Preliminary Exam Questions – 2005
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Anthony Goodrow

Thermo/Kinetics – Maboudian/Clark

What are the three laws of thermodynamics? What is the first law for open and closed systems? What is the difference? What is the definition of fugacity? What units does it have? Describe how fugacity is used for liquid mixtures. Raoult's Law for Grown-Ups – discussion of activity and fugacity coefficients and how you would calculate them. Discuss how you would use Raoult's Law to do bubble point and dew point calculations

What are the assumptions behind PFR and CSTR reactors? What do concentration profiles look like? Plot conversion vs. residence time/reactor length. How to find volume required for a given conversion in a PFR and CSTR, discussion of design equations for each. What is an elementary reaction, what does it mean? If you have a reaction A→B→C and you want to maximize B, which reactor do you use and why? Discuss residence time distributions for PFR and CSTR and graph response. Derive RTD for CSTR starting with design equation.

Process Control/Design – Keasling/Cairns

Tell us about your design project. How do you separate organics from wastewater? How do you regenerate activated carbon? Picture you have an exothermic reaction in a tank and a coolant fluid in a jacket around it, how would you control the temperature in the reaction? What kind of controller would you use and why? What are your manipulated outputs and measured inputs? (Turns out the answer is a feedforward-feedback controller.)

How do you make Ni for Ni-Cd rechargeable batteries? What ore can you find Ni in? What steps do you need to do to react ore to get Ni? Write the cathode and anode reactions for the electrolysis step.

Transport – Schaffer/Balsara

Fluid in an annulus of a cylinder, find velocity profile if inner cylinder being pulled axially at v_o. Pan of water and you put a capillary in it. What happens? How high does the water go up? What causes this? Frozen turkey in an infinite pan of water. Approximate turkey as a slab. Draw the temperature profile in the turkey for different times. Assume the rate of melting is slow.

Joe Peltier
Process Design: Keasling/Cairns

Started out by discussing my senior design project, which took about 15-20 minutes. Then Keasling wanted to know what would be the best way to control a CSTR with an exothermic reaction. I said you'd need a temperature probe, and he wanted to know why you'd want a temperature probe in the tank instead of using a GC to measure outlet stream composition. I said because temp probes are cheaper, but he was really going for the fact that temp probes give a continuous measurement, while GC's don't. Then he wanted to know which control algorithm to use (P, PI, or PID). Essentially he was just looking for a discussion on the pros and cons of each. Then I was handed back over to Cairns who wanted to know how to make lithium. I had memorized the process from the binder, but I didn't understand why you'd do things that way (I'm no electrochemist, nor do I claim to be). Unfortunately, Cairns did want to know why you'd do things that way, and I basically said "I don't know." Somehow, I still managed to fumble my way through. He also wanted to know specifically how to design the electrochemical cell, which I hadn't gone over but somehow managed to pull out on the fly (I was rather proud of myself for that one).

Thermo/Kinetics: Reimer/Katz

Although it was in the context of a flash problem, Reimer was essentially looking for an explanation/derivation of fugacity, activity, and modified Raoult's law as though I were teaching it to

undergrads who'd never seen it before. He also wanted to know how to determine fugacity coefficients (eq. of state) and activity coefficients (UNIFAC, UNIQUAC, etc).

Katz had me derive the non-steady state mass balance for a semi-batch reactor. Then we had a discussion about Michaelis-Menten kinetics and how the rate varies with substrate concentration. Then we talked about PSSH and the quasi-equilibrium assumption, and what each approximation assumed about the relative rates of the elementary steps involved in enzyme kinetics. This included drawing those handy rate diagrams that Iglesia is so found of. Then Katz had me derive the differential equation for diffusion to and reaction on the surface of a catalyst pellet. Then he wanted to know how the apparent rate of that reaction varied with temperature. This included considering the effects of temp on both the rate constant and the diffusivity.

