EngrD 2190 – Lecture 2

Concept: Designing a Chemical Process –
Unit Operations and Process Flowsheets

Context: Hydrazine Synthesis (exercise 2.27 – solution is posted)

Defining Questions:

Why does every recycle loop need a purge?

What is the preferred method for separating substances?

Key Point: You are not expected to provide the chemical reactions.
Chemical reactions will always be given.

Read Chapter 2, pp. 19-25.

Due Today after Calculation Session

EngrD 2190 - Chemical Process Design & Analysis - Fall 2025
Cooperative Learning

Name _____ Cornell NetID _____

Homework is assigned Friday and due the following Friday at noon. Shade the cells for ***all*** times you ***can*** meet each week. ***Circle the day*** you prefer for your first team meeting each week.

	Fri	Sat	Sun	Mon	Tues	Wed	Thurs	Fri
morning: 10 am. - noon								
afternoon: 1 - 4 p.m.								HW due
late afternoon: 4 - 7 p.m.								
evening: 7-10 p.m.								

How would you prefer to work the homework?

Complete the exercises individually and then compare *final* answers as a team.

Start together as a team, separate to work the exercises individually, and then reconvene to compare answers.

Work together as a team from start to finish.

I have no preference.

How many times would you like to meet with your homework team each week?

One long session (perhaps two hours).

Two or three shorter sessions.

I have no preference.

Where would you like to meet with your homework team each week?

North Campus West Campus

Engineering Quad Collegetown

Other: (please specify)

During team meetings, informal conversation not germane to completing the team's task is …

essential for building camaraderie.

tolerable - enjoyable but unproductive.

frustrating and unproductive.

Can you attend TA Office Hours Sunday 7:30-9:30 p.m.? Yes No

Can you attend TA Office Hours Wednesday 7:30-9:30 p.m.? Yes No

What level of emphasis do you plan for EngrD 2190, relative to your other courses?

1 2 3 4 5
low high

Do you have a preference for your teammate(s)? If so list the names of your preference(s).

Potential teammates must submit your name.

Are you participating in team athletics or other extracurricular activities (band, ROTC, etc)? If so, list the sport or activity and list the times you **cannot** meet with a homework team.

Which issues should the TAs emphasize when they select your teammates? Circle the important issue(s). Cross out insignificant issue(s).

Collaborative Learning – Homework Teams

Tackling challenges in the ChemE curriculum on your own can be difficult but facing them together with your teammates makes the process much more rewarding and enjoyable. It is so inspiring to see how collaborative discussions can spark different ideas, leading to deeper understanding and more effective solutions. You are not alone! *TA Angel Liang (’26)*

Due to its problem-solving nature, EngrD 2190 encompasses a new way of thinking about processes, thinking that heavily benefits from team collaboration. There is very rarely only one ‘right’ answer and arriving at the optimal solution requires iteration through many designs. Working closely with peers to propose designs not only leads to more creative solutions but also helps you build a close-knit community within ChemE, which will prove very valuable throughout the curriculum! *TA Lara Capellino (’26)*

I think collaborating with people with a wide variety of interests in ChemE can be helpful for developing a broader view of the different fields and career pathways in the major. Try to work with people that have different experiences and interests from your own throughout the course! *TA Sean McInnis (‘26)*

I entered 2190 as someone who never worked with others on homework because I could always manage on my own. If you feel this way, this class will likely be a turning point in your academic career where you must evolve to relying on others for most classes. You may find this advice trite, telling yourself, like I did: “Of course I can work in a team. I know how to collaborate with others.” But do you really? Or will you resist working with others until you are truly stuck? EngrD 2190 is an opportunity to set aside ego and lean on each other. If you’re already comfortable with this idea, take the initiative to reach out and draw others in. If you’re not, treat developing your teamwork skills as part of the coursework itself. *TA Johnny Lowry (‘26)*


Start of Fall '25
CHEME
BBQ
Party
27 August
2025
5pm-7pm
Olin Hall Front Lawn
Games and food with your ChemE classmates!

