EngrD 2190 – Lecture 3

Concept: Design – Creative Problem Solving, Part 1

Design is sequential problem solving.

Must define the ***real*** problem at each step.

Context: Strategies for Separations – purifying Br_2 (not in textbook)

Defining Questions:

What are our options for separating chemical substances?

Today's lecture is not in the textbook, but it involves the same concepts as the heptane purification – section 2.2.1

Read Chapter 2, pp. 25-42.

EngrI 1120 and EngrD 2190

50 of the 68 freshmen in EngrI 1120 in Fall 2024
are enrolled in EngrD 2190 Fall 2025 – 74% retention

The enrollment in EngrD 2190 is 86.

36 in EngrD 2190 (42%) did not take EngrI 1120

Benefits of EngrI 1120:

Know some peers.

Had a favorable reaction to ChemE.

~~Learned core concepts and skills of ChemE.~~

EngrD 2190 – First Team Assignments – Fall 2025

Team 1	NetID
Gabby Alvarado	gaa68
Valerie Ruiz	vr336

Team 2	NetID
Ward Dobeck	wed47
Chuck Fang	cf544
Cullen Mccarthy	cpm227

Team 3	NetID
Maame Amanpene	ma2399
Areebah Junaid	aj633
Sophia Zheng	sz683

Team 4	NetID
Evan Brezicki	ejb323
Andy Glesmann	arg292
Bradley Reiff	bjr235

Team 5	NetID
Greg Demos	gd332
Kanat Schoeberlein	kts59

Team 6	NetID
Minwoo Chung	emc358
Bill Nguyen	nn347
Wilson Zhang	wtz5

Team 7	NetID
Nicolas Banks	onb6
Andreas Custelcean	aec327
Jude Thomas	jct268

Team 8	NetID
Noor Dewood	nnd26
Sofia Romero	scr226
Shivani Parmar	ssp238

Team 9	NetID
Luke Aengenheyster	lma226
Connor Lucente	cbl64
Wilman Vlach	wlv23

Team 10	NetID
Sally Mallin	sam595
Kenzie Vasbinder	mrv49
Evelyn Ziaee	ez253

Team 11	NetID
Isabelle Bennie	ikb25
Steffanie Jones	scj56
Anna Voronova	asv44

Team 12	NetID
Youyou Xie	yx645
Hank Xue	zx344
Xinchi Zhang	xz985

Team 13	NetID
Gavin Chaing	gac233
Syon Khatter	sk3297
Vanshikha Sabbi	ls2242

Team 14	NetID
Sumama Haque	smh442
Daniel Herzenstein	dh762
Trevor Williams	tew63

Team 15	NetID
Eliza Gifford-Powell	eg659
Elizabeth Kline	elk92
Eva Yang	ey282

Team 16	NetID
Rhiannon Donovan	rd627
Anika Mahadeshwar	ajm546
Giorgia Santore	gs752

Team 17	NetID
Minjin Kim	mk2597
Aaron Legg	all288
Tomou Takahashi	ktt37

Team 18	NetID
Amber Belk	adb329
Dolly Hritz	drh258
Parth Vaidyanath	prv24

Team 19	NetID
Julianna Cross	jjc454
Nadia Diaz	nld46
Keira Kim	khk56

Team 20	NetID
Matt Hirsch	mh2623
Noah Reckhart	nar85
Santiago Rodriguez D'Ercole	sar356

Team 21	NetID
Simeon Hur	sh2659
Eleanor Reid	egr58
Sofia Ziegler	srz25

Team 22	NetID
Charlene Chan	cc2878
Shannon Hitscherich	srh254
Lizeth Montemayor	lm945

Team 23	NetID
Audrey Fu	af643
Aaron Salit	ams876
Em Vincent	ekv24

Team 24	NetID
Alice Burke	amb625
Mary Kanak	mck236
Noah Parfrey	ncp49

Team 25	NetID
Izabela Grigorov	ig295
Lauren Hsu	lkh58
Evelyn Sangree	ehs95

Team 26	NetID
Alex Cheng	ac2968
Patrick Donahue	pnd25

Team 27	NetID
Anwesha Ghosh	ag2662
Malvika Rao	msr298
Besi Santana	bs862

Team 28	NetID
Ellie Fredine	eaf247
Jasmine Hwee	jh2875
Maddie Li	ml2825

Team 29	NetID
Lila Chami	lc2259
Lila Kaman	lk567

Team 30	NetID
Tanbeer Islam	ti232
Josh Lennon	jsl379
Ayush Tripathi	at969

Collaborative Learning – Homework Teams

Teamwork, coordination, and execution are all crucial skills for engineers, regardless of which field or industry one goes into. Each person within the team has diverse ideas. There should be discussions, healthy disagreements, and efforts to bounce ideas off each other. One should always keep an open mind and combine all the beneficial ideas into one final product; this attitude is truly the essence of collaboration. *TA Kong Chen ('26)*

Always show respect to your team members. You will see these people everyday for the next three years, and everyone has their own unique strengths and weaknesses. EngrD 2190 is a great opportunity to learn how to work effectively in teams with people from different back-grounds and maintaining a level of respect is the first step to being successful *TA James Chen ('26)*

The collaborative learning you do in your homework teams as well as the calculation sessions gives great experience for the future ChemE classes as well as your work in the professional world. Different perspectives are so important to the process of scientific discovery and being able to compromise and combine differing ideas will lead to success. You may also meet the next Robert Langer! *TA Liam Gillespie ('26)*

Take the time to meet and work with your classmates. I met many of my closest friends in ChemE in EngrD 2190. Also, be open to new perspectives and opinions. This class is very design-heavy, which creates opportunities for creativity and multiple valid solutions. Sometimes you and a teammate may disagree, but both answers can still be correct, so be open to that. *TA Amy Wu ('26)*

Homework 1

Homework 1 due Friday 9/5:

Process Analysis: **2.7.**

Process Design: **2.24 and 2.25 (A only)**.

