Not Your Average Flipped Classroom: An Online, Multi-Media "Textbook" for Introduction to Chemical Engineering

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AIChE

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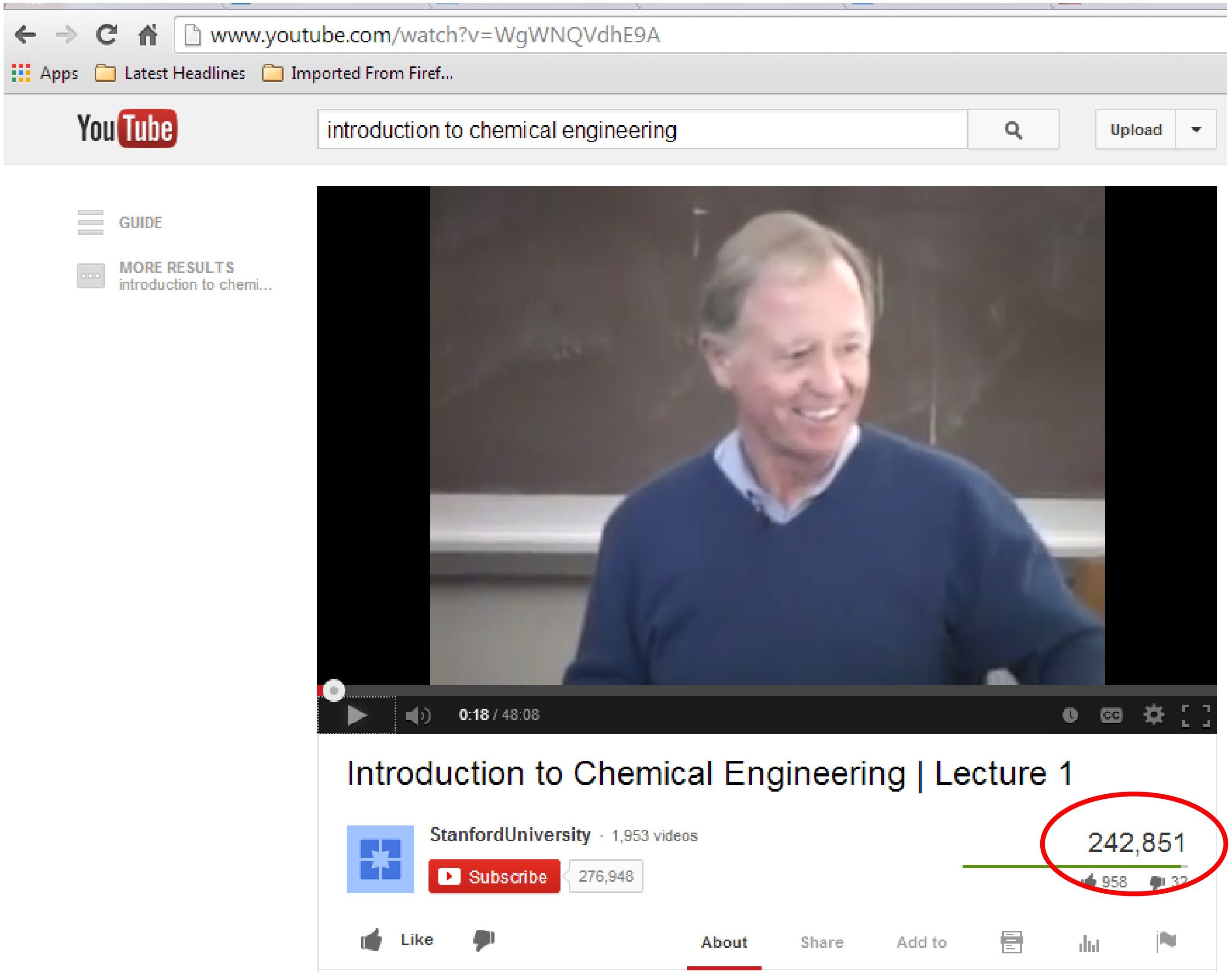
Outline