Transport: Muller/Radke

Muller wanted me to derive the relevant transport equations for the rear window defroster on a car. This is just like the electrical wire problem in the binder (and BSL) except in rectangular coordinates. I used a shell balance (which is what I'm good at) instead of the general equation of energy (which I hated memorizing and consequently probably couldn't have written down even if they wanted me to), and they seemed happy with that. Needed to write down boundary conditions (matching fluxes) and discuss how to determine heat transfer coefficients. I just said you'd use some empirical correlation that would depend on whether you assumed free or forced convection. They seemed happy with that. Muller also wanted to know how I would determine the temperatures on the inside and outside of the glass. I started to go through it, but she stopped me. She evidently wanted something else, but I wasn't getting her drift. Eventually she just dropped it, and we moved on. To this day I feel like I missed something pretty simple there.

Then Radke posed a nearly analogous problem involving the mass transfer of O_2 through a contact lens and subsequent O_2 consumption in the cornea. All the equations were the same as in Susan's problem, except I had to throw in Henry's law. They wanted to know how to determine the mass transfer coefficient. Same as above, except with the Sherwood number instead of Nusselt.

Before I started each of these problems, they wanted me to draw what I thought the profiles would look like. They seemed to be testing my intuition more than anything else. This was a recurring theme throughout the whole 45 minutes.

Paul Cordeiro
Design (Blanch and Prausnitz)
- Senior Design Project (Prausnitz)
- Vitamin D light catalyzed problem, COOH group separations (Blanch)
- What to do with CO2 emitted from a stack on a power plant, (separations with amine i.e. ethyl-amine/ethanol-amine), where do we ultimately put it? (ocean floor)
- Know common functional groups and what interacts well with them

Kinetics & Thermo (Chakraborty and Bell)
- Why do proteins unfold at high temperature? (G=H-TS)
- Delta g vs rho plots (favored state has lower gibbs energy)
- Binodal and spinodal discussions (meanings, metastable region)
- Fruit juice concentrate problem (like osmotic pressure, unequal chemical potentials of water in two phases)
- O2 $\rightarrow$ O + O, elementary, what is rate law? (1st order) How does this happen? (not uni-molecular, rate law derivation), Plot potential energy vs O-O bond distance (reaction coordinate drawing—moorse potential, NOT Lennard Jones)
- Parallel reactions, maximize desired product, KNOW WHAT DEFINITION SELECTIVITY HE WANTS—Write something and explain it! He nailed me for not using the one he wanted
- Thiele Modulus definition and limiting cases

Transport (Balsara and Schaffer)

- Towing an iceberg, estimate how much evaporates (mass and energy balance, like wet bulb problem)
- Slab of turkey at bottom of bucket, 1-D problem, Plot temperature profiles at various temperatures, how long to melt small thickness delta x? (mass and energy balances, like wet bulb again) Why treat as steady state? (alpha >>1)
- Capillary in tank of water, what does water surface look like? pressure balances (bernoulli's equation), why does the water level form a meniscus? (surface tension)

Jonathan Germain
Kinetics & Thermo with Reimer and Katz

- How do you get Keq from deltaG? Dont forget that it is deltaG with the little zero above it
- How do you get deltaG?
- How do you get deltaH and deltaS experimentally? Tie this to the third law of thermodynamics
- Keq is defined in terms of activities; turn this into concentrations. How do you calculate the activity coefficient
- Given a langmuir-type reaction, derive the rate expression; use the PSSH. - What if there is an oversupply of reactant? Shortage of enzyme/catalyst?
- Put the reaction on the surface of a catalyst pellet; how does the rate expression change. What are the concentrations involved? How do you get them?
- What is the effect of a diffusion limited regime on the apparent rate of reaction? On the apparent reaction rate constant?
(This was my best of the day; both professors gave solid encouragement throughout and were generally quite kind.)

Transport with Graves & Schaffer

- Startup of flow controlled by a flat plate (semi-infinite problem)
- Conduction between 2 cylinders; dont forget that there is a small air gap between the two cylinders, no matter how well they are held together
- Talk a little bit about the boundary layer above the cylinders and the temperature gradient there. How does this relate to the Nusselt number?
(This one was pretty good, but it was the first of the day and I was quite nervous. Schaffer was encouraging, but I couldnt tell what Graves was thinking. He seemed to like the result in the end, though.)