Read process design guidelines on p. 57.

See table of physical data on pp. 86-7.

You may assume perfect gas-solid separations;
no solids in the gas stream and no gas in the solids stream.

Work in teams. Submit one solution set per team.

Submit *after* lecture next Friday or deliver to the EngrD 2190 mailbox in the hallway across from 111 Olin Hall. ***Not to my mailbox.***

Homework is your chief means of assessing your command of the material.

Do not copy from other sources, such as graded homework and posted solutions from previous years.

Do not use past solutions to check your answers. Process analysis is part of process design. You should be developing methods of assessing your designs.

Homework Guidelines

EngrD 2190 - Chemical Process Design & Analysis

Homework Guidelines from Your Friendly TAs

"Form follows function - that has been misunderstood.
Form and function should be one, joined in a spiritual union"- Frank Lloyd Wright

Neatness is not rewarded explicitly in EngrD 2190. However, we want you to develop a professional style. We will be in a better mood when grading a neatly written assignment; it is to your benefit to put forth the extra effort. We won't decode scribbles. Therefore, it is to everyone's advantage that your work be neat.

Rules

- Submit only one solution per exercise per team.
- We divide the grading between TAs. So, you must start every solution on a new page. No more than one solution per page. If a solution spans multiple pages, staple the pages of that solution.
- Please use a paper clip to collect your solutions.
- Paper is cheap and recyclable. Use only one side of a sheet. Use only clean-edged paper.
- Write the names of all ***contributing*** team members on each solution. Identify the weekly team coordinator.
- Write your team code (e.g., Team 5) on the upper right corner of ***every*** solution.
- Show all work and identify your final answer. Box your numerical answers where appropriate.

Suggestions for Neatness and Clarity, Especially for Flowsheets

- Avoid cluttered solutions. Leave space for us to add helpful comments.
- We prefer final submissions in pencil, with colors when appropriate. If you choose to use pen, there must be no crossed-out mistakes.
- Please use vertical and horizontal lines for streams. Avoid crossing streams. If streams must cross, use the convention on p. 18 of your textbook.
- Label every stream's components. Label the phases of each component [liquid, gas, solid, or dissolved] for streams leaving separators.
- Inputs should enter at the flowsheet periphery and outputs should leave at the flowsheet periphery.
- Draw large designs with your paper rotated 90°; use the landscape (not portrait) orientation.
- Every stream should have exactly one arrowhead. A stream connecting two units with no arrowhead is ambiguous. Because streams always reach a unit, arrowheads, too, should meet a unit.
- Every unit whose operation depends on temperature should be labeled with that operating temperature, *especially* gas-liquid separators.
- A gas stream leaves through the top of the separator. A feed stream enters at a side.
- A reactor must have exactly one input stream and exactly one output stream.
- Avoid clutter: do not label splitters and combiners.
- A purge is a stream, not a unit. The unit that produces a purge is a splitter. Label purge streams as "purge" rather than listing stream contents. A purge stream labeled with chemical names looks like a major product stream, which is incorrect.
- Gas streams that you wish to mix do not require a mixer; a combiner is sufficient.

Homework Re-grades

- Be courteous: we spend a lot of time grading your work.
- If the total points were added incorrectly, any TA will accept your team's solution for re-grade.
- Study the solutions posted on the EngrD 2190 homepage for the preferred answers. We will not consider a re-grade unless you have looked at the posted solution.
- If you think we graded unfairly, you *must* attach a note to the assignment to be forwarded to the TA who graded the exercise. Please remember that we strive to discount similar errors uniformly. If you want us to regrade a problem, we will regrade the entire problem on that same scale. If we find an error that we had previously missed, your score may decrease after re-grading.

Homework Guidelines – The Rules

Rules

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- We divide the grading between TAs. So, you must start every solution on a new page. No more than one solution per page. If a solution spans multiple pages, staple the pages of that solution.
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Cooperative Learning

Motivation

Cooperative learning …

- increases the amount of information assimilated
- improves information retention
- develops higher-thinking skills: analysis and critical evaluation
- improves interpersonal and communication skills
- enhances self-confidence

What is it?

Cooperative learning is more than just working in groups. To be effective, cooperative learning must involve the following elements:

Positive interdependence. Team members are obliged to rely on one another to achieve the goal. If any team members fail to do their part, everyone suffers.

Individual accountability. All students in a group are held accountable for doing their share of the work and for mastering all the material.

Face-to-face constructive interaction. Although some of the group work may be parceled out and done individually, some must be done interactively, with group members providing one another with feedback, challenging one another's conclusions and reasoning, and perhaps most importantly, teaching and encouraging one another.