- Motivation behind creating online textbook
- Process of developing online textbook
- Overview of design and content
- Flipped classroom format: in-class activities
- Lessons learned
- Future plans

Motivation

- Concerns about existing textbooks
  - None matched content of our class
  - Want textbook to reflect excitement and challenges of modern chemical engineering
  - Rising costs
- Additional benefits of an online textbook
  - Easily adapted:
    - Stay current
    - Incorporate examples/content from other faculty members who teach the class in the future
  - Incorporate various types of media (ex: videos, applets, etc.) to enhance learning
  - Free to general public (and easily portable for other instructors beyond Stanford wanting to use any portion of the material)

Motivation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Process of Developing Online Textbook

- Identified target areas for learning enhancement
  - For each lecture: identified most difficult concepts and possible methods to address each challenge
    - Solved example problem
    - Video demonstration of physical phenomenon
    - Detailed derivation of equations
    - Further explanation of concept and/or illustrative examples
- Developed working list of planned additions with specific content and responsibilities

Process of Developing Online Textbook

- Identified target areas for learning enhancement

Module	Topics	Problem Areas	Possible Type of Video	Suggestions	Other Notes
12	Human body as stirred-tank	Use of non-steady state terms in balance eqn	Practice Problem	Explain derivation of non SS terms and explain that at SS derivative wrt time goes to zero	
13	Drug PK when stirred tank fails	Volume of distribution	Lecture/Mathematical explanation		Practice Problem 2 might need to be moved later because clearance rate has not been introduced yet
14	Drug PK of an oral drug	Oral bioavailability	Lecture/Mathematical explanation (including how to estimate and its definition on a plot)		
15	Energy and Energy Balances	Using the general balance eqn and plugging in for different types of energy	Practice Problem	Note definiton of KE,PE, Delta U, and Delta H, heat transfer coefficient, sensible vs. latent enthalpy changes	
16	Energy in Solar Thermal Plants	Enthalpy Tables and Calculating enthalpy changes for different state changes, choosing a reference state	Practice Problem	Practice problem 5, or problem 1 from Discussion section 7 last year	Practice Problem 4 control volume boundaries need to be inside arrow (so streams are exiting the control volume)
17	Energy Balances in CO2 Sequestration	Calculation of Delta H of reaction (using extent of reaction and standard enthalpy, and using heats of formation) and incorporation in balance equation	Practice Problem		The serpentine rock problem presents the use of the heat transfer coefficient and using heats of reaction, emphasizing these concepts would be helpful.
					Figures in this module could be improved

