

Preliminary Exam Questions 2003

Compiled by Jeff Nye

Calvin daRosa

Transport (Graves and Schaffer)

This one wasn't too bad, but I struggled much more than I should have. They first asked about the textbooks I used in undergrad, as well as my professors for transport. Then Schaffer asked about flow in a pipe from a water heater to a shower. After struggling with getting the viscosity of water (1 cP) into something useful, we talked about heat transfer from the liquid into the pipe material and then to the outside. He asked about the boundary conditions and what allowed me to make the assumptions that I did (linear T profile in the wall, constant T at the surface). So I boxed it around a little more than I would have liked, and after about half an hour they decided it was time to move on, and Graves asked me to derive the equation for laminar flow in a cylindrical pipe (H-P). So I started from Navier-Stokes, and had to discuss the assumptions made in that equation, then he asked what allowed me to neglect radial flow. I talked about that for a bit and then he told me to get back to solving it since I had only about a minute left. So I ran through what I could, told them the BC's and said that it would be parabolic. Then Graves said I was done. Then I further said that the maximum velocity would be at the center. And he said something like, "no, really, leave." So I left.

Process Design (Iglesia and Lynn)

It turned out being the one I did the best in. They asked me to discuss my senior design project, so I probably spent about 15-20 minutes drawing and discussing my process flowsheet and saying why we did what we did. After that, Iglesia moved on to a scheme to produce hydrogen on board a car for use (I guess) in a fuel cell. So we talked about the reaction, and why they were endothermic or exothermic (I still don't get all of that conversation, but it sounds like I at least said the right things). So we talked about how to heat or cool the materials, then how to separate the CO from the hydrogen and other things because it poisons the catalyst. We didn't really get through all of it, but they seemed satisfied enough.

Thermo/Kinetics (Clark and Reimer)

First, Reimer asked me how to find the equilibrium conversion of a given reaction from things I could find in a typical textbook. So I wrote the equilibrium constant in terms of activities and then related that to fugacities and then tried to discuss fugacity and how to determine it. Then I talked about getting the delta G from delta H and delta S. That was about it for Thermo. Clark asked about the rate and whether the reaction would be more favored at high or low T. Then we talked about optimum PFR temperature profile for an exothermic equilibrium reaction. Then we just ended up talking about how we would deal with the changing temperature, considering an energy balance as well. All in all, it wasn't too bad and it was a pretty friendly room.

Alyssa Redding

Kinetics and Thermo (Clark and Maboudian)

My first question, after the describe your text books and background, was: You have a reaction $A+B=P$, and you want to know the order of the reaction with respect to B, but you can't measure the concentration of B directly. How do you do this? I was a little lost at first, so he told me that I had some lab equipment, and I could have anything I wanted. I wanted a reactor. What type? A batch reactor works best because you don't have any other complications. This wasn't something that I had even thought about since kinetics class in undergrad, but the answer is that you could find the rate order with respect to A, and then make a guess for B and check. Through this discussion, I had to discuss activation energies, the preexponential factor, transition state theory, and derive mass balances for different reactor types. I had Dr. Clark, who really focuses on your

ability to say a key phrase. Then Dr. Maboudian asked me to draw a PvT diagram for a pure substance, and then to focus on the vapor/liquid line, and switch it to a PV diagram (or a TS diagram). I had to prove that the heat of vaporization is the area under the tie-line for a liquid to vapor phase change.

Transport (Muller and Balsara)

The classic lid on a long, thin, box problem. Derive the velocity profile inside the box. This involves discussion of Navier-Stokes equation along with the continuity equation and a mass balance. I needed to know how to solve the second order differential equation. Although they didn't ask me to explicitly find all of the constants on the board, they wanted me to explain how to get them. Once I was done with this problem, they asked me to do an energy balance of a "waterfall." Here you have a cold wall on which vapor condenses and falls, forming a thin film. They confused me because I kept wanting to write out a specific energy balance and take into account all of the gradients, but they wanted a general equation.