Today!

ChemE Welcome-Back Barbecue!

Today (Wednesday) 5-7 p.m. on Olin Hall's West Lawn.

All ChemE-Affiliated and ChemE-Prospective Undergraduates

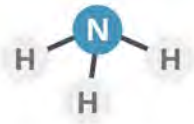
and key ChemE Faculty Members and Staff.

Sponsored by Cornell's Student Chapter
of the American Institute of Chemical Engineers (AIChE)

ENVIRONMENTAL IMPACT OF INDUSTRIAL REACTIONS

The chemical industry accounts for about 10% of the world's energy demand and 7% of its greenhouse emissions. Here we take a look at the top 5 chemical products responsible.

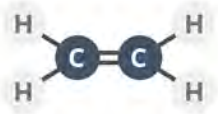
1 AMMONIA



Synthesis
Haber-Bosch process

Major uses
Fertilizers, medicines, and cleaning products

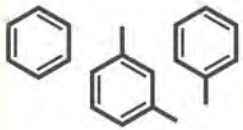
2 ETHYLENE



Synthesis
Cracking of long-chain hydrocarbons

Major uses
Making polyethylene

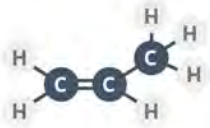
3 AROMATICS



Synthesis
Catalytic reforming of naphtha

Major uses
Solvents and reagents in chemical reactions

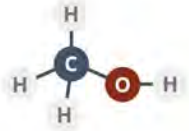
4 PROPYLENE



Synthesis
Cracking of long-chain hydrocarbons

Major uses
Making polypropylene

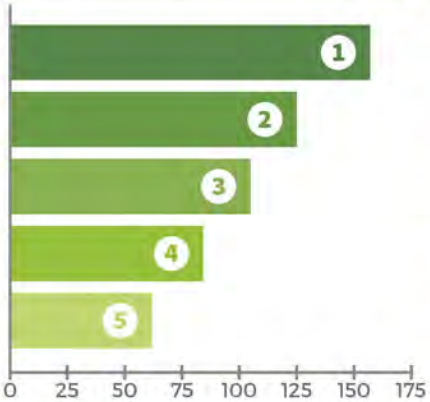
5 METHANOL



Synthesis
Reactions with CO, CO_2, and H_2

Major uses
Making other chemicals

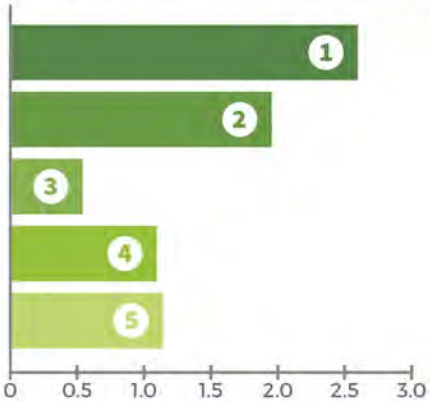
PRODUCTION VOLUMES



MEGA-METRIC TONS/YEAR

1 Mt: Equivalent to the mass of nearly 5,000 Statues of Liberty

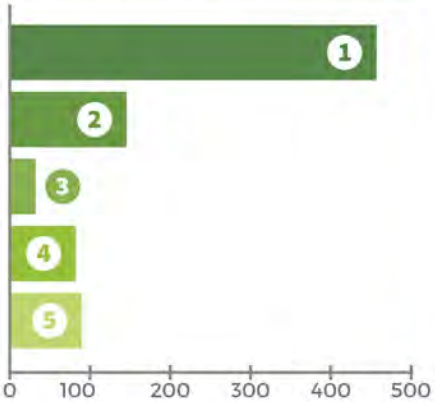
ENERGY CONSUMPTION



EXAJOULES/YEAR

1 EJ: Equivalent to the energy from about 174 million oil barrels

GREENHOUSE GAS EMISSIONS



Mt OF CO_2 EQUIVALENT/YEAR

1 Mt CO_2 eq: Equivalent to 25% of the CO_2 emitted from a coal power plant per year

Source: DECHEMA, 2010. For ethylene and propylene, figures are representative of the steam cracking process.