Appropriate use of collaborative skills. Students develop skills in leadership, decision-making, communication, inter-reliance, and conflict management.

Group dynamics. Each team must set goals, periodically assess what they are doing well as a team, and identify changes to function more effectively in the future.

Rules:

- Rotate the role of coordinator each week.
- Individual homework scores will reflect the team homework score and individual participation in the team's homework solution.
- Peer ratings reflect only participation, not academic ability or contribution to the homework.

For Homework 1, coordinator is first person listed on team assignments

Suggestions:

- Every team member attempts every homework exercise before each weekly meeting.
- At each weekly meeting randomly select a team member to lead the discussion on each exercise. You might draw cards or roll dice.

The goal is not to complete the homework. The goals are to learn how to work exercises similar to the homework and to develop problem-solving skills.

Study/Work Rooms Near Olin Hall

Kinkeldey ('57) Room on the 8th Floor [enter through the 8th floor book stacks or through the A. D. White Library] - quiet study space.

Visit at least once

Sources for Homework Help

Office Hours

Instructors: T. M. Duncan 344A Olin Hall 255-8715 or tmd10@cornell.edu
Office Hours: Monday noon – 2:00 p.m. or by appointment
M. C. Kowal 248A Olin Hall 255-8611 or mcl238@cornell.edu
Office Hours: Thursday 1:30 – 3:30 p.m.

Teaching Assistants: Office Hours: 7:30-9:30 p.m. Sunday (245 Olin) and Wednesday (128 Olin)

Preston Holopeter (grad) ph443@cornell.edu

Lara Capellino	lc834@cornell.edu	Angel Liang	al799@cornell.edu
James Chen	jzc28@cornell.edu	Johnny Lowry	jjl326@cornell.edu
Kong Chen	kc823@cornell.edu	Sean McInnis	scm254@cornell.edu
Liam Gillespie	lgg49@cornell.edu	Amy Wu	asw254@cornell.edu

You all have card key access to Olin Hall

Text: *Chemical Engineering Design and Analysis - An Introduction, 2nd edition*
T. M. Duncan and J. A. Reimer, Cambridge University Press (2019).

In Class

Schedule: Lectures: Mon, Wed, and Fri 9:05 - 9:55 a.m. 245 Olin Hall
Calculation Session: Wed 2:30 - 4:25 p.m. 128 and 245 Olin Hall

Homework: There will be 8 to 10 homework assignments, due Friday at noon. Homework may be submitted before lecture Friday or delivered to the EngrD 2190 mailbox. Late work will not be graded. Solutions will be posted and will be discussed in the calculation section.

Experiential Modules: There will be 4 experiential modules which will meet at times outside of lectures and calculation sessions. Lectures will be cancelled these weeks.

Examinations: There will be three preliminary examinations:

Tuesday, October 7, 7:30 - 9:30 p.m.	128 and 245 Olin Hall
Thursday, October 30, 7:30 - 9:30 p.m.	128 and 245 Olin Hall
Tuesday, November 25, 7:30 - 9:30 p.m.	128 and 245 Olin Hall

No make-up exams are scheduled. A student that misses an exam without an official university excuse or medical excuse will be penalized. A student excused from a preliminary exam will take a make-up exam during the last session of final exams, Saturday, December 20, 9:00-11:30 a.m.

Final Exam: *to be scheduled by the University Registrar* 128 and 245 Olin Hall

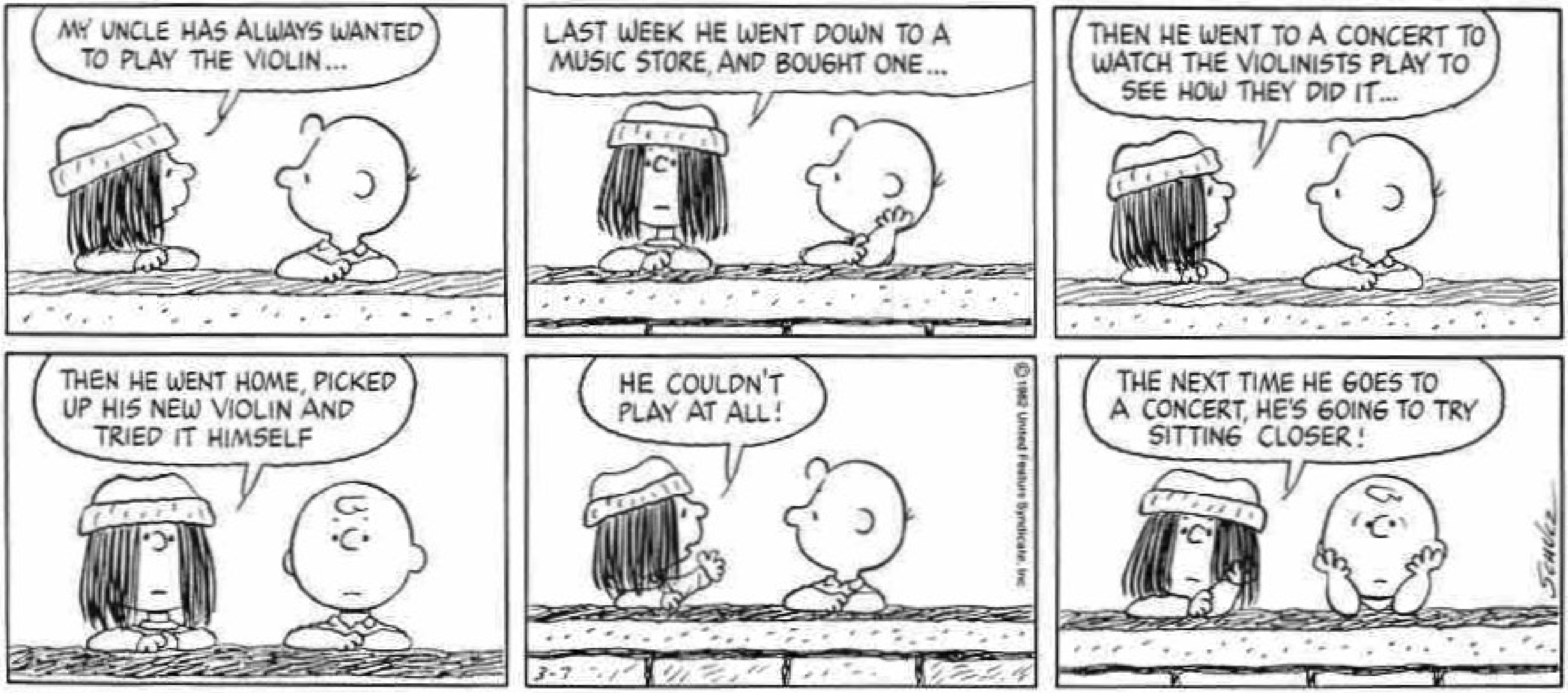
Grading: The final grade will reflect performance on homework, preliminary exams, professional participation, and the final exam, with the following weighting:

Homework	20%
Experiential Modules	10%
Preliminary Examinations	45%
Final Examination	20%
Professional Participation	5%

On Line

Information On Line: course homepage: https://duncan.cbe.cornell.edu/cheme2190/
Textbook errata and blank graphs: https://duncan.cbe.cornell.edu/Graphs/

Learning Skills

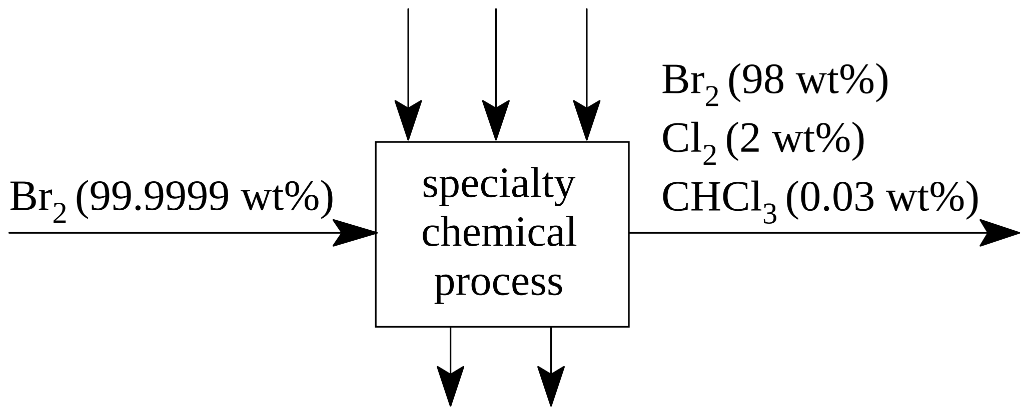


Peanuts by Charles Schulz, March 07, 1982

Learn by *doing*, not by watching.

Lecture 3: Options for Separations and Defining the *Real* Problem

Highly pure bromine is used as a solvent in the manufacture of a specialty chemical.



We wish to recycle the bromine waste stream.

Problem: Separate Br_2 from Cl_2 and $CHCl_3$.

First Guess? Liquid-Gas Separation!

Problem: Separate Br_2 from Cl_2 and $CHCl_3$. Liquid-Gas Separation?