Design and Control (Prausnitz and Lynn)

The obvious: "Did you do a design project? Tell us about it." I used a project that had several different pieces of equipment, including a condensation with liquid nitrogen. How is liquid nitrogen made? Linde cycle. How does it work? Expansion into a vacuum. What do you do with the oxygen you produce, why do we want to make pure oxygen (because they do). This led to a discussion about steel processing, from which I learned quite a bit. Next they asked about how to make ammonia. The Haber process. What is ammonia used for? Fertilizers and explosives. "So, which fertilizer was used in the Oklahoma City bombing?" Knowing very little about fertilizers, they gave me the choice between ammonium nitrate or ammonium phosphate. I then remembered that it was ammonium nitrate, but they made me prove why by writing out the combustion reactions. Then I was asked about extractive distillation, which I didn't study, so I was asked how to break an azeotrope. I replied by adding a solvent or using pressure swing. I was asked about supercritical CO₂, and why it is a good solvent. Finally I had to list all of the properties of a good solvent, and time was up.

Pat Coles

Transport (Newman, Radke)

Newman first hit me with "How would you find the overall heat transfer coefficient of a system?" I asked him to clarify the system, and he said a heat exchanger. I was caught off-guard (I was expecting to have to set up and solve some PDE), so it took me a good forty minutes to figure out that any flow rate can be written as a driving force over an effective resistance. (Electrical current is related to potential difference in this way, fluid flow rate is related to pressure drop this way, and of course heat flow rate is related to temperature difference in this way). In a heat exchanger, this effective resistance is the sum of the convective resistances of the two fluids plus the conductive resistance across the pipe (usually negligible). The resistances add like electrical resistors in series.

After finally getting the answer, Radke asked me to set up the problem of a ball being blown in the wind but hanging by a spring from the ceiling. It was just about balancing the force of friction with the tension in the spring. Radke was especially helpful in this exam, but Newman never gave any positive feedback. I stumbled and stuttered my way through this exam and performed far below my expectations. Afterwards, I wished I'd taken a deep breath half-way through and thought about the original question that Newman had asked. I just kept dwelling on heat exchangers and log mean temperature differences, and I didn't see the big picture. Getting yourself out of these sorts of traps is something you'll have to deal with. You're all very smart, you can think your way through these exams. I found the morning exam particularly difficult. It seems that many people's confidence skyrockets after the first exam.

Process Design (Prausnitz, Blanch)

These are two incredibly nice, jovial guys. But don't let that fool you. They are very smart and are judging your every comment. I got my worst grade in this exam, but felt the most confident coming out of it. Prausnitz did most of the talking. He asked me two quick questions about my seniorproject: "Why does fuel-grade ethanol need to be so pure?" The answer was that any water in your engine can freeze. "How did you break the azeotrope in ethanol/water distillation?" My answer was pressure-swing distillation, in which you have two columns in series operating at different pressures.

He then asked how I would recover acetic acid from an aqueous stream (use extraction with an organic solvent like some sort of oil). They asked me to estimate how long it would take for a benzene spill on the surface of the earth to seep down into water lines 10 meters underground. I non-dimensionalized the diffusion equation to get a characteristic time (equal to L^2/D). Finally, Prausnitz asked if I was familiar with the Joule-Thompson coefficient. Based on the J-T coefficient, how would you make liquid hydrogen? The throttling process is used to liquify many gases, but hydrogen is unusual in that it has a negative J-T coefficient (it heats upon a pressure decrease). However, there exists a temperature (called the inversion temperature) below which H₂ has a positive J-T coefficient. So first you use liquid N₂ to cool the H₂ below its inversion temp, then you compress and throttle the H₂.

Thermo/Kinetics (Arup, Katz)

Arup asked the same stupid question about water splattering in hot oil. Spinodal decomposition was supposedly the magic phrase. I don't know why you have to say that stupid phrase, I just thought the answer was simply that the water boils. Then he asked me to explain why a protein unfolds at higher temperatures using thermodynamic arguments. He said to draw various isotherms on a free energy versus something diagram (I forget what "something" was).