PERIODIC GRAPHICS

“Chemical engineers design processes based on chemical change.”

represented by process flowsheets

Every chemical process comprises discrete steps, called *units*.
Units are connected by *steams*.

} Principle of *Unit Operations*.

Unit Operations was the original paradigm of chemical engineering (ca. 1910).

Exercise 2.27: Synthesis of Hydrazine

Hydrazine, N_2H_4, is an important chemical precursor to agricultural chemicals such as algicides, fungicides, insecticides, the gas precursors in automotive air bags, and pharmaceuticals such as Isoniazid, a drug to treat tuberculosis. Hydrazine is also used as a rocket fuel to maintain satellite orbits; the decomposition of one liquid molecule to three gas molecules provides propulsion.

$$N_2H_4 \rightarrow N_2 + 2H_2$$

Hydrazine is traditionally synthesized industrially by the Bayer process, which uses chloramine, NH_2Cl, which is synthesized from ammonia and chlorine. The Green Chemistry movement strives to replace hazardous oxidizers, such as chlorine, with innocuous oxidizers such as hydrogen peroxide. For hydrazine synthesis by green chemistry, the overall reaction is as follows.

$$2NH_3 + H_2O_2 \rightarrow N_2H_4 + 2H_2O$$

In this modified process, only two synthesis steps are required. The first step is conversion of acetone, $CH_3C(O)CH_3$, to the acetazine, $(CH_3)_2C{=}N{-}N{=}C(CH_3)_2$, in aqueous solution at 50°C.

$$H_2O_2 + 2CH_3C(O)CH_3 + 2NH_3 \rightarrow (CH_3)_2C{=}N{-}N{=}C(CH_3)_2 + 4H_2O$$

The second step is the hydrolysis of acetazine into hydrazine and acetone in aqueous solution at 50°C.

hydrolysis: $(CH_3)_2C{=}N{-}N{=}C(CH_3)_2 + 2H_2O \rightarrow N_2H_4 + 2CH_3C(O)CH_3$

The hydrazine is distilled from the aqueous solution as a hydrate, $N_2H_4 \cdot H_2O$.

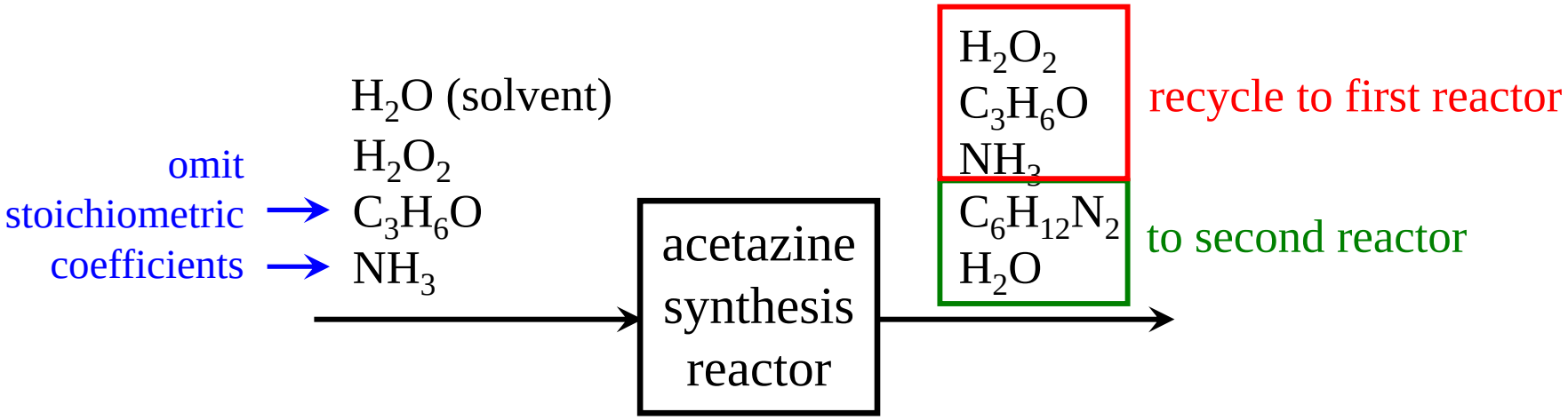
Design a process to produce hydrazine hydrate from ammonia and hydrogen peroxide. The hydrogen peroxide is available as a mixture of 70% hydrogen peroxide in 30% water.