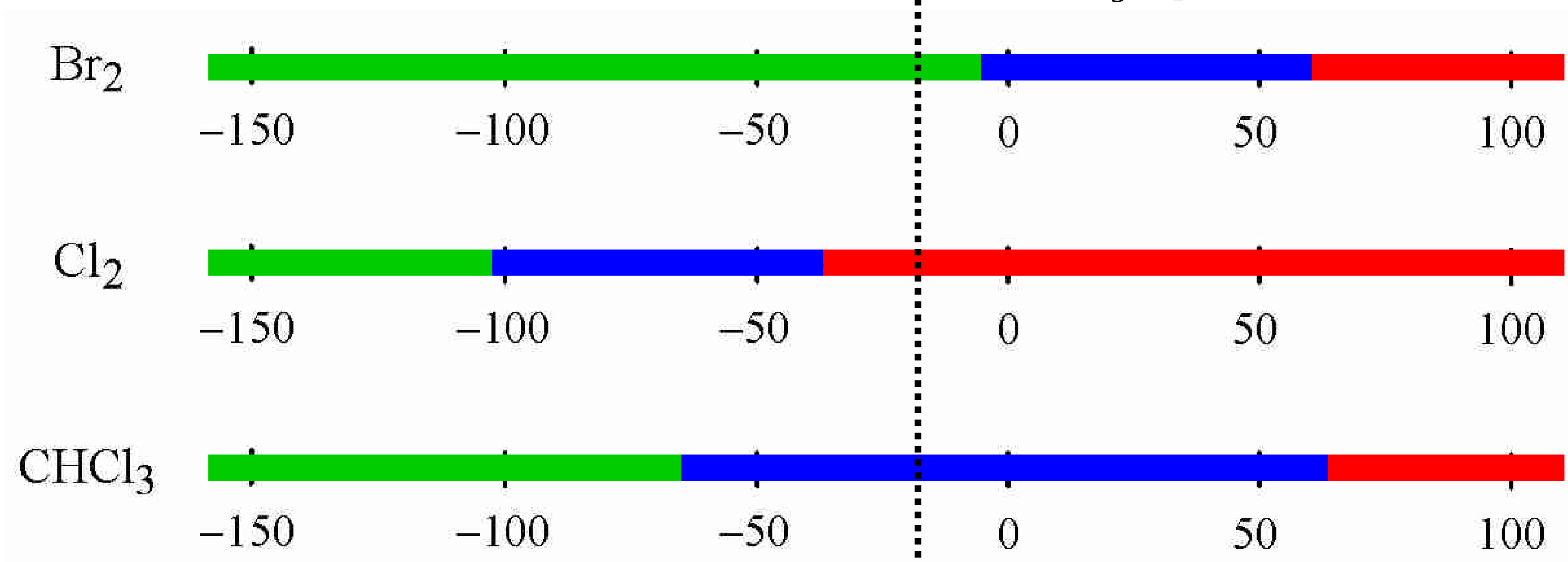
	melting pt (°C)	boiling pt (°C)
Br_2	−7	59
Cl_2	−101	−35
$CHCl_3$	−64	62

Too close for <1 ppm purity.

Solid-Liquid Separation?

−20°C: Br_2 solid
Cl_2 gas
$CHCl_3$ liquid

Solid
Liquid
Gas (red = hot)



Aside: Gas-Liquid Separation vs Liquid-Solid Separation

Gas-Liquid Separation

gas density = 0.001 × liquid density

Bubbles rise quickly.

no gas in liquid phase

no liquid in gas phase

Gas-liquid separation is 'clean.'

Easy to pump gases and liquids.

Liquid-Solid Separation

solid density = 1.2 × liquid density

Solids settle slowly.

no solids in liquid phase (eventually)

liquid in granular solid phase

Liquid-solid separation is not 'clean.'
Must deal with wet solids.

Difficult to 'pump' solids.

conveyor?

auger or extruder?

Stages and Styles of Learning

Stage	Style
Perception	**Sensory** **Intuitive**
Assimilation	Visual Verbal
Organization	Inductive Deductive
Processing	Active Reflective
Understanding	Sequential Global

Perception

Sensory and Intuitive

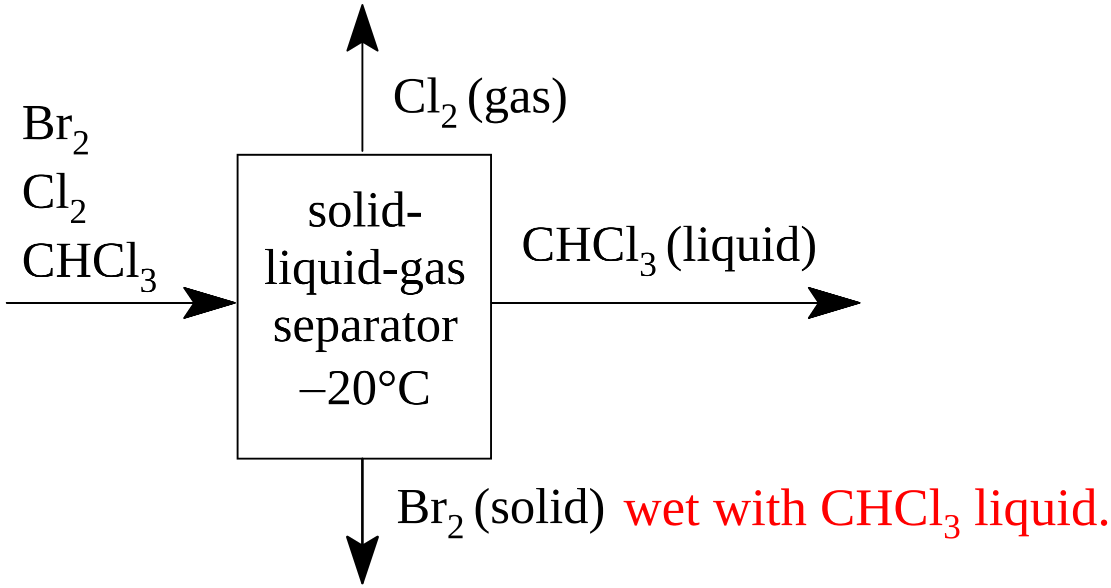
Sensor	Intuitor
Preferentially selects sensory information (what is seen, heard, touched, etc.)	Preferentially selects intuitive information (abstractions, possibilities, hunches)
Looks at what is happening	Looks for meanings and connections
Likes facts and data	Likes theory and models
Is more likely to be practical	Is more likely to be innovative
Likes solving problems by standard methods - dislikes surprises	Likes innovation - dislikes repetition
Experimentalists, physicians, accountants	Theoreticians, psychologists, economists
Is patient with details but doesn't like complications	Is impatient with details but doesn't mind complications
Has trouble with time-bound tests (can't read as fast as intuitors)	Has trouble with any test (starts solving problems before reading the entire problem)

Perception

Sensory and Intuitive

- 70% of the general population are sensors, 30% are intuitors
- Engineering professions comprise both sensors and intuitors. Aerospace engineering attracts more intuitors; civil engineering attracts more sensors. Research engineers are more likely to be intuitors; plant engineers are more likely to be sensors.
- Most professors are intuitors.
- Intuitors are comfortable with concepts and symbols; sensors prefer reality. Words and mathematics are symbolic. Consequently most higher education is geared to intuitive students.