Somehow I did well on Katz's question. He's pretty vague with his questions, so my advice would be to repeat everything he says to make sure you've clarified what he's asking. He said "Suppose a technician measures the activation energy of this surface-catalyzed reaction to be zero at high temperatures. What's going on?" I reasoned this one through by first writing down the Arrhenius equation and realizing that high temperatures typically lead to higher reaction rates. However, higher temperatures do not necessarily significantly increase the rate of mass transfer in catalysts (Knudsen diffusion). Thus, higher temperatures can put us in the mass-transfer-limited regime. So I said that we had falsified kinetics due to mass transfer resistance to the catalyst surface or within the catalyst interior. Along the way, he asked me to draw a plot of potential energy versus reaction coordinate and a plot of $\ln(k)$ versus inverse temperature, where k is the rate constant. Although these graphs contributed nothing to my ability to figure out the answer, they seemed to make Katz happy. (I think Katz was trying to say that when mass transfer controls the rate, we see no temperature dependence, i.e. no activation energy, because a reactant at the edge of the boundary layer has the same potential energy as a reactant on the catalyst surface.)

Here's my overall advice when you're hit with a problem that you have absolutely no clue how to approach. Just start reciting aloud the things that you DO know about the problem. (For example, you always know that free energy is minimized and entropy is maximized at equilibrium, you know that energy and momentum are always conserved, and mass is conserved whenever there's no nuclear reactions. These principles will never fail you.) Professors will take this sort of understanding into account when figuring out your grade. Also, be confident and pleasantly forceful with your answers if you know you're right.

Esther Winter

Transport (Muller and Balsara)

You have a plate which oscillates under an infinite pool of water. Find the velocity profile in the pool of water. [$v_z = a \cos(\omega t)$ and pool infinite in x & y directions]

Set up Navier-Stokes and boundary conditions. Guess soln of the form $v_z = \exp(bx)\exp(i\omega t)$, solve for b. Math identities that were needed were given.

Design/Process (Keasling and Cairns)

What is MTBE? Draw the structure. What is it used for? How do you separate it from ground water? Under what conditions? What do you do with the MTBE once you have separated it?

Make titanium. Know what form metal found as in nature, good reducing/oxidizing agents, valence numbers of different metals, how to set up anode and cathode reactions, how to draw electrolytic cell.

Thermo/Kinetics (Maboudian and Peterson)

What is the first law? Write it for an open and a closed system. What is fugacity? What is chemical potential? Draw p-V diagram with constant temperature line. Know liquid vapor equilibrium. Basically, know everything there is to know about fugacity. Make sure notation is correct (i.e. subscripts etc, they were picky)

Design equation for a PFR. Expressions for conversion. How does design equation change when there is a change in volume? Write chemical reaction for synthesis of ammonia. Exothermic or endothermic? What happens when the pressure is increased? Write the chemical reactions for synthesis of sulfuric acid. Exothermic or endothermic? What happens when the pressure is increased?

Kevin Sivula

Thermo/Kinetics (Arup and Eugene)

Arup asked me to describe the energy and entropy differences in a system at two different temperatures. the lower temp had 2 phases and the higher temp had 1 phase. [I looked at $G = H - TS$ here]. Then he asked me the water-drop-on-oil-spinodal-decomposition question. Eugene looked confused the whole time, but then he asked me to describe how density changes in a reactor would change the design equations. he still looked confused. then he asked me various basic questions about an reversible endothermic rxn he had me write down (my choice). I didn't think i did that well because Prof. Petersen looked confused the whole time and even when i would say something correct he would look at me and say : " Well okay". oh well i passed.

Process Design (Harvey and John P.)

these guys were nice i could have said anything and let them tell me the answer and still pass. they asked me about characteristic times for diffusion and acetic acid extraction and extractive distillation and supercritical co2 extraction of caffeine. they were not interested in my design project except to know what is was. they asked me no control questions. the rest is hard to remember.... it was so long ago....

Tranceport (Nitash and David)

nitash asked me to solve for the velocity profile in a semi-infinite fluid with an oscillating plate boundary condition. he helped me along and when i was finished he said i could go, but dave wanted to asked me a short one: it was about streamlines in a oil drop ascending in water, qualitative only.

Enrique Gomez

Transport (Graves/Schaffer)

Graves: A capillary is partially filled with liquid and air is flowing perpendicular to its one entrance. Find how to relate the diffusivity of the liquid in the capillary to the change in liquid height.

Schaffer: A spherical oil drop is placed in a glass of water. Describe (Force balance). Will there be any flow within the drop? Although these questions were very fair and both professors were helpful I managed to trip myself up throughout the exam. I honestly thought I had failed, but I ended up with a good grade. I suppose the moral of the story is that people are often pleasantly surprised about the outcome of these exams. Always keep thinking and work through the problems, even if you can't seem to get anything right.