Process with Keasling and Blanch

- First, I explained to these guys how long ago my senior project was. I told them that I had done my best to resurrect it, but they let me move on to other things. - We have a reaction (A->B) which uses UV light. We also have side reactions:
        A->C (under heat)
and B->D (under uv)
so we need to get B out of the reactor as quickly as possible to preserve B and keep it from heating up to preserve A. Design a reactor: where should the light be? where should the cooling water be?
How do we figure out how long the reactor should be?
How do we control the temperature in the reactor? Write the appropriate balances and draw the controller
Now, make it a feedforward-feedback controller. Draw it and write the balances

(This was my worst for the day; the reactor part was solid, but I couldnt go past the feedback controller. They passed me though, so it was ok.)

Paul Hudson

Thermo and Kinetics – Bell/Chakraborty
Arup checks his stats sheet and loosely tries to relate a question to what my project might be, asking me **why a protein unfolds in organic solvents? Why is it folded naturally in water?**
(delta G delta G delta G! "energy-entropy" in the folding process). Next was the idea of the spinodal on a PV diagram for a real fluid He asked me to draw G vs. V diagrams and show him what it looked like in the spinodal region. I think that there is no barrier to go from one state to the next, so any perturbation will send it on its way to nucleation. He then gave me some convoluted story about the peoples of Africa making juice concentrate by dipping a bag of juice water into brine. The water leaves the bag because of a higher chemical potential. Osmotic pressure is not what he was looking for. Luckily I had heard this before and deftly avoided the phrase.

Bell then chimed in and asked me about the temperature dependence of the rate constant. I mentioned the partition functions in the pre-exponential factor, then immediately knew that I had just invited him to make me look a total fool talking about that. After blubbering through the **difference between the partition function in gas and liquid phase reactions**, it was time for PSSH, which we didn't get much into save that I told him that it assumes the concentration of the intermediate is not zero at initial. **Why do you think the rate constant has an exponential dependence on temperature?** I said it looked like a probability term, something that I had never thought about until I was there staring at it, sweating. he opens his mouth, the sound waves travel across the room, time dilates, etc.ears...."derive the thiele modulus and you may go." sheesh.

Transport- Graves/Schaffer
Some of the horror stories I had heard about Graves had me thinking that transport would be the worst, but he and Schaffer were very friendly. They checked their little report sheet and saw I was from North Carolina. So we chewed the fat a bit about basketball and I told him that I had used Geankoplis and a coursepack (Rumor has it he asks everyone). He then asked me the **wet bulb problem**, in the clever guise of a towel hanging out of a car window. How to measure the temperature of the towel? He corrected a negative sign I had put in the energy balance (it would later show up in my grade) and then asked me **how I would get the mass and heat transfer coefficients**. I said Chilton-Colburn, but Dave chimed in and reminded me of the $Sh=Re^x Sc^y$ equation too.

Dave's question was about **fluid in between two cylinders**, and how to find the velocity profile when one of them is pulled back quickly. I had actually memorized the Navier-Stokes for cylindrical coordinates, but all those equations started swimming around in my head and all I could write was rho. I told them about my plight but he didn't seem to mind and he kinda pushed it out of me. I told him that I would integrate it twice and he didn't make me find the integration constants. **Then he asked me how to find the required force and I said it was F=tau*A**. Graves reminded me of his presence by asking a question about **why the tensor was symmetric**. I was pretty amped about trying to prove why it must be, and started in on the board, but he just laughed and said he was just trying to trip me up, and that he didn't expect me to know since I was "a Geankoplis guy." Well, little did he know that they had sent jackals to destroy a lion! I reached over that table and grabbed him by the collar, hard. Then, quite asymmetrically, I head-butted him and Schaffer at the same time. Next, I politely asked them if they wanted some more, and after their declinations I informed them that they both got B-.

No, that's not how it happened at all! In truth these guys were very patient and it was a very friendly room, thanks to Geankoplis. I should write that guy a thank you letter.