Process of Developing Online Textbook

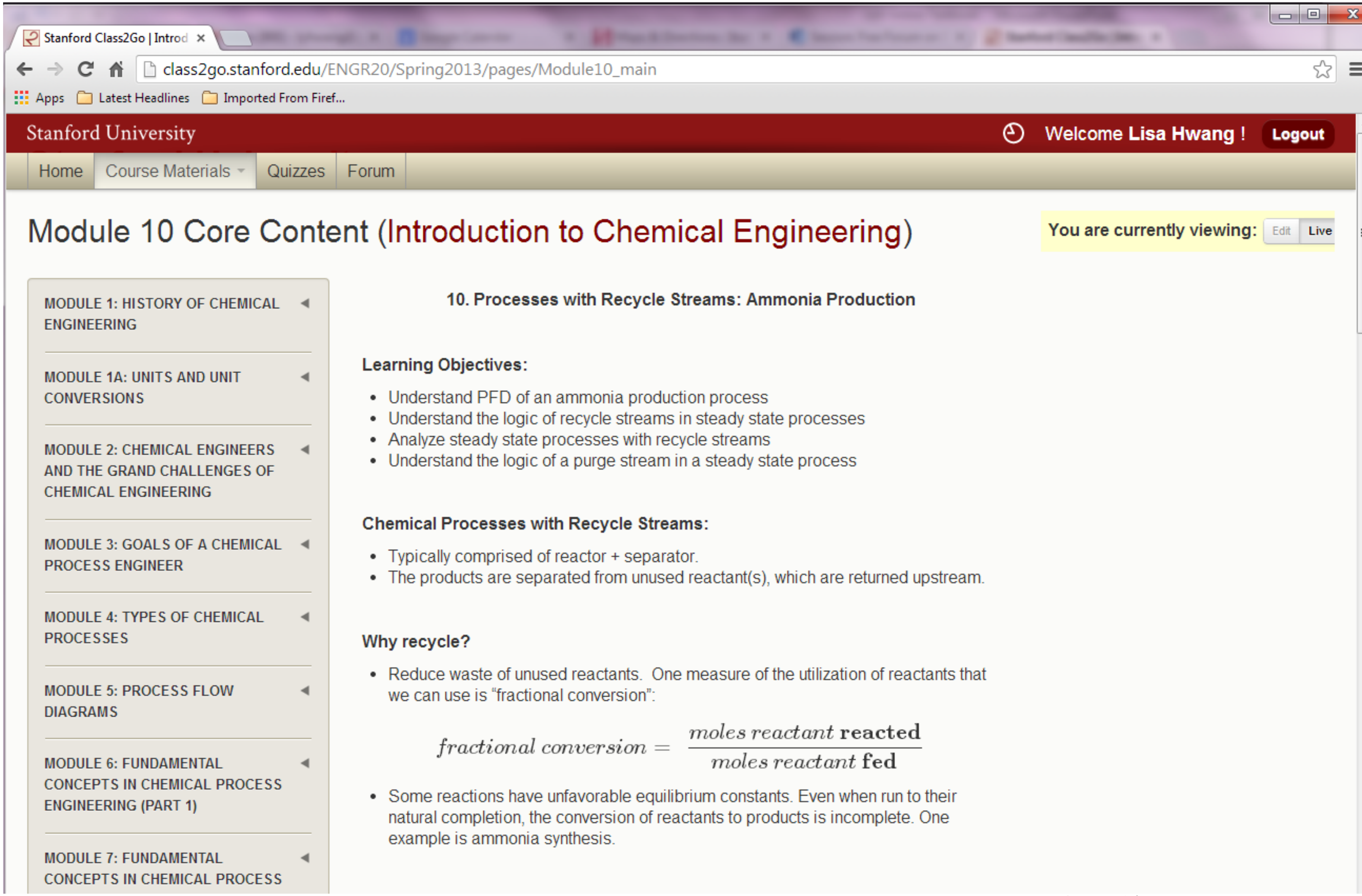
- Developed working list of planned additions

Module	Video	Video type	Who	Module update	who	Notes
3	Volumetric productivity (time and volume): antibiotic exan	video or screencast	Briana	none		
4	**extended methylene blue demo**	video	Briana or Chaitan			*** Chaita
	qualitative example illustrating residence time (ex: people i	screencast	Briana	residence time (general idea)	Lisa	
	semi-batch example in module	screencast	briana			
	semi-cont example in module	screencast	briana			
5	illustrating dev and major guidelines (connecting arrows t	screencast	lisa	(DONE)	Lisa	
					Lisa	
6	CV example	screencast	lisa	(DONE)		
7	raoult's law		briana/or find one (	include at beginning: list of all	Lisa	
	le chatelier's principle		briana/or find one (	lisa (go through, think throug	Lisa	
	ex: beaker and colored water: steady-state (after some	video	briana			
	Exciting examples of "beating equilibrium"	video/screencast	Chaitan or intervie	(could use for ChE promo videos)		
8	**stirred tank: red stream + yellow stream into beaker, or**	video (2)	briana	include at beginning: list of all the major concepts tc		
	flux	video demo or look onlin	chaitan			
	flux	video or screencast	lisa	check module throughout	Lisa	
9	molecular balance (setting up balance using reaction info)	screencast *	briana	modify throughout	briana	*** Lisa w
	atom balance (setting up and solving)	screencast *	briana			
	practice problem 1 (setting up and solving but using diff p	screencast *	briana			
10	calcs for w/o recycle	screencast	briana	see notes in module word do	Lisa	*** could
	choosing CV	screencast	briana		Lisa	Lisa for ab
	calcs with recycle	screencast (could be com	briana		Lisa	
11	**demo showing phase equilibrium where easy to visualiz**	video (could find other vi	briana or online sea	module edits as noted in wor	briana	
	single stage equilibrium separation PFD (general conventic	screencast	briana			
	single stage with detailed calcs of problem in module	screencast	briana			
	why add 2nd stage	? (screencast or extendec	briana			
	2 stage detailed calcs	? (screencast or extendec	briana			
	extend idea to dist column	screencast				
12				add more steps to the math in module (either linked		