Thermo/Kinetics (Chakraborty/Katz)

Katz: Kinetics of a zero order reaction, temperature dependence, $\ln r$ vs $1/T$ plot, why might a reaction not follow zero order kinetics (but instead fall short) at high T 's, basic PFR questions.

Chakraborty: Why does a protein denature with an increase in temp? Why does cheap soap lather more than expensive soap? This test was tougher and longer than it sounds, but I can't remember the rest.

Process Design (Cairns/Iglesia)

Cairns: How do you make phosphoric acid (how is it most commonly found in nature)? How can you make phosphoric acid from elemental phosphorous?

Iglesia: Design a car that uses hydrogen as a fuel source. What raw material would you start with (methane)? We didn't get into how we would use the hydrogen as a fuel, but instead worked on the process to make and purify the hydrogen, especially from CO.

Tim "All talk no action" Whitehead

My favorite day of the year, by far.

Process Design (Prausnitz/Blanch)

What was your Senior design project? - I forgot it, so we moved on. How do you separate a dilute stream of acetic acid from water? Why is distillation a bad idea here? Several permutations on this question. What is the characteristic time for a pollutant to travel in the ground? design a wastewater treatment facility (Basically Harvey was looking for an aeration facility where you engineer the dimensions of the plant, the rate of the O₂ bubbling up, etc. Don't forget evaporation.) Midway through, Prausnitz asked, have you had a plant design course before? I pretty much knew I failed by that point.

Transport (Newman/Radke)

What is this friction factor that we speak of? Draw a f vs Re for flow in a pipe. Why does the friction factor decrease as Re increases in laminar flow. What is the relation? How is this flow different than around a sphere? Cut short. Ball on a string with air flowing past it. Do a 2-D force balance on the ball to determine the friction factor given a velocity of air. Cut short. Prove that the stress force countering flow is linear and opposite to the direction of flow. This just entailed setting up a shell force balance.

Thermo/Kinetics (Chakraborty/Katz)

You have to watch out for Katz. His questions are unpredictable and convoluted, so you have to wait until he leads you where he wants you to go. His kinetics question was, "you have a highly exothermic, zeroth order reaction, going $A \rightarrow B$, occurring over a catalyst. What does this immediately tell you about the rate mechanism?" I started drawing L-H kinetics absorption patterns and was stopped. he made me draw a Langmuir isotherm and we had a talk about the relative rates of adsorption energies that each of the species had. We then talked about the

efficiency of CSTR/PFR for this reaction. Don't get frustrated with his direction, just roll with it. Arup was more intrigued with his e-mail than with the exam, but he piped in with two quick baby thermo questions: Why do proteins denature more readily in organic solvent? Why is the soap industry so large? Everything with this guy is minimizing Gibbs and the tradeoff between entropy and enthalpy.

A.J. Howes

Kinetics and Thermo (Clark and Maboudian)

Started off with thermodynamics from Maboudian: What is the first law of thermodynamics? How does the equation change for an open system? What does the PV term in enthalpy mean exactly? I forget the next question, but I definitely drew a P-V diagram. She asked me about the different areas on the graph (liquid, vapor, liquid-vapor equilibrium, critical point, etc.). We then got into the definition of the chemical potential and fugacity. What is chemical potential? What is fugacity? Why do we use fugacity and not chemical potential? Definition of the fugacity coefficient. She had me draw a P-x-y diagram, point out the bubble point and dew point. Then she asked a question about what equations I would need to use to find the composition of a given mixture at the dew point and a given pressure. We then ran out of time. Next, Clark asked questions about Kinetics: He had me right down the classic equation for a series reaction. I then wrote out the rate equations. I drew a graph on the board of the changing concentration of each of the species with time. Then, he wanted to know what my options were for a reactor (ideal reactors). What assumptions are implicit with these reactor types? Which reactor would I choose here and why? Then we fumbled through some questions about reaction order and mixing when we ran out of time. I felt pretty good coming out of this one and it turned out to be my best of the day.

