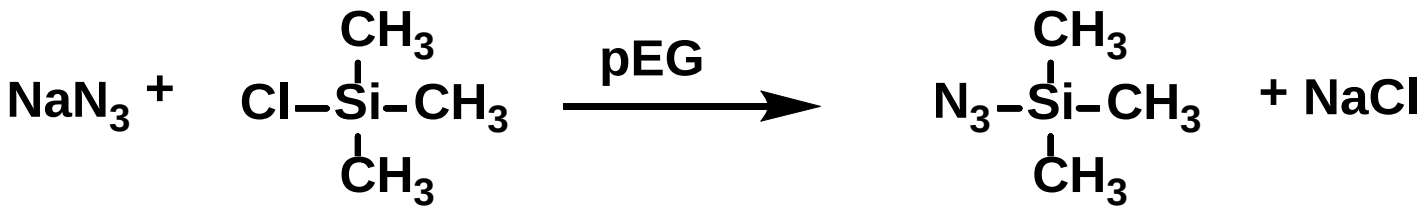
Adhere to the Rule of Six

There should be **no less than six carbons per energetic functional group**.
Six carbons (or other atoms of about the same size) per energetic functional group (**azide, diazo, nitro**, etc.) provides sufficient dilution to render the compound relatively safe.
In general, olefinic, aromatic, or carbonyl azides are much less stable than aliphatic azides

Azido azide: the most explosive compound

NaN_3: an explosive and toxic compound

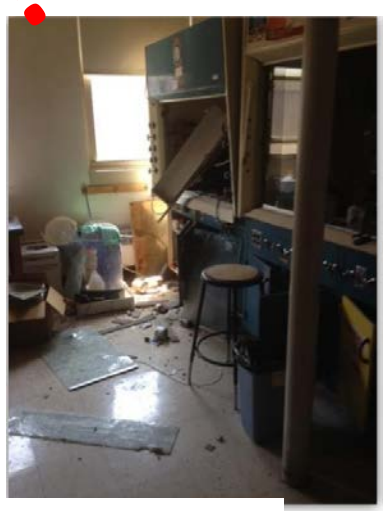
University of Minnesota (2014):



200 g

Hood / lab destroyed
Graduate student in hospital (he recovered)

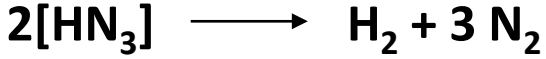
Scale!!!!



Likely causes (official cause unknown)

1. **R-N_3 + pEG300 (moisture?) yielded hydrazoic acid**

volatile, explosive and toxic

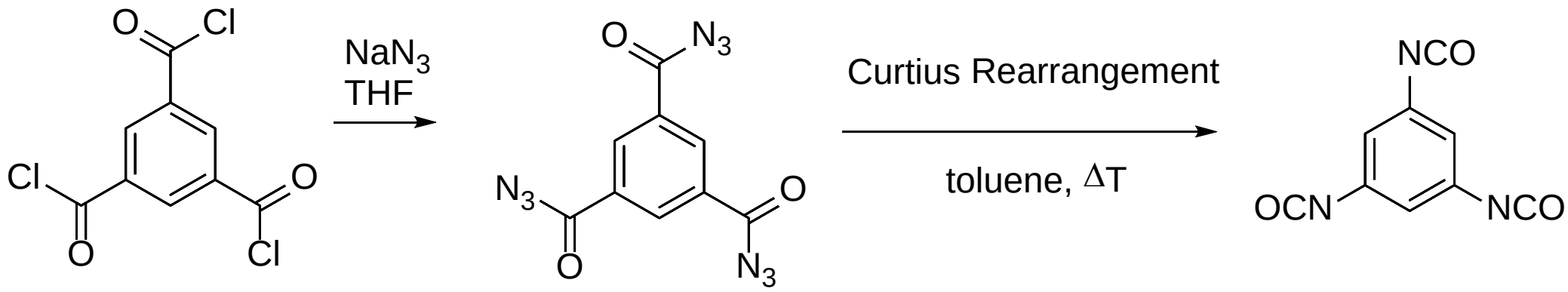


2. Overheating of NaN_3

Organic Synthesis

Caution! This reaction should be conducted behind a safety screen in a hood. If the system is not completely dry, the presence of toxic hydrazoic acid is probable.