Process Design –Blanch/Keasling
I had memorized all these great things to say about my design project, which wasn't necessary at all, since they were not interested in knowing what it was. Blanch started with reactor design for making vitamin D. Vitamin D is the intermediate in a UV activated reaction, but too much UV makes it form an unwanted. Excess heat also forms an undesired. I had done my undergraduate research on UV activated reactions, so this was like a blessing for me. I told him a clear tubular reactor would be in order, with a clear cooling

jacket. **Why tubular he asks**. I told him that with a PFR its easy to size it to get the maximum amount of intermediate, and that it was more efficient for this assumedly first order reaction. Keasling then asks how I would control it and I told him that a measure of reactor temperature would be appropriate, with the cooling water flow rate as the manipulated variable. He then threw a new twist, that the cooling water temperature varies, so I would need to add a **feedforward** controller. No equations, no talk of P PI or PID. He just wanted to hear feedforward. Now that we have D, how do we separate it? Its obviously very similar to the reactant, since UV light only breaks one bond (ketone to alcohol). I told him that we could add something that will react with the ketone and precipitate it or something. He wanted specifics. I kicked myself for not reviewing the functional groups and I would recommend a brief jaunt into the o-chem book for anyone who has Blanch.

We moved on and I couldn't believe it when Keasling asked, "**have you ever heard about MTBE**?" My god had I ever! I acted this one out pretty good, and made it look like I was really stumped at first at how to separate it from groundwater. After mentioning activated carbon, Harvey starts talking on and on about how expensive it is so I get the hint and talk about regenerating the membranes. We still had about 10 minutes left, and I asked for the third time if they wanted to see any of my design project. Keasling told me that it was time for me to celebrate, and then I pointed out that all of the students at Berkeley from NC State worked for him. He started laughing. Loud. Then Harvey starts laughing. Louder. I started laughing. LOUDEST. Harvey pulls a bottle of champagne from his back pocket and I suggest we design a process to separate that booze from its bottle. Hilarity ensues.

Reed Asay
Kinetics/Thermo ((Reimer/Katz)

This is the one I did best in but remember the least. Reimer asked me a thermo question about an equilibrium reaction for tin oxide with HCl. How would you determine the amount of product formed? This involved describing in detail how to find delta G from delta H and delta S. Talked about the 3rd law and how to find absolute entropy from heat capacities and for multiple transition states. Next, described how to find K from delta G and talked about fugacities. He wanted me to explain how to find fugacities from equations of state.

Katz asked about diffusion onto a solid sphere (marble). This one became more of a transport problem as he next asked me to give an equation describing this diffusion, but didn't ask me how to solve it. Then, he asked me to change it for diffusion into a pore on the sphere. The last question was about which reactor would not have runaway for this type of reaction and would be easier to control. It's a CSTR, even though I didn't know that before hand.

Process Design-Iglesia/Segalman

Tough crowd. They asked me to describe my design project. After that 30 seconds was over, Segalman asked me how to desalinize water. After I completely choked on that one, Iglesia asked me how to make ammonia (Haber process) and how I would make the reactants for this reaction.

Transport - Muller/Radke

Radke asked about the temperature profile through a windshield with a constant heat generation term. He wanted me to draw it before I solved it. After solving the heat transfer equation, I had to explain the boundary conditions, one of which is a stagnant medium. How do you get h values for both boundary conditions (one is free convection)? He also asked about relative humidity and how to get it from Raoult's law.

Radke then had to leave, but his phone kept ringing throughout the remainder of the exam. But Muller asked me to draw the concentration profile for a contact lens. It's almost the same, but with equilibrium concentrations across any and all boundaries.