Process Design (Iglesia and Lynn)

This one was no fun. It also proved to me I should have read over my senior design project a little more carefully. It started out okay as Lynn asked me about my design project and I gave my little five-minute spiel they expected. My project was on cheese whey ultrafiltration. Then, Lynn started to ask me questions. They started out easy, but got hard very quickly ... he asked very specific questions about the compositions of my streams and I told him I did not remember. He then asked me about the difference between Ultrafiltration and Reverse Osmosis (which sadly I did not know was the size of the solute molecule ...). Then, it was Iglesia's turn to take a crack at me. He asked me how I would get hydrogen for a fuel cell. I said from reacting steam with propane (this was the only process I knew). He did not like that. Instead, we went with methane. I managed to understand the reactions fairly well (Le Chat principle for endothermic reactions with more moles on the left hand side of the equation). I also brought out the water-gas shift and how it was exothermic and needed to be at lower temperatures. I also got hand guided into a discussion about heat integration. We ran out of time before we could talk about separating out left over carbon monoxide. He seemed disappointed, but I managed to pass. I thought this was going to be my worst one of the day, but I turned out to be wrong ...

Transport (Balsara and Schaffer)

One question: velocity profile of an infinite plate oscillating in an infinite media. Balsara asked the question and guided most of the talk. Schaffer asked questions when I did something wrong (which happened a lot ...). This exam was my last of the day, I was very tired, and I had put a lot of stress on myself because I thought I failed process design. I drew the profile on the board. They then hand held me through the general equation for the velocity profile. Then, I had to find out what the constants were in the general equation they provided me with. So, I started with the Navier-Stokes equation and the continuity equation ... BAD IDEA. We had done this problem in Clay's class last semester and I knew the governing PDE. I just should have wrote it down. Instead, I wrote down the Navier-Stokes ... or so I thought. I made like 4 errors in the equation, corrected all but one of them, at which point Balsara broke out BSL and proceeded to make fun of me for not having memorized the equation. Well, I eventually got the governing equation, solved

for the constants, and did everything they asked. I knew this had not gone well, but I did get through it and I never gave up. I thought that would have helped me to pass, but they failed me anyway. So, a few things I learned: (1) never use Navier-Stokes unless you have to; (2) If you do need to use them, make sure you actually know what they are EXACTLY; (3) If you think you failed an exam earlier in the day, let it go. You probably did not. Even if you did, it will only make it worse if you think about it.

Chris Roper

Transport (Newman and Radke)

Consider the Alaskan pipeline. How large do the pumping stations need to be? What is the temperature profile in the pipe? Consider a sphere of naphthalene hanging by a wire with wind blowing by it. How long will it take for the naphthalene ball to completely vanish? Describe the correlation used to estimate the mass transfer coefficient for this situation. Where do the constants in the equation come from?

Thermo/Kinetics (Chakraborty & Katz)

Consider an adiabatic PFR with an exothermic zeroth order reaction occurring. What will the conversion versus distance down the reactor profile look like? What situations could lead to a zeroth order reaction rate? Consider a well mixed polymer system made of two separate polymers. Below a certain temperature these polymers separate into two separate phases. Explain this phenomenon. Why does soap work (thermodynamically)? Why is the reaction rate constant an exponential function of energy? What is embodied in the pre-factor? Why is the kT/h term in front of the ratio of partition functions? Consider the momentum of the transition state. Will the TST estimated rate constant be greater or less than the experimentally measured rate constant?

Process (Prausnitz & Lynn)

Did you have any summer jobs and what did you do at them? What was your senior project? Draw the PFD and explain. Separating acetic acid from water is a common industrial problem. How would you do this? What kind of liquid absorbent would you choose and why? Why is a quaternary amine a good choice? How would you assure that the acetic acid did not dissociate? Explain the size of the activity coefficients of water in acetic acid, and acetic acid in the given solvent. What do you know about the J-T coefficient? How does liquefaction work? How would you liquefy hydrogen given the sign of its J-T coefficient? What is a more efficient process for liquefaction: constant enthalpy expansion or constant entropy expansion? Why is constant enthalpy expansion implemented more often?