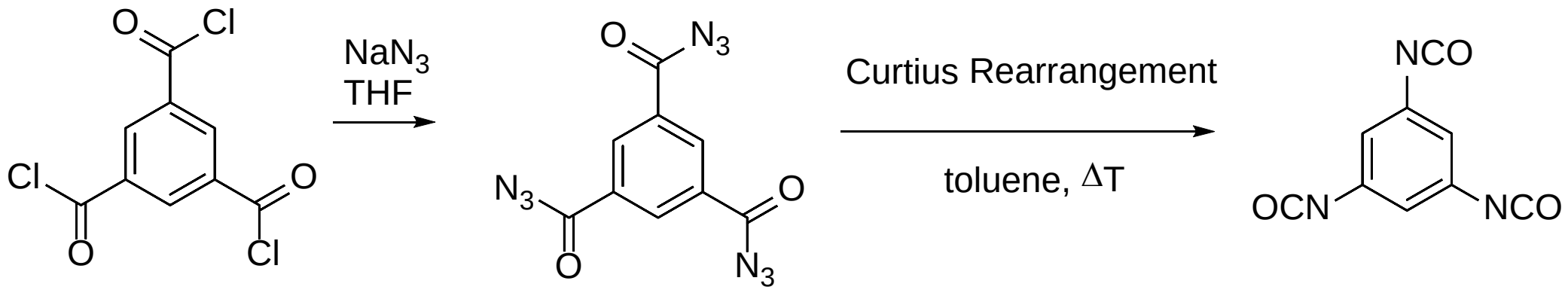
TU/e: Synthesis of triacyl trisazide gone wrong



Is it a good idea to make the trisacylazide?

Calculate C/N ratio and look at the rule of six

TU/e: Synthesis of triacyl trisazide gone wrong



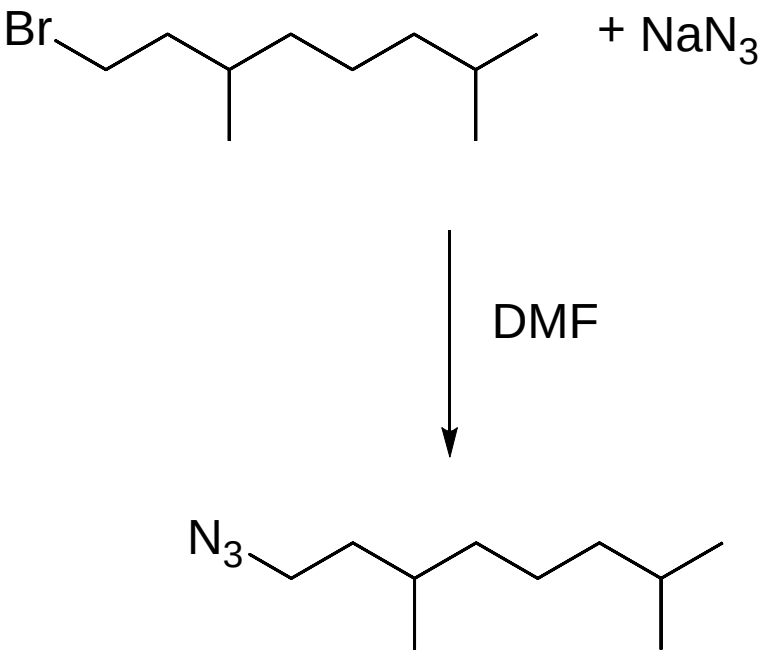
TU/e (1999):

- **PhD student makes 1 g of tris azide. Isolation via extraction, concentration and subsequent Curtius rearrangment: no problem**
- **PhD students scales up the reaction to 5 g: explosion: glass in face and hands, safety glass of hood destroyed, PhD student rushed to hospital (she made a full recovery)**

Solution:

- **limit scale to 1 g**
- **concentrate never above 0.1 M**

Real life example: synthesis of 3,7-dimethyloctylazide



- Check all chemicals with chemwatch http://library.tue.nl/catalog/AZDatabaseDetails.csp?Record=26286&RecordSub=1&Language=dut
- Check C/N ratio and rule of 6
- Supervisor says to perform reaction at 200 g scale. Is this a good idea??
- Which safety measures will you take (gloves, waste, etc)