Brian Mayer

Transport (Newman/Radke) – (i.e. good cop and more talkative good cop)

After I walked in to Newman's office, the two of us talked about where I grew up, the professors I had in college, etc. (Radke walked in late.) After the ceremonial chitchat, Newman opened with a gimme question: Given a double-tube heat exchanger and the inlet flow rates and temperatures, how would you go about calculating the outlet temperatures. Newman gave me free reign on how the exchanger was set up (i.e. co-current, counter-current, blah blah blah. The problem essentially amounted to three equations: two "m*C*deltaT"s and a "U*A*deltaT." Then Clay asked me qualitatively what makes up the overall heat transfer coefficient and how would I go about estimating it. I just talked about how it was akin to resistances in series. I said we could neglect the conduction term assuming a highly conductive thin-walled metal tube. Clay then asked me a question about how "h" would change in Newton's law of cooling if we used condensing steam as our heating fluid. It took me a while to get this, but essentially it would increase (dramatically, I was told) b/c as condensate formed, it would fall down (because the heat exchanger was vertical) leaving more volume for more condensate to form…or something like that. That question was more or less a breeze.

Then Clay asked me about packed bed formation in a vertical tube with a screen in the middle that caught particles that were coming in with some inlet fluid. In essence he wanted the change in bed height with time (dh/dt) using a modified Hagen-Poiseuille law (which he eventually gave me), the volume fractions of the pertinent species (which he also gave me), and some other business I can't remember. Good thing for you guys, he asked the same question to others, so you might want to check their stuff for better info.

After I squirmed through Clay's question he gave me another about coffee making. It was an offshoot of the previous packed bed question that I didn't understand. Thank God we ran out of time. Overall I felt pretty good about the exam. If you have Clay and he seems like he's getting a bit impatient and starts giving you part of the answer in kind of a brusque way, don't worry. I figured out he's really only doing it to get the trivial stuff out of the way and get you to the meat and potatoes (if you will) of the problem.

Thermo/Kinetics (Katz/Arup)

I really had a good time in this exam. It was more discussion than "Brian at board with chalk." Katz (as many classes before mine have said) can give some convoluted questions. We told me he wanted me to talk about zero order kinetics (big surprise there) and how they happen. He had me begin by writing some arbitrary reaction involving a surface, and deriving the rate expression. He stopped me half way through because he saw I knew what I was doing. Then he took me on a tangent, asking me about PSSH and QEA, when they apply, and if I could draw the arrow diagrams that Iglesia liked so much. Then he asked which reactor would be better for a zero order reaction. I had some trouble with this (I was making it too hard). With some prodding, I finally blurted out that it didn't matter between the CSTR and PFR…which should have been obvious to me from the beginning. Katz seemed pleased over all and turned it on over to Arup.

Arup asked me some questions about phase diagrams (which I had anticipated) and what they meant qualitatively. From the beginning he was focusing heavily on stuff I mainly learned in ChE 240, which I thought was interesting as I was under the impression that Prelims covered undergraduate material. He then asked me about a free energy vs. density diagram and I covered the three cases: liquid state favored, vapor state favored, and the equilibrium case. It was fairly straightforward. He was very anal about the difference between free energy and energy, so get those two straight in your head and don't say energy when you really mean free energy. He asked some other basic questions that I can't recall, but they were simple to work though.

Arup then stopped me and asked if I knew how to cook. I didn't think I understood him right away but, yes, he was really asking me if I cooked. I said, "yes," and he proceeded to go into the token water splattering in oil problem. As usual the key phrase is "spinodal decomposition" but I didn't say that because he would have known that the only reason I knew that was because I has read some other student's summary. Going in, I really didn't understand the concept but Arup and I just discussed it for a while. He seemed OK with my answers and they let me go.

Process Design/Control (Prausnitz/Blanch)

What a horrible, horrible exam. Prausnitz started by asking me about my senior design project. After 3 minutes they shut me up – clearly uninterested in ethylene oxide production. I was good so far, until this point where Blanch and Prausnitz started a tag-team battle from hell from which there was little chance of escape. Harvey asked me to design a heat exchanger to selectively condense on organic from a mixture. It seems easy in hindsight but I had no idea what he wanted me to say. I just stood there like a deer caught in headlights. After struggling through, we moved on. Prausnitz asked how we get oxygen from air (Hinde Process) and grilled me on every little detail about each unit operation. That was OK. Then he asked me why we need oxygen and nitrogen (oxygen for steel and nitrogen for ammonia synthesis [Haber process]). Then Blanch chimed in with another design question. He asked me how I would design a HCl absorption tower. I should have just walked out of the room. He asked why you couldn't use the equilibrium/operating line construction (The equilibrium line is infinite for all liquid mole fractions). Harvey asked me if I knew the maximum amount of HCl that could go into water (evidently 36 normal…whatever). This question was followed by a series of others that I neither understood nor cared about. Then time was up and failure was inevitable.