How to start the design of a process flowsheet?

Don't fixate on where to start. Choose a part of the chemical process and begin.

I like to start with a key reaction.

$$H_2O_2 + 2C_3H_6O + 2NH_3 \rightarrow C_6H_{12}N_2 + 4H_2O$$



5 substances in reactor effluent. Separate into 5 streams?

Separate into 2 streams?

How to separate? Basis for separation? Gas-liquid separator (*preferred method*)

What temperatures in the gas-liquid separators?

Need boiling points.

Physical Properties at 1 atm

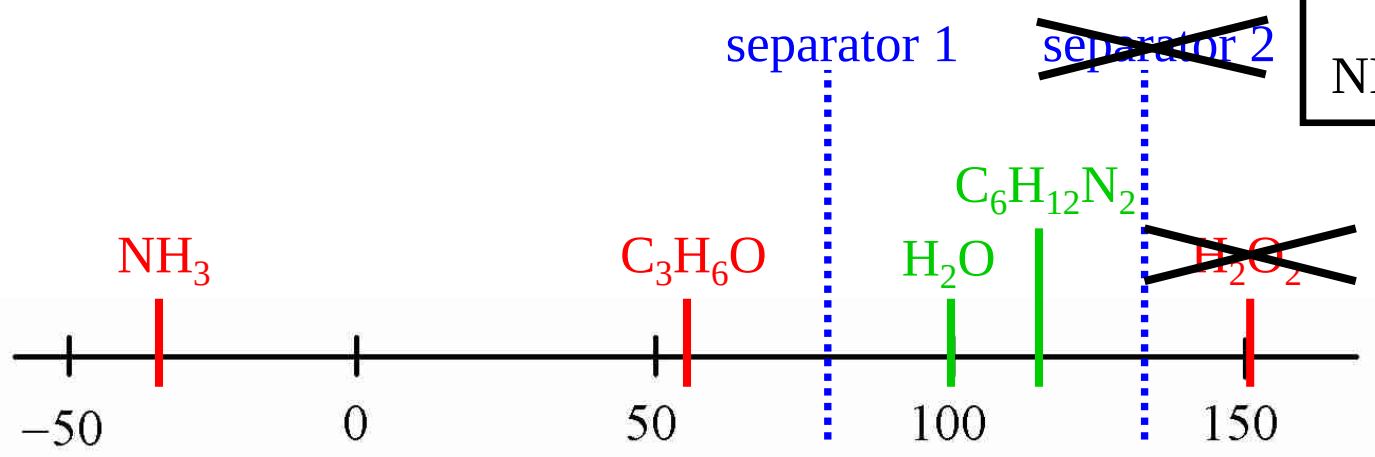
	melting pt (°C)	boiling pt (°C)
H_2O	0	100
H_2O_2	–0.4	151
NH_3	–78	–33
N_2H_4	1	114
$N_2H_4 \cdot H_2O$	–40	119
acetone, C_3H_6O	–95	56
acetazine, $C_6H_{12}N_2$	–13	113

to 2nd reactor recycle to 1st reactor

How many separators?

Separator temperatures?

use excess NH_3 and C_3H_6O



- You may assume that if acetone and ammonia are in excess in the acetazine synthesis, the H_2O_2 is completely consumed.