Design & Content of Online Textbook

- Organization & Use of Modules
  - Each module corresponds to ~ 1 lecture.
  - Students required to review each module prior to respective class meeting.
  - Components of each module:
    - *Core content*: what we expect students to review prior to each class meeting
    - *Practice Problems* (with solutions)
    - *Checkpoint Quizzes*: 3-4 basic concept questions answered online before class time

Design & Content: Module Overview



Design & Content: Module Overview

Stanford Class2Go | Introd

class2go.stanford.edu/ENGR20/Spring2013/pages/Module10_main

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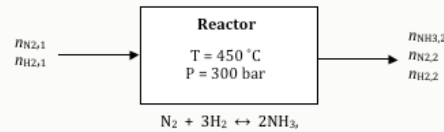
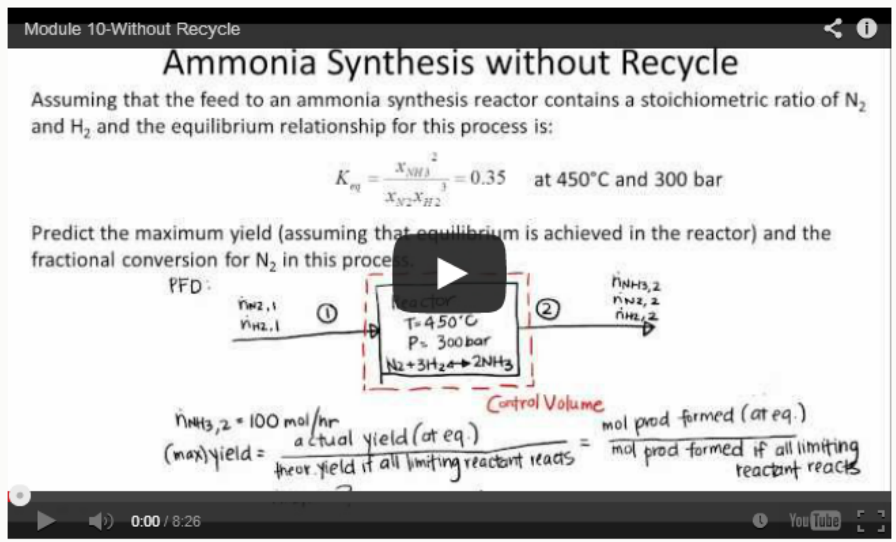
Consider: Ammonia synthesis (without recycle)



Let's assume that we have a stoichiometric feed of N_2 and H_2. We can determine that the maximum yield (assuming equilibrium is achieved in the reactor) is 0.25 and the fractional conversion of N_2 for this process is also 0.25. To see these calculations, you can either watch the video below, or you can click here to see the text.