Jingchun Zhang

Thermo & Kinetics (Arup, Peterson)

1. Derive the conversion of a volume-changed reaction.
2. Derive the conversion of PFR.
3. The fruit juice concentrating problem: derive osmosis equation
4. Soap problem: surface tension
5. Protein unfolding problem: entropy increase & volume increase

Process Design (Iglesia, Cairns)

1. Make H_3PO_4 from ore: complete process
2. Make H_2 in automobile: from methane, the reaction is endothermic and the heat is provided by combusting methane.

Transport (Newman, Graves)

1. Derive the boundary layer equation: why some terms are neglected
2. Arnold problem.

Joe Vegh

Design/Process (Cairns/Keasling)

(8:00 am is too early for design)

Tell us about your senior design project...My project was making ethylene by oxidative dehydrogenation of ethane via a fluidized catalyst bed reactor...I talked for a few minutes about the overall process, drew my PFD, and talked a little about why this was more preferred over the traditional thermal cracking of ethane, etc. Cairns asked me what was coming in and out of my reactor. Keasling asked me about the water gas shift reaction ($\text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{H}_2$), since I had a wgs reactor in my design. Cairns asked about how I separated out all the hydrocarbons in the product stream, so I went into more detail on my distillation train, the fact that it was cryogenic, etc...Then, Cairns told me that I should be concerned with carbon depositing on the walls of my reactor and pipes, and asked me where that carbon would come from. Cairns asked me to write down the equilibrium reaction for C(s) deposition, which, after I reasoned for a few minutes, and arrived at the point that the CO was the culprit, I eventually came up with $2\text{CO} \rightleftharpoons \text{C} + \text{CO}_2$, which Cairns told me was a very important equil. reaction known as "Boudart(sp?) Equilibrium". I told him that I was unfamiliar with it, and told him we hadn't considered that at all in our design. He laughed. Then he asked what might I do to prevent this deposition, and after I suggested a few things (based on pressure, Le Châtliers principle, Adding more O₂, etc) he told me that in practice, you'd add more water to your reactor inlet stream in an effort to push the wgs reaction forward and convert more of the CO to CO₂.

Keasling: Are you familiar w/ MTBE? I said, I think so, and I drew the structure, which we had just talked about during review the day before... Keasling took a few minutes and said... "yeah, I guess that's what it looks like." Then he asked about what it was used for (gasoline additive) and what the problem was with it (it gets into the ground water). Then he asked how we'd get it out of the ground water, and I pretty much named every type of extraction process I could think of, before I finally got to Activated Carbon (Cairns suggested I think about filtering drinking water). Then Keasling asked how Activated Carbon works. I tried to make it too complicated, when the answer they were looking for was that the activated carbon surface is hydrophobic, and tends to physically adsorb other hydrophobic molecules). This was a painful question to answer...Keasling was frowning most of the time, while Cairns seemed indifferent to my plight (although he did give a few hints). I thought I had failed this one, but I eeked by somehow and they passed me.

Transport (Muller and Balsara)

They pretty much worked together through this whole exam. Muller started by talking about how they were both interested in Rheology. Then, she told me I had an infinite plate with a semi-infinite fluid on top of it, and that the plate was oscillating horizontally at some frequency (i.e. $v = (v_0)\cos(\omega t)$). She then asked me to basically solve for the velocity profile. I started w/ Navier-Stokes, and cancelled out all of the unneeded terms, reducing it to $(\rho)(d(v_x)/dt) = (\mu)(d^2(v_x)/dy^2)$. (y was into the fluid, x along the plate) Muller then asked me about boundary conditions, and the ones they were looking for were no slip at the plate, and the fact that you can assume v to be 0 at an infinite distance from the plate. She asked me if I knew what the solution would look like if the plate was just at a constant velocity. I said I wasn't sure, but I told her you could solve it w/ a similarity transform. She nodded, and said that it turns out to be the error function. Balsara then told me to look at the boundary condition in the complex plane, and gave me the form of the solution assuming it was separable in the complex plane. From there, I just had to plug the solution form Balsara gave me ($v_x = A(\exp[\text{Beta} \cdot x] \exp[i\omega t])$), into the diff eq from navier stokes. Then, you can solve for Beta, which gives you two roots. this gives you a final solution of the form of $\exp[i\omega t](c_1 \exp[+\text{beta} \cdot x] + c_2 \exp[-\text{beta} \cdot x])$, applying the