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	melting pt (°C)	boiling pt (°C)
H_2O	0	100
H_2O_2	–0.4	151
NH_3	–78	–33
N_2H_4	1	114
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acetone, C_3H_6O	–95	56
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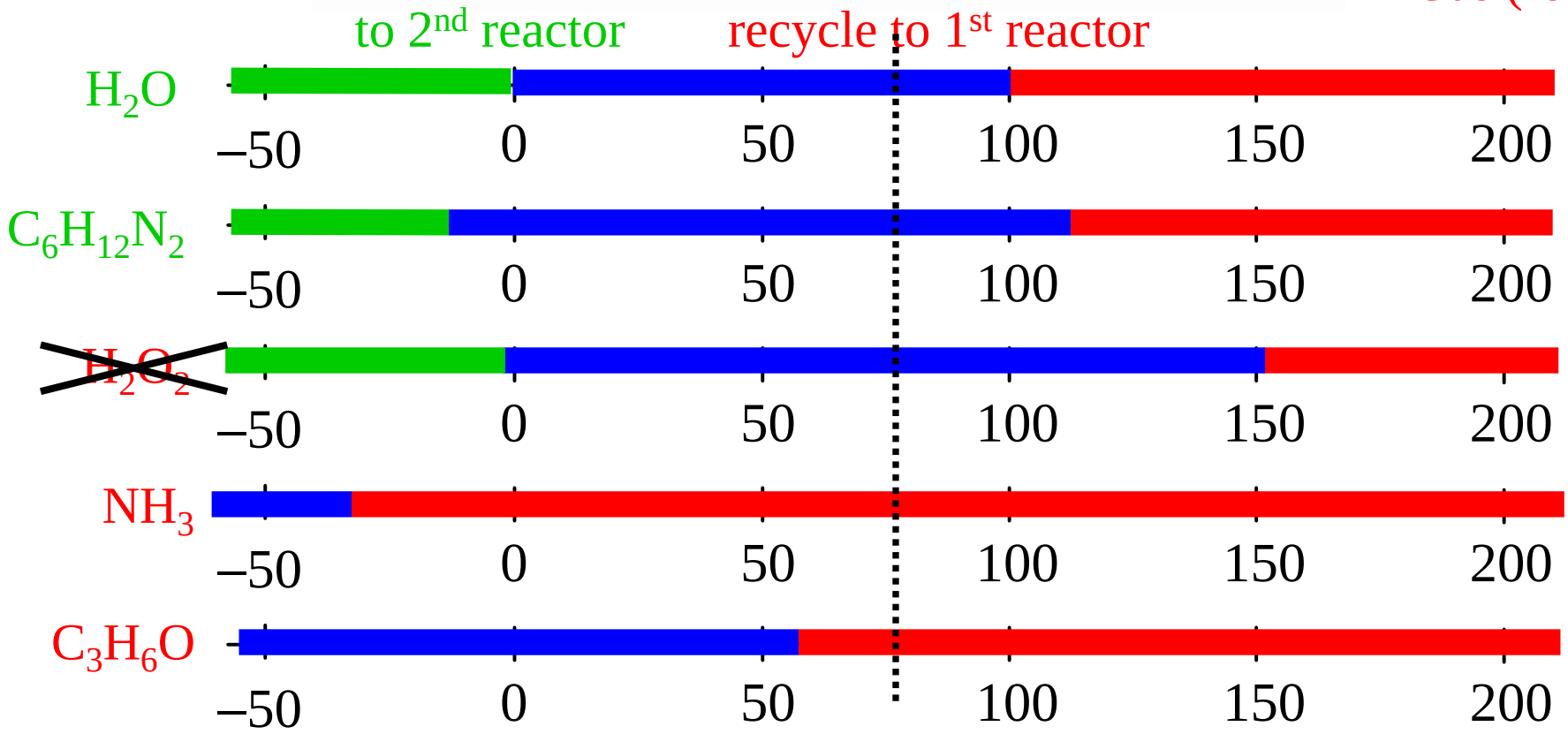
Instead of a boiling point number line, use phase lines.