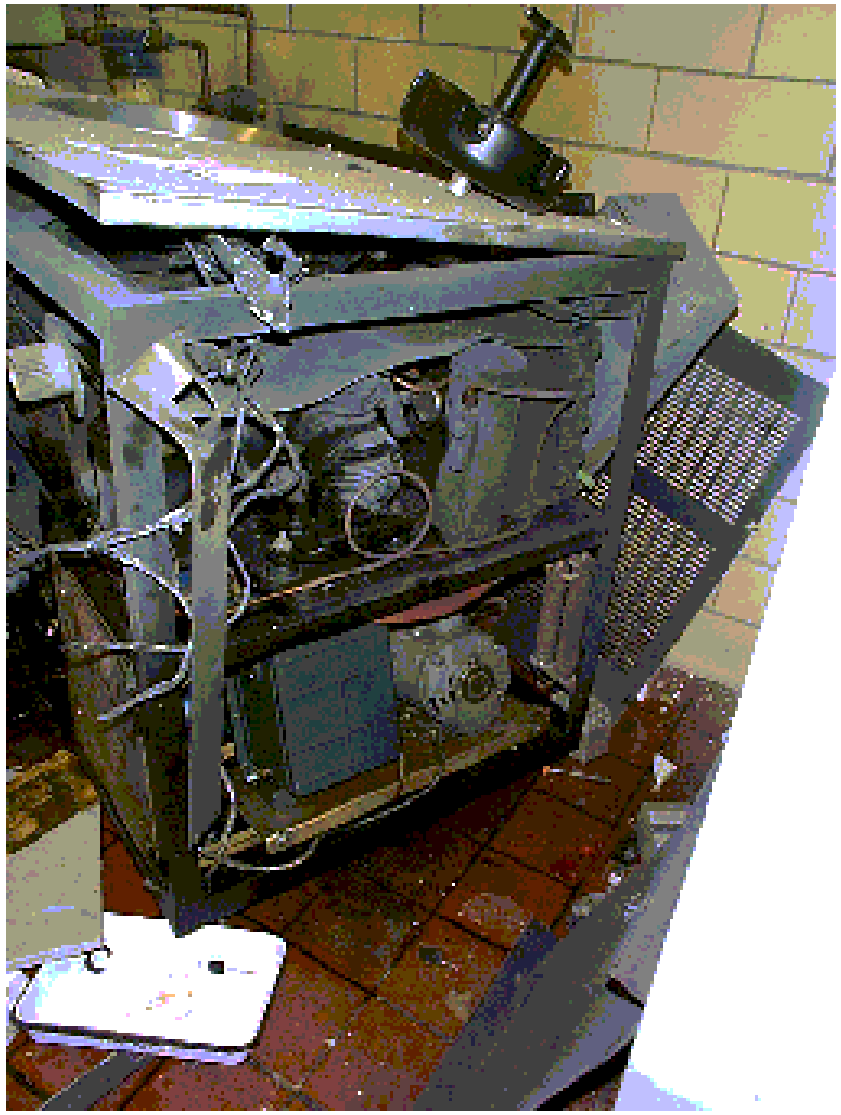
Biology oriented people think they are safe?? Not really…

https://www.youtube.com/watch?v=LzJuvls9Iqo

centrifuge

20,000 rpm or more
(washing machine is 1000 rpm)

Centrifuges in the lab: what can possibly go wrong?



1998 Purdue University:
A campus laboratory was seriously damaged when the rotor of an ultracentrifuge failed while in use. Flying metal fragments damaged walls, the ceiling and other equipment. The shock wave blew out the laboratory's windows and shook down shelves.

Unbalanced centrifuges and poor maintenance cause run-a-way centrifuges and severe lab accidents,

Most Common Injuries in the Lab

Eyes

Everyone should wear safety goggles.
Do not wear contact lenses in the lab!
When wearing glasses, use special safety glasses for better protection

Chemical splashes and errant shards of glass could still hurt your eyes around the edge of the glasses

Most Common Injuries in the Lab

Cuts & pricks

Scalpels

Syringes

Glassware that breaks/explodes

NEVER force tubing over glass through a stopper with the palm o your hand.

NEVER use force on glass stoppers

The best way to prevent this injury is to wear gloves, but when you do wear gloves, you lose dexterity, so you may be more clumsy than usual

Most Common Injuries in the Lab

Burns / irritations

Hot plates / heat gun / Bunsen burner
Corrosive chemicals
Irritating chemicals

- Always check heating plates before touching
- Wear appropriate gloves when using corrosive chemicals
- Wear protective clothing (closed shoes, long trousers, lab coat)
- Tie hair behind your head

Most Common Injuries in the Lab

Poisoning: mild to severe to lethal

- $Hg(CH_3)_2$ exposure resulted in death 1 year later.
- protective gloves in use at the time of the incident provided insufficient protection, and exposure to only a few drops of the chemical absorbed through the gloves proved to be fatal
- dimethylmercury rapidly permeates different kinds of latex gloves and enter the skin within about 15 seconds

Karen Wetterhahn 1948 - 1997

Lessons learned:

Gloves are not wonder stuff that really protect you

Exercise: who has ever been physically injured in a chemical lab?