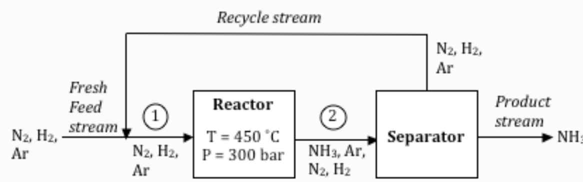


This tells us that 75% of the N_2 that is fed into the reactor is going unused (i.e. wasted)! As discussed in Module 7, *a major goal of chemical process engineers is to "beat equilibrium". We can do this by recycling the unused reactants back into the reactor to achieve higher overall conversion of N_2 and H_2.*

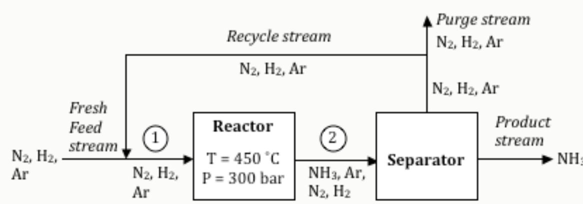
Design & Content: Module Overview

00:00 / 10:27

Purge Stream: In real ammonia processes, argon is often included as an inert gas in the feed stream because it is too expensive to separate argon from nitrogen, although it is fairly easy to separate argon from ammonia to obtain our pure product.