Solid
Liquid
Gas (red = hot)



Stages and Styles of Learning

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

Assimiliation

Visual and Verbal

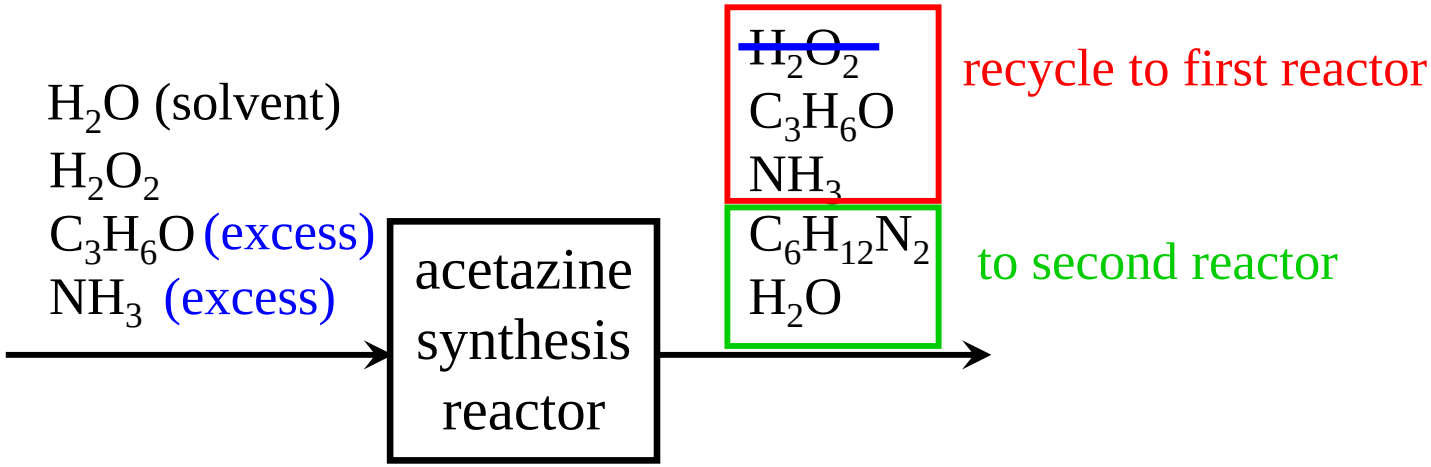
Visual Assimilator	Verbal Assimilator
Prefers pictures, diagrams and symbols.	Prefers written and spoken words.
Gathers more from what is seen.	Gathers more from what is heard and read.
Might say: "I don't see what you are saying." "Show me what you mean." "Oh, I get the picture."	Might say: "This paragraph doesn't sound right." "Explain this to me."