Problem: Separate Br_2 from Cl_2 and $CHCl_3$



Problem: Dry the solid Br_2 wet with liquid $CHCl_3$.

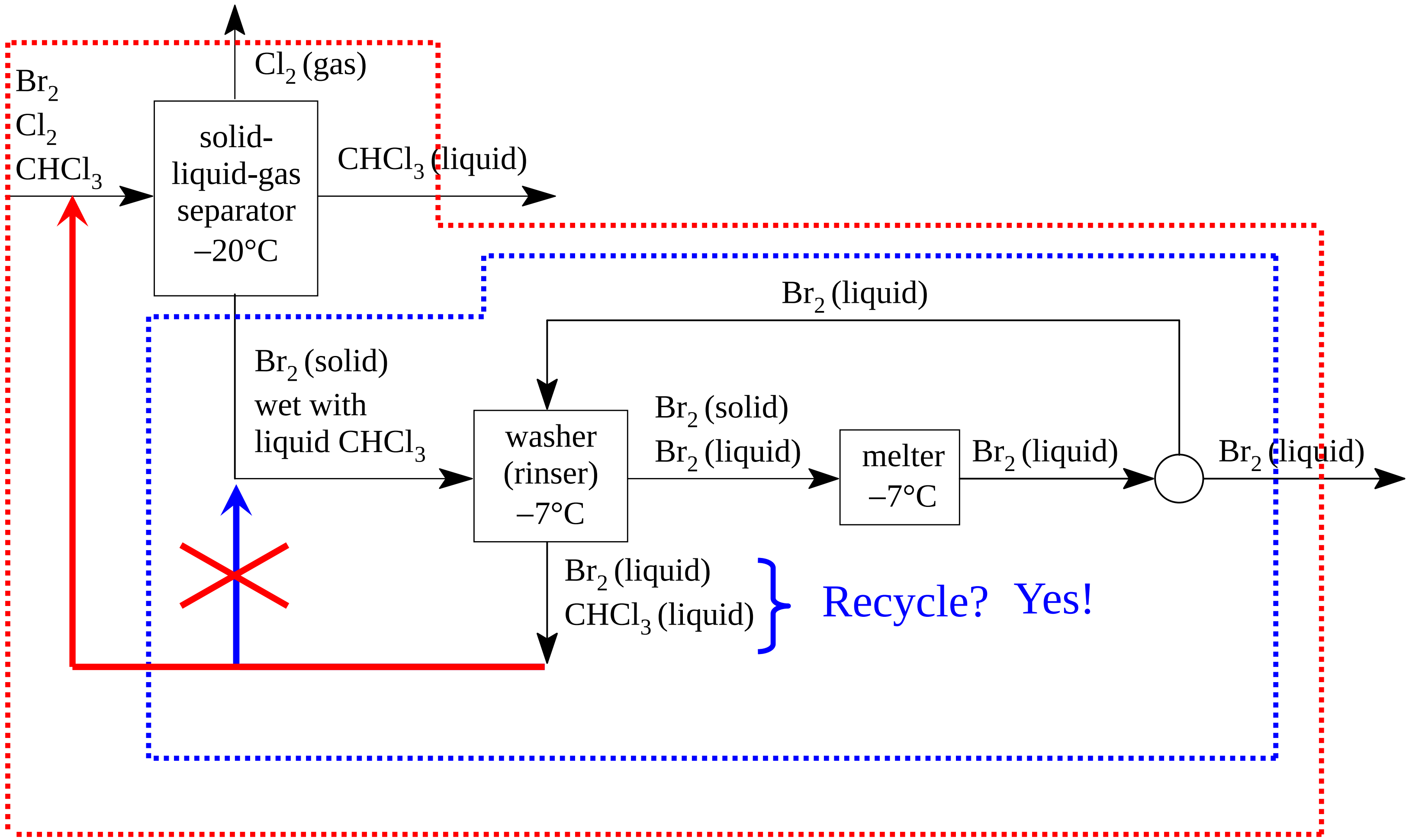
Redefined **Problem:** Replace liquid $CHCl_3$ with an acceptable liquid; wash the solid Br_2.

Criteria for an acceptable washing liquid:

- Must be easy to separate from Br_2. or need not be separated from Br_2.
- Must be a liquid below –7ºC.
- Must not react with Br_2. or the product of the reaction can be reconverted to Br_2.

Wash the solid Br_2 with liquid Br_2.