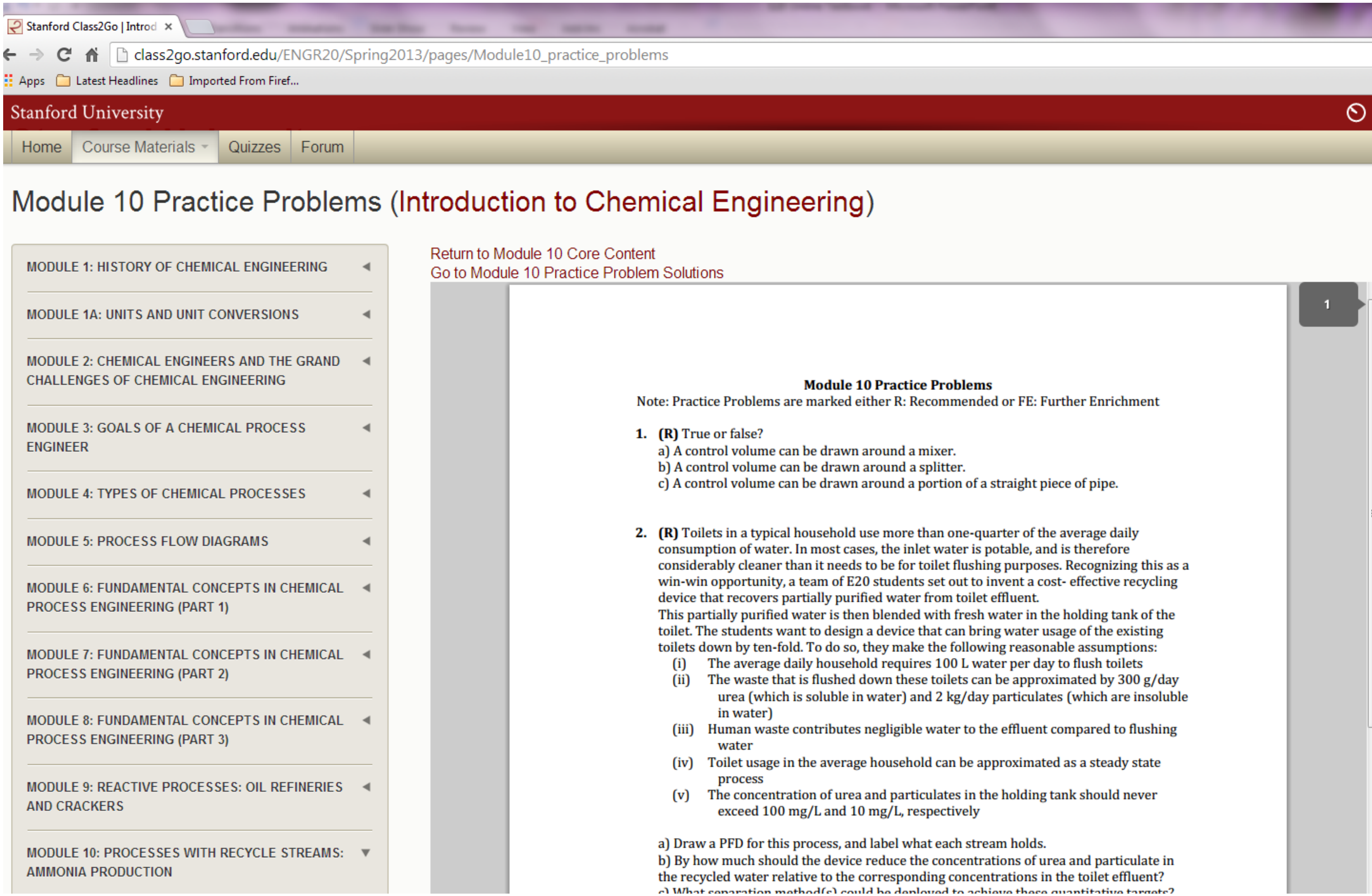


The problem with the above PFD can be seen when considering a balance on argon for the overall process: the process as drawn above *cannot operate at steady state!* The argon in the overall process will accumulate! Therefore, ***a fraction of the recycle stream needs to be purged while the remainder is recycled back to the reactor***. Note that we will have to waste some small amount of unused reactants in this purge stream.



Module 10 Practice Problems
Module 10 Practice Problem Solutions

Design & Content: Practice Problems



Stanford Class2Go | Introd ×

class2go.stanford.edu/ENGR20/Spring2013/pages/Module10_practice_problems

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Module 10 Practice Problems (Introduction to Chemical Engineering)

Return to Module 10 Core Content

Go to Module 10 Practice Problem Solutions

1

Module 10 Practice Problems

Note: Practice Problems are marked either R: Recommended or FE: Further Enrichment

1. **(R)** True or false?
   a) A control volume can be drawn around a mixer.
   b) A control volume can be drawn around a splitter.
   c) A control volume can be drawn around a portion of a straight piece of pipe.

2. **(R)** Toilets in a typical household use more than one-quarter of the average daily consumption of water. In most cases, the inlet water is potable, and is therefore considerably cleaner than it needs to be for toilet flushing purposes. Recognizing this as a win-win opportunity, a team of E20 students set out to invent a cost- effective recycling device that recovers partially purified water from toilet effluent.
   This partially purified water is then blended with fresh water in the holding tank of the toilet. The students want to design a device that can bring water usage of the existing toilets down by ten-fold. To do so, they make the following reasonable assumptions:
   (i) The average daily household requires 100 L water per day to flush toilets
   (ii) The waste that is flushed down these toilets can be approximated by 300 g/day urea (which is soluble in water) and 2 kg/day particulates (which are insoluble in water)
   (iii) Human waste contributes negligible water to the effluent compared to flushing water
   (iv) Toilet usage in the average household can be approximated as a steady state process
   (v) The concentration of urea and particulates in the holding tank should never exceed 100 mg/L and 10 mg/L, respectively

   a) Draw a PFD for this process, and label what each stream holds.
   b) By how much should the device reduce the concentrations of urea and particulate in the recycled water relative to the corresponding concentrations in the toilet effluent?
   c) What separation method(s) could be deployed to achieve these quantitative targets?

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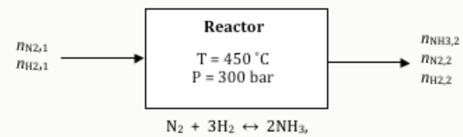
Design & Content: Multiple Delivery Options

Consider: Ammonia synthesis (without recycle)