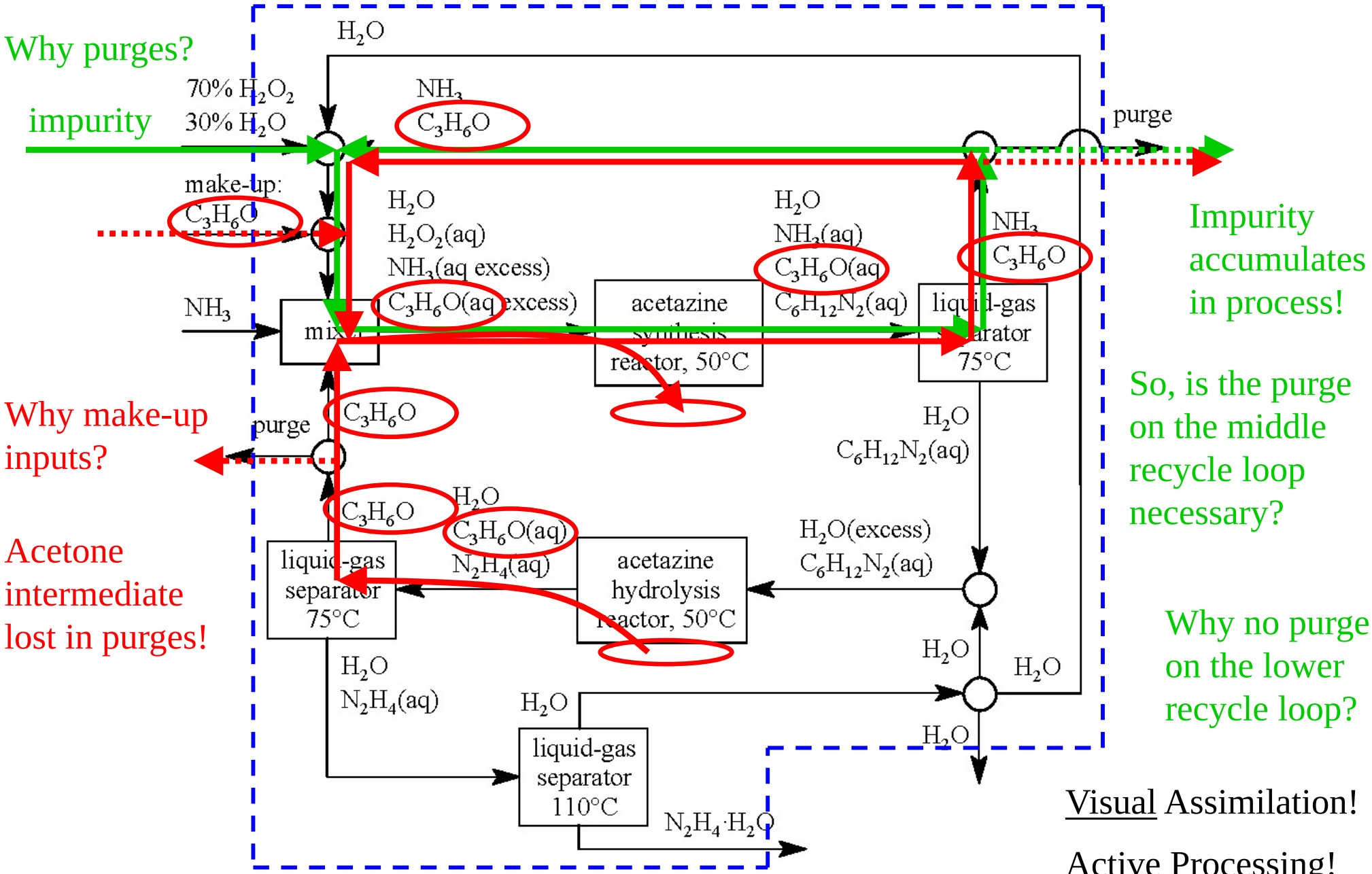
Assimiliation

Visual and Verbal

- Visual and verbal processing occur in different parts of the brain.
- If the information is not presented in your preferred mode, you are less likely to assimilate the information.
- Lectures and textbooks emphasize words and equations, which is verbal information.
- Most people in our culture prefer visual information.

Return to the process flowsheet …





Overall process must agree* with overall reaction:

$$2NH_3 + H_2O_2 \rightarrow N_2H_4 + 2H_2O$$

*Neglect minor streams: purges and make-up inputs

Defining Question

Why does every recycle loop need a purge?

"*It's always something. If it's not one thing it's another.*"

Gilda Radner, SNL 1978-1980

Stages and Styles of Learning

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Perception	Sensory Intuitive
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Processing	**Active** **Reflective**
Understanding	Sequential Global

Processing

Active and Reflective

Active Experimentation	Reflective Observation
Prefers to process information actively, such as explaining, drawing, or testing.	Prefers to process information introspectively.
Thinks out loud.	Thinks to oneself.
Might say: "Let's try it out and see what happens."	Might say: "Let's think about this."
May jump into a task prematurely.	May never get started.
Works well in groups.	Works better alone or in pairs.

Processing

Active and Reflective

- Most lectures are incompatible with both types; actives don't have opportunity to act, reflectives don't have opportunity to reflect.

How to design a chemical process?

Start at a key process unit - usually a reactor.

Grow incrementally
by successive problem solving.

Define the *real* problem.