1. What happened?

2. Why did it happen?

3. Did you need treatment?

4. What did you learn for the future?

Groups:

1. Anjana Daniel Melissa
2. Linlin Stephen Africa
3. Michela Alis Shreyas
4. Maria Manos Boris new

Anja:

1) Benzoylisocyanate solution in DCM shot into my eyes after syringe plunger got stuck and using force to push solution through

2) I did not wear proper overlay safety glasses

3) washed with water and went to hospital, looked OK, no treatment needed. After a couple of h it was not itching anymore. No problems afterwards.

4) *Always* wear proper overlay safety glasses when performing a chemical reaction. Be very carfull with syringes that get stuck. Do not use force!

The most important thing of an accident is that you (and others) learn from it and that you can take action to prevent future accidents: REPORT TO SAFETY PERSON AND EVALUATE

Hazards that need to be considered

Scale & exothermic reations

Things that are safe an manageable at 5 g scale are not on 500 g scale

1. Exothermic reactions: stirring / cooling / condensing all become more demanding Risks: runawy reaction and explosion (eg Grignard reaction done at too large scale and too fast addition of the bromide)
2. Reactions that produce gasses (HCl, N_2) are dangerous when done at larger scales in inappropriate equipment

Perform reactions always at small scale first

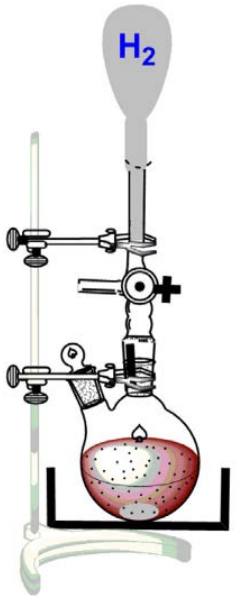
- Make sure you **check temperature during reaction** and how much the temperature increases
- If you want to do a real scale up, team up with a process engineer and calculate how much heat will evolve, how to best stirr, and cool, and how to best do the reaction so it will not runaway
- If reactions are heterogeneous, check how mixing affects the reaction outcome

Hazards that need to be considered

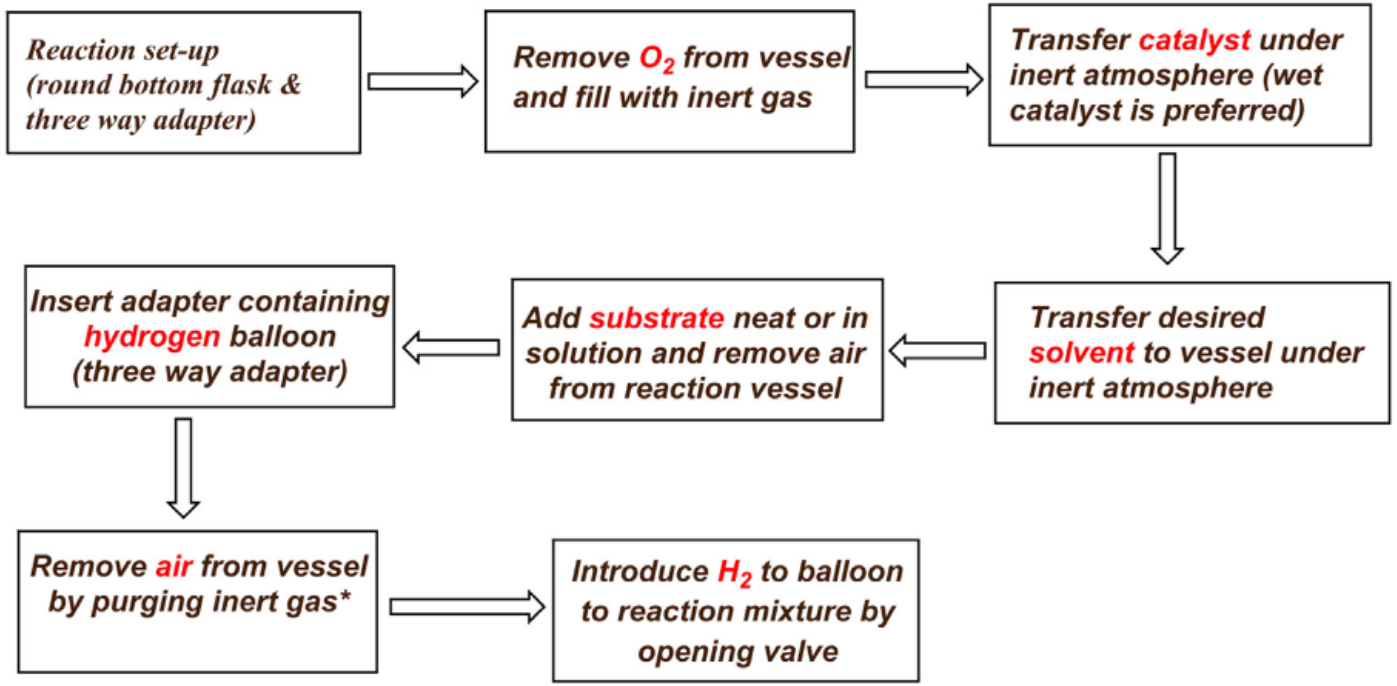
Incompatible chemicals and chemical waste