Justin Virgili

Process Design (Keasling and Cairns)
1. Describe your senior design project. Additional questions regarding controls schemes (Keasling).
2. How do you make zinc? (Cairns)

Keasling seems to ask about controls despite the fact that we were told that controls were no longer on this segment of the exam. I hadn't had a controls course, but learned the basics from students that had and reading a bit. For Cairns, it's all about memorizing enough ore to metal processes to have an idea of getting through both familiar and unfamiliar processes.

Thermodynamics / Kinetics (Katz and Chakraborty)
1. Something regarding conservation of mass and not wanting to have infinite flux in a slab with an A -> B reaction occuring.
2. Surface reaction on a solid particle. Set up the governing equation and talk about the radial concentration profile.
3. Given reaction rate vs. temperature data, how would you determine the activation energy of the reaction. This involved the Arrhenius expression for the rate constant and plotting the data $\ln(r)$ vs. $1/T$ (see Fogler). Diffusion and reaction limited regimes.
4. Definition of temperature – relate it to kinetic energy I think.
5. Why does phase separation occur in polymers?
6. What is going on thermodynamically when oil is thrown into boiling water (nothing observed) versus water thrown into hot oil (spattering).

Fogler seemed like good preparation for Katz's questions. For Chakraborty's questions Smith Van Ness and Abbott didn't help a ton other than just reviewing the basics. You're probably better suited reading the first 3 chapers of Chandler's Stat Mech text and looking at the types of questions he asks (he asks a lot of the same from year to year) to get an idea of their flavor.

Transport (Graves and Newman)
1. Surface reaction with Si and oxygen to form SiO_2. Write an expression for the change in height of the SiO_2 layer with time.
2. Heat exchanger problem and solving for inlet / outlet temperatures. Basically a ln mean temperature problem.

Work a lot of examples on the board and under pressure. I got flustered on the first question and had a difficult time thinking clearly at all after that. Both examiners were pleasant in the beginning and Graves

especially got a bit impatient with me as the examine progressed. I think this is more his personality rather than a direct reflection on how you're doing, your grade, etc.

Megan Fox

Transport (Muller and Balsara)
This was my first prelim, so I was a little nervous and it took me a little bit to get some direction. Muller and Balsara started by asking me what books I had used as an undergrad. After that, my first question was about designing a rear window defroster on a car. But we're not talking those fun little wires that line the rear window. "Imagine a shmear of a heat source in the window." What things do you want to consider in the window defroster's design? What would the temperature profile look like? I had a hard time understanding what Muller was trying to get at – not point or line sources supplying the heat. The whole window is one big heat source. I was confused, but plowed away with the energy balance in Cartesian coordinates and a couple of appropriate boundary conditions. Muller and Balsara looked confused most of the time. Actually, Balsara just scowled. I'm pretty sure there should have been a parabolic temperature profile, but not symmetric. We did discuss some other things during this whole process – how to find heat transfer coefficients, some dimensionless numbers (Nu, Re, Pr). After this, Balsara asked me about a capillary tube in a large disk of water…the capillary tube is open on both ends. He didn't actually ask me a question – just had me set up the problem, then scowled some more as I floundered, wondering what he wanted me to do with it. Turns out I was supposed to do a force balance on the water surface inside the capillary tube. Remembering surface tension was apparently the key. I walked out feeling alright, but not great. I failed this one, but apparently the other two people who had Muller and Balsara failed too. Oh well.