Process to Separate Br_2 from Cl_2 and $CHCl_3$

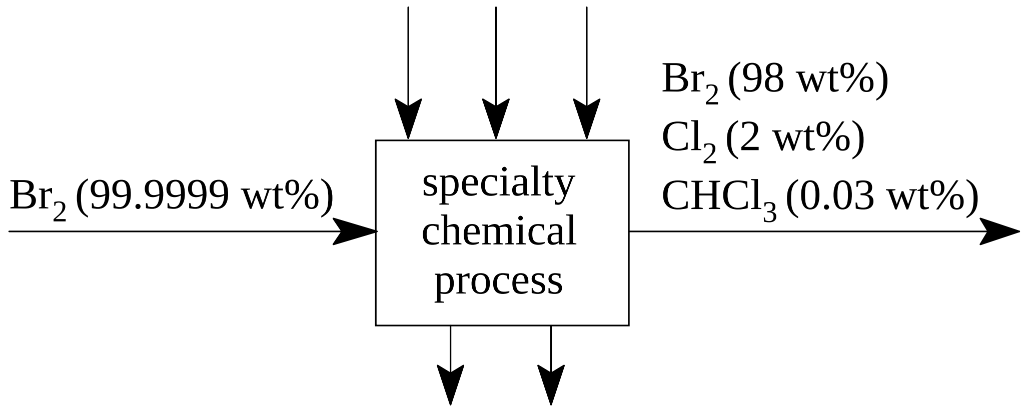


$CHCl_3$ enters the washing process, but $CHCl_3$ never leaves the washing process!

$CHCl_3$ enters the process, and $CHCl_3$ leaves the process!

Return to Original Design Challenge

Highly pure bromine is used as a solvent in the manufacture of a specialty chemical.



We wish to recycle the bromine waste stream.

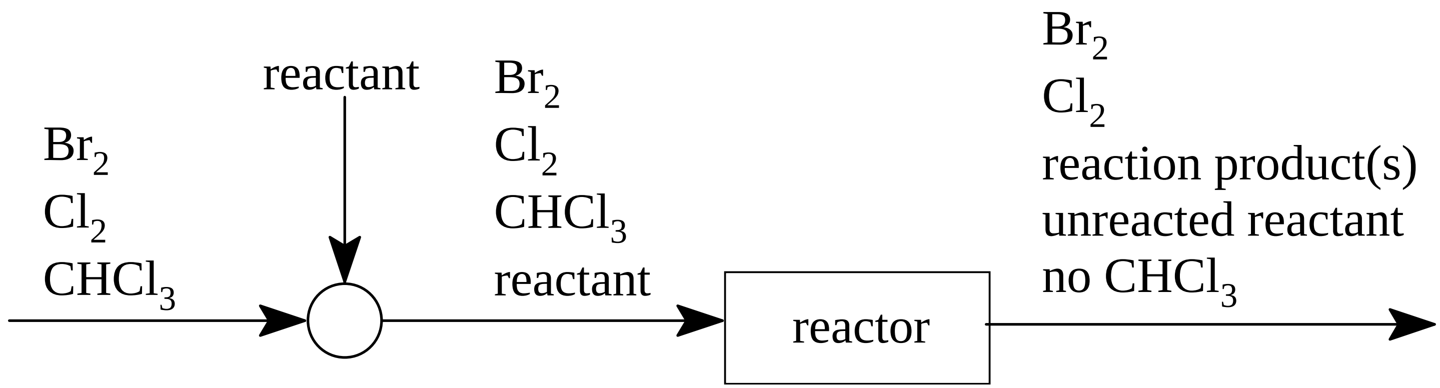
Problem: Separate Br_2 from Cl_2 and $CHCl_3$.

***Redefined* Problem:** Produce Highly Pure Br_2.

Original problem statement implied we must preserve Cl_2 and $CHCl_3$. Cl_2 and $CHCl_3$ are expendable. Convert Cl_2 and $CHCl_3$ to easily separable substances.

Separation by chemical reaction!

Separation by Chemical Reaction



Criteria for an acceptable reactant:

Should not react with Br_2.

Should convert $CHCl_3$ into a substance easily separable from Br_2.

Should completely consume $CHCl_3$.

Should be easily separable from Br_2.

Separation by Chemical Reaction

A good reactant is Br_2. Here is the chemistry.