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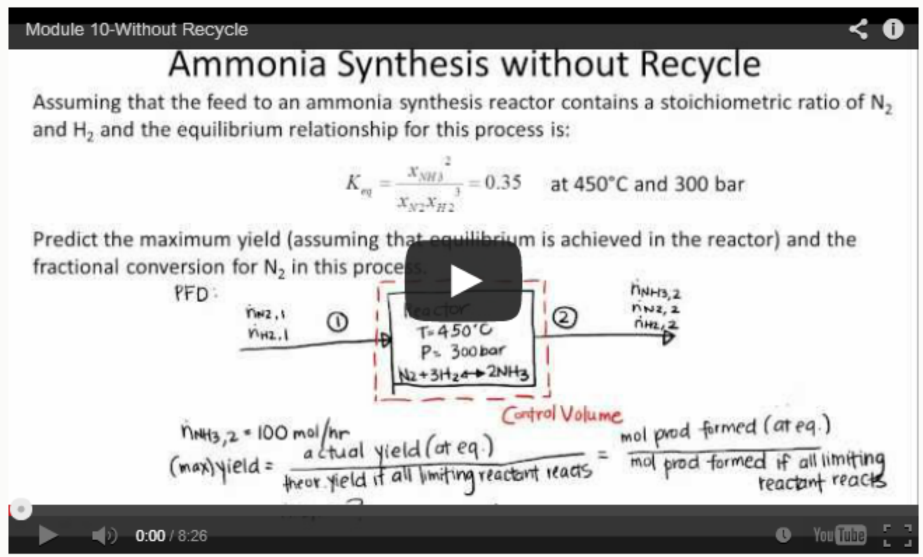

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Design & Content: “Recall” Pre-Req Topics

Example of reaction equilibrium: Ammonia synthesis

- $N_2 + 3H_2 \leftrightarrow 2NH_3$
- How can we determine the extent to which the reaction has occurred at equilibrium at a given *T* and *P*?
- **Recall:** from the above definition, the system will reach equilibrium when its chemical potential ceases to change with time. This will happen when the chemical potential reaches a minimum value at a given *T* and *P*. From this corollary, it can be derived that, at equilibrium:

$$\frac{x_{NH_3}{}^2}{x_{N_2} x_{H_2}{}^3} = \text{constant} = \mathrm{K_{eq}}$$

Thus, knowing the value of K_{eq}, the yield at equilibrium can be calculated. For a review of this concept, see this video link (Reactions in Equilibrium) or use your own review resources.

- **Recall:** Since the above reaction is exothermic, as *T* increases, the reaction yield will decrease according to Le Chatelier’s principle.
- **Recall:** For all reactions (exothermic or endotherm
(as per the Arrhenius equation)

Flipped Class Format

- In-Class Activities
  - Clarify any commons points of confusion based on Checkpoint Quiz results
  - Real-world examples problems
  - Work on group projects
  - Lectures providing more depth on particular topics
  - Interactive exercises individually or in groups

Additional Non-trivial Issues

- Choice of Platform
  - Support and learning curve for instructor/developer
  - Constraints and capabilities of platform: how well do they match YOUR needs?
- Designing Navigation

Lessons Learned

- Have all videos and all online content finished before first day of class.
- No videos longer than 10 minutes (ideally 6-7 min).
- Platform technical support is critical.
- Must have clear goals for what online component is intended to accomplish.

Future Plans

- Will transfer to new Stanford-supported platform (OpenEdX) for spring 2014.
- Continue to make/improve enhancements for target areas.
- Improve perceived connection between online textbook, in-class activities, and exam/problem set problems.
- Not yet accessible to public but plan to:
  - Platform issues
  - Have avoided any copyrighted content

Acknowledgements

- Wes Choy
- Greg Bruhns
- Amy Collier
- Jane Manning
- Funding from VPOL Faculty Seed Grant

S1: Process of Developing Resource

- Background:
  - Spring 2010: revamped course content to reflect modern chemical engineering (used required textbook but little course content mapped directly to textbook; no practice problems that reflected types of problems in problem sets and exams).
  - Spring 2011: no required textbook; provided our lecture notes and practice problems; recorded full lectures.
  - Spring 2012: Assigned students to review modules (lecture notes) prior to each lecture and answer 3-5 online conceptual checkpoint questions prior to class; continued to build practice problem bank from previous problem sets and exams.
  - Spring 2013: First time on Class2Go platform