Process Design (Cairns and Keasling)
These guys were nice. They started by asking me what my senior design project was, so I spent about 20 minutes going over it. They stopped me here and there to ask questions. Mainly, they pointed out things that wouldn't have worked or we should have included, and asked me what I would have done to fix it or change it. Keasling asked me a very basic question about controls on a tank – how would I control the temperature in a bioreactor? What kind of controller? (PID – good control, and few temp variations in a CSTR/FBR). Physically, how would I control the temp? (With the cooling water flowrate. You'd need a feed backward controller looking at the temp of the reactor contents AND a feed forward controller looking at the actual temperature of the cooling water.) I learned during this exam that you actually have to have some feed back controller when you have a feed forward controller. Cairns then asked me how I would make phosphoric acid. I was ready to bust out the process for phosphoric acid I'd so diligent memorized from the prelim binders, but he didn't want to hear that. How would I make phos. acid from phosphorus found au natural? I knew you'd mine P as a phosphate, but I didn't know where to go from there. He was pretty nice and walked me through the process. If you've got Cairns, I'd recommend taking a quick look at the periodic chart and knowing element valencies.

Kinetics and Thermo (Maboudian and Bell)
Maboudian and Bell were pretty straightforward and both pretty nice. Bell went first and asked me about kinetics. What are the factors that affect the rate? What is the equation for the rate constant and what does each term mean? He then set a problem with reaction $A + B \rightarrow P$. He had me draw a graph where the rate increased linearly with [A] and increased, then plateaued with [B]. What's going on? B is absorbing to a catalyst (which has limited sites) and A is reacting with it as a gas. He did a couple more questions along the catalyst rxn theme, had me find the rate equation. It was then thermo time. What are the 3 laws of thermodynamics? Draw a P-T diagram, then a P-V diagram. How would I calculate the work in a phase transformation? This involved me deriving the Clausius-Clapeyron equation. Maboudian likes to hear specific things, and we had a little bit of a debate over the definition of entropy; I had learned the definition from Lira's "Introductory Chemical Engineering Thermo", which I guess is a little different from what she teaches from. But it was all OK in the end.

John Daniels

Transport (Muller/Balsara)
They asked me which texts I used for transport. I knew things were not going to go well when Dr. Muller only recognized one of the three. The first question was about solving for the heat generation in a rear windshield defroster. In reality these are discrete wires, but they wanted the simpler case where it was considered to be "smeared out across the whole windshield." The idea was to match the heat flux both inside and outside of the car as your boundary conditions for the steady state energy balance. They wanted you to get the h's from Nusselt number correlations based on forced or natural convection. The only reason I know how to do this problem is that Dr. Muller demonstrated it in Transport at the beginning of the next semester. Dr. Balsara's next question was determining the height of liquid in a capillary tube. This apparently had to do with surface energies, contact angles, and other things I had no clue about. As far as I know, nobody from this section passed, so good luck.

Kinetics/Thermo (Bell/Chakraborty)
Dr. Bell started with having me explain the rate law and all of the various parts of what affected it. Things like concentration, temperature, activation energy, etc. He then wanted to know the physical meaning behind the activation energy. Next he had me draw up some response curves for a hypothetical system. It was A+B->C in the presence of a homogeneous catalyst. This was to work in the pseudo steady state hypothesis because the response with increasing B was similar to a Langmur isotherm. Then came some generic questions from Fogler about competing reactions of differing orders, how you would maximize the selectivity of your desired product and what kind of reactor you would chose. Pretty easy, but good questions. Next Dr. Chakraborty asked about gas to liquid phase change. I didn't really understand some of the subtleties in his questioning but I stumbled through it. It had to do with minimizing Helmholtz energy (the one I know the least about). To do this, at low T, E must be minimized while at high T, S should be maximized. Thus at some T, there will be a shift, in this case from gas to liquid.