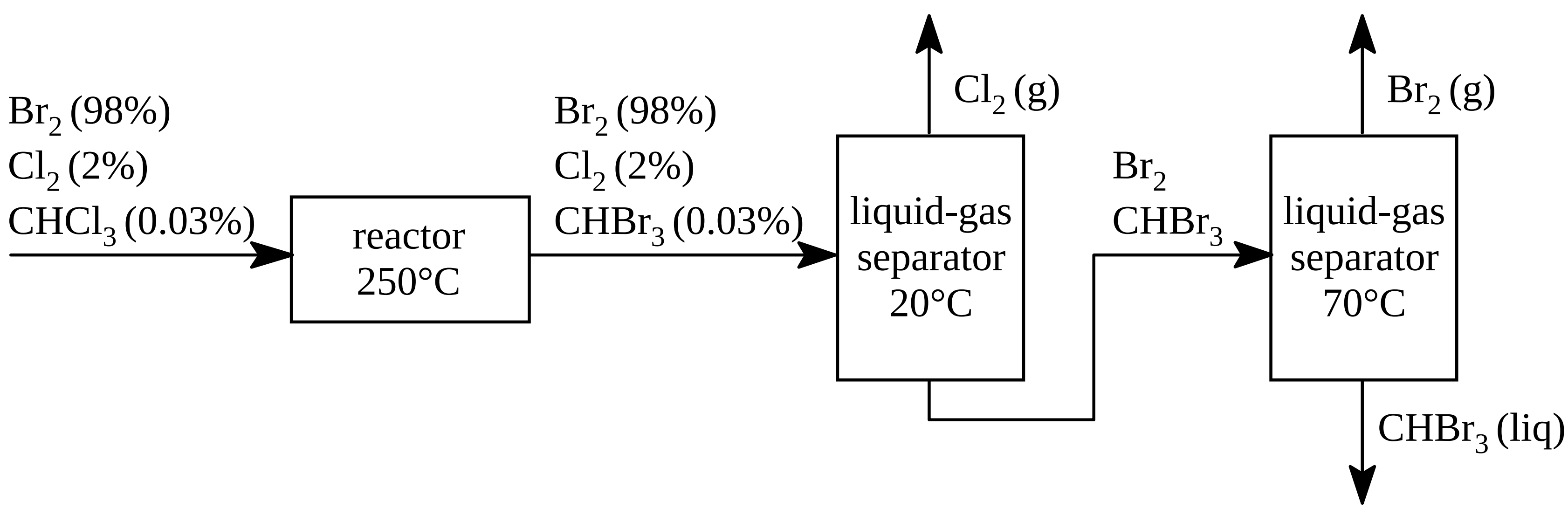
$$CHCl_3 + Br_2 \rightarrow CHCl_2Br + ClBr$$

$$CHCl_2Br + Br_2 \rightarrow CHClBr_2 + ClBr$$

$$CHClBr_2 + Br_2 \rightarrow CHBr_3 + ClBr$$

$$2ClBr \rightarrow Cl_2 + Br_2$$

The boiling point of $CHBr_3$ is 150°C at 1 atm. The reactions take place at 250°C. With a properly designed reactor, the reactions go to completion.



Defining Question: Options for separating substances?

1. Phase: separate liquid and gas
2. Phase: separate solid and liquid.
3. Chemistry: exploit different reactivities.

Problem Redefinition

Following periods of political instability during the 1980s and 1990s, Portugal had the highest drug use rates in the world; one in ten Portuguese citizens were heroin users at the country's lowest point. The rate of HIV infection was the highest in the European Union and drugs were imported in staggering amounts.

Problem: Stop the importation of drugs into Portugal.

Real Problem: Reduce drug use among Portuguese citizens.

In 2001, Portugal decriminalized the possession and consumption of all illicit substances. Rather cracking down on and punishing drug users, Portugal created care facilities to treat users and help them overcome their addictions. Drug use plummeted, as well as HIV infection rates, overdose deaths, and crime overall.

from TA Francis Ledesma, Cornell ChemE Class of '19

PhD UC Berkeley, 2024

Post-Doctoral Scholar, Active-Learning Initiative
Cornell 2024-26

Problem Redefinition

Wildfires are a natural feature of the dry climate typical of the Western United States. Before humans claimed this land, there were frequent low-intensity fires which cleared brush and activated new growth. These fires are an essential part of a healthy ecosystem.

98% of all fires are stopped before they get bigger than 300 acres, to protect small towns. This leads to an unintended consequence; when fires do catch, there is more fuel for the fire in the dense undergrowth and fires that evade containment can be extremely destructive.

Problem: Prevent wildfires through more persistent fire-fighting efforts.

Real Problem: Prevent the destruction caused by large-scale wildfires.

This redefined problem statement encompasses improved fire-fighting and affords more solutions, such as:

1. Allow small-scale fires to burn or even set "prescribed" fires, to reduce fuel for larger fires.
2. Mechanical Thinning: clear out excess undergrowth to remove fuel for the fires.

from TA Olivia Young, Cornell ChemE Class of ‘19

PhD program in Medical Engineering, MIT

Venture Creation Associate at Flagship Pioneering

Problem Redefinition

The Federal Emergency Management Agency (FEMA) executes an emergency response after a hurricane strikes. FEMA evaluates a hurricane's impact on a community to ensure people receive essential resources like food and water. FEMA classifies the infra-structure in communities in three categories: operating, affected, and destroyed. It is imperative that FEMA assesses the damage to infrastructure as quickly as possible, so people in the most deeply affected areas receive the earliest and most robust forms of aid.

Problem: Send teams to canvas door-to-door in an affected area to assess the damage.

Real Problem: Determine the impact a hurricane has on a community.

The redefined problem allows using drones to quickly assess the damage. FEMA found a solution called the Waffle House Index. The agency uses the operating status of Waffle Houses, a popular 24/7 diner chain in coastal areas, as a measure of infrastructure and supply chains shortly after a hurricane. After a hurricane, Waffle Houses are rated as operating fully, limited operations, and closed. FEMA uses the operations data provided by Waffle House to aid in assessing damage. For example, a Waffle House with limited operations may have a limited menu, telling FEMA that the infrastructure surrounding the community is affected enough to limit the transport of food, but stable enough to allow people to drive to the Waffle House.

from TA Ameer Basrai, Cornell ChemE Class of '18
Editor, CU Nooz
Senior Engineer, Roivant Sciences