Azide and cyanide waste: never add to acid waste!!! **Always keep basic**
In 2018, a 26-year-old lab worker was found unresponsive near potassium cyanide at Frontage Laboratories Inc. in Pensylvania. She died.

Pd-C waste: pyrophoric in presence of H_2 and flammable solvents: **use SOP to work safely and keep waste covered with water!**



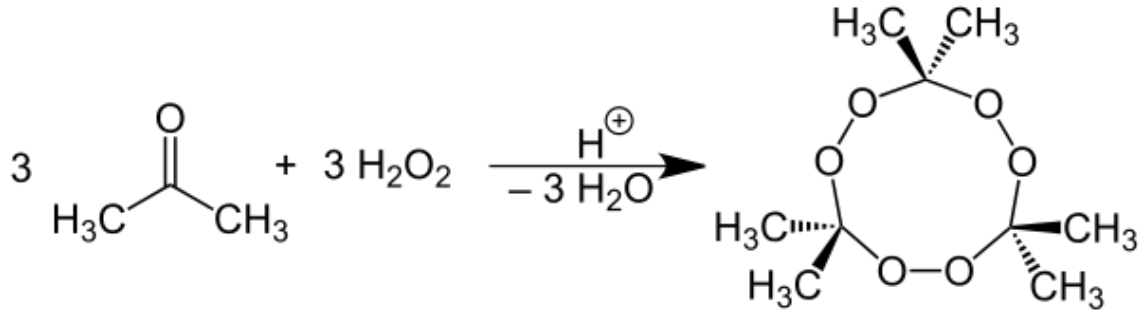
SOP:



Hazards that need to be considered

Incompatible chemicals and chemical waste

H_2SO_4 and H_2O_2 (used for cleaning glass filters) in combination with acetone: triacetoneperoxide formation which is explosive



TATP has been referred to as the "Mother of Satan". It was found in the accidental explosion that preceded the 2017 terrorist attacks in Barcelona and surrounding areas

DMSO takes everything across your skin

DMSO may greatly promote the toxic properties of solutes because of its unique ability to penetrate synthetic rubber protective gloves and the skin

Use proper gloves (butyl rubber / neoprene)!

Hazards that need to be considered

Compressed gasses / liquid gasses / condensation of gasses / working with gas cylinders

- Liquid oxygen in the cooling trap because of wrong use of the vacuum pump: blue colour. This superoxidant oxidises all organic molecules, and can cause an explosion
- Overpressure in argon lines and RB flasks: glassware has poor ressitance to high pressure.
- Underpressure in argon lines and RB flasks: if glass has a crack, the line / glassware can implode

Hazards that need to be considered

Sparks in combination with flammable gasses / volatile liquids

2016: Acccident at BASF (Ludwigshafen)

- Maintenance required on one of the pipelines
- By accident a pipeline was cut that contained a butylene mixture
- Butylene mixture leaked out and was ignited due to the sparks produced by the angle grinder
- The resulting fire caused an explosion, killing 5 people and injuring 44

Hazards that need to be considered

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How dangerous is life for chemists??

https://www.labsafety.org/memorial-wall

Prepare well, use your common sense and start small!

- Get acquainted with the safety procedures and laboratory practices in your lab
- Ask when you do not know something: *sharing is knowing*
- Learn from mistakes from you and others


Questions ?