Design (Prausnitz/Segalman)
My senior design project was barely mentioned. They asked me what it was (synthesizing styrene from methanol and toluene) and they asked me where I'd get the methanol. I said synthesis gas. They asked me how to make it. I outlined steam reforming, partial oxidation, and the water gas shift. Dr. Prausnitz wanted to know how I would remove the CO_2 from the stream. I finally arrived at absorbing it in water with ethanolamine added to improve absorption. Then he asked how I would get the CO_2 back out. Reduce the pressure. Then he wanted to know what I would do with the CO_2. I said to vent it as it isn't directly a pollutant, at least not like NOx. This was mildly acceptable, but what he wanted was to have it react with CaO. Pressurize it and it becomes $CaCO_3$. Problem is the only way to make CaO is to take $CaCO_3$ and reduce the pressure so that CO_2 comes off, giving you no net gain. The moral of the story is that nobody knows what to do with waste CO_2, so I think it was fine that I didn't have an answer. Next Dr. Segalman asked how I would purify salt water to give pure water. Three methods are evaporation, reverse osmosis, and freezing/filtration. Evaporation works, but is expensive. They wanted to reduce energy costs by increasing the pressure so that it vaporizes at a higher temperature, then using the water vapor to heat the next evaporator at a lower pressure. Cheaper, but still not cost effective. Freezing/filtration works, except that it again takes a lot of energy and that the frozen icebergs are covered in salt water, meaning they'd have to be washed off. Reverse osmosis is the best bet. You just have to be sure to exert the water's osmotic pressure to achieve separation. The final question they asked me is what I would do with the condensed salt water. I said dump it back into the sea provided there were no toxic chemicals or thermal extremes to worry about from the stream. This was acceptable. Dr. Prausnitz led most of the time, but he was very nice about it and very helpful.

Paul Albertus

Process Design, Iglesia and Segelman
Discuss the production of hydrogen from methane. Follow through each component assuming incomplete reaction and impurities. Discuss techniques for removal and purification.
Production of coffee, supercritical CO_2 extraction. Why does the process work based on solubility/molecular arguments. Solids handling - follow the process through step by step and discuss

appropriate equipment. Batch or continuous? What about using supercritical water to complete the extraction? Would another separation step by required (e.g. would flavor be effected)?

The mistake I made preparing for this exam was memorizing large number of process diagrams: be sure to also go through processes and figure out what happens to every component and the operating conditions of every piece of equipment as a way to better understand design issues.

Kinetics and Thermo, Bell and Chakraborty

Kinetics: diffusion of reactants to a surface through a boundary layer. Description of the problem and conceptual questions. Write a mass balance for the boundary layer (amount diffusing in = amount reacted). Exothermic reaction occurring in a PFR. Discuss temperature and concentration profiles for a variety of reaction orders and operating conditions (e.g. adiabatic vs. external HT).

Thermo: Draw a graph of G vs. molar density. Discuss how this diagram relates to phase equilibrium for a pure component. What is the definition of temperature (average kinetic energy of molecules). Discuss the thermodynamic reasons for why water freezes in terms of the minimization of Gibbs free energy ($G=H-TS$, H has to do with potential energy between molecules, T has to do with kinetic energy, S doesn't vary much within a phase, so depending on the value of T the relative contribution of the H and TS term is different.)

Transport, Balsara and Schaffer

I had three questions during this exam.

1) You have an iceberg in the far north and are towing it to the equator. Develop equations to determine the amount of iceberg remaining at the equator. The first thing I did was solve for the Reynolds number to the nearest order of magnitude and found turbulent flow. Then I wrote a coupled mass and energy balance, using the film heat transfer coefficient, and discussed what it would be a function of (Re, Pr). I then described other information that would be needed (e.g. starting iceberg mass) to complete the problem.

2) You have two concentric pipes, and are pulling the inner pipe through the outer pipe. Determine the velocity profile in the fluid between the pipes. I wrote out the NS equations and eventually realized the pressure drop term should be zero (assuming atmospheric at either end of the stationary pipe). They carefully questioned me about BCs and the reason for the development of the velocity profile (friction between the fluid elements). Finally I discussed how to solve the NS equations with the BC given.

3) The rear-window defogger question. What is the criteria for operation (must keep the inside pane about the dew point)? What will the temperature profile inside the glass look like? Do a shell balance and discuss the terms. Finally why is it more effective to clear windows with cold air than hot air when starting a vehicle at first (has to do with humidity in the air)?