BCs, this simplifies, and converting back into sin/cos from the complex form, you end up with a decay term and an oscillatory term. Muller then asked if I wanted to find the characteristic distance from the plate at which the maximum velocity was basically zero (say 5% of the max at the plate), what would I do. (look at the decay term, solve for x). Balsara was very helpful making sure I didn't make stupid algebra errors, and they readily gave me some helpful values (i.e. \sqrt{i}) and the fact that 5% is approx $\exp[-4]$. Muller then followed up by asking me if the system was a semi-infinite solid instead of the liquid, with the plate as a heat source, which was oscillating in Temperature, would this solution be any different. I just replaced my v's w/ T's and put alpha in the right place, and said no, you'd end up w/ this. What about if the plate wasn't flat? Would it still be analogous? I said, no, I don't think so. Muller chimed in and said, right, because you'll end up w/ a pressure term in the case of the fluid, which won't appear at all in the heat case. I finished this one fairly easily and quickly, so they let me go about 20 minutes early.

Thermo/Kinetics (Reimer/Clark)

This was the most conceptual of all my prelims, so it's kind of hard to relate the open ended questions they asked: Reimer started out w/ thermo: Given a canister that we hold at some pressure (so a cylinder w/ piston), we have two phases inside. Given the pressure outside and the overall temperature, how can we calculate the saturation pressure of the liquid. I began by saying that the fugacities of the phases were equal, Reimer slowed me down, and said, aren't you jumping ahead? So, I backed up and started by equating chemical potentials. Then, from the fugacities, I ended up w/ modified Raoult's law, and talked about how we can calculate fugacity coefficients. After I talked about Pitzer-type correlations and the law of corresponding states, Reimer asked me how else I could calculate them, and I said, directly, from an equation of state, and I wrote down the integral form of the fugacity coefficient equation. He asked me what EOS you could use, and I started talking about the Virial equation, and he stopped me, making a comment to the effect of "I don't want some semi-empirical equation that stat-mech people came up with to make them feel better about their results", so, I kind of drew a blank, but he prompted me to think about what eq's engineers use, so I said Peng-Robinson. Then Reimer asked me about chemical reaction equilibrium, given some reaction between dimethyl zinc and hydrogen selenide (which is used in thin film processes), he basically wanted the form of the K equation based on activities and from there we went on to standard Gibbs of reaction. How would I calculate it $\Delta G = \Delta H - T\Delta S$. I said we could get H from calorimetry. And so, he asked me how we define S (3rd Law) and how I'd calculate it for an ideal gas.

Clark: "Ok, let's take this reaction (the dimethyl zinc one), let's call one of the reactants A, and I want you to define some sort of kinetics problem from that in a tubular reactor. Let me know what assumptions you make as you go. I'll tell you that the other reactant is in great excess". So, I said that that would mean the reaction should depend only on A, and then I assumed it was a first order reaction in a PFR. We went from there to the PFR design equation, which I just wrote down, and which Clark was happy I "didn't waste 15 minutes deriving, although I'm sure you could derive it if you were asked to". (I nodded my head). He had me write down some other rate related stuff, and then asked me to look at the reactor if it were a packed bed, so we started talking about what would change. I mentioned that if you have diffusion into the catalyst, you'll see a different overall rate. We went from there to the effectiveness factor, he asked me some questions about the Thiele modulus, which I didn't have to derive (hooray)-is it big or small for diffusion/reaction limited, etc. Then he asked what would happen if we weren't diffusion limited at all, would the packed bed do anything to our PFR assumption. I said, yeah, it could lead to axial dispersion. How would you calculate the degree of dispersion? (RTD). How would you incorporate that into your design equations? (dispersion coefficient).

I guess that's it. Overall, I thought pretty much everyone was friendly and helpful, and no one really tried to trip me up just to watch me suffer, for the most part.

Nerayo Teclemariam

Transport: (Schaffer & Graves)

Graves: What textbooks did you use as an undergrad? Derive the Hagen-Poiseuille flow using a BSL shell balance. Asked me questions like what is that term, and why does it act over that area? List assumptions you made. Show velocity is constant from continuity equation.

Schaffer: If I took out a long beer can from a cooler and wanted to know how long until it reached a certain temp what things are important?

Thermo & Kinetics (Maboudian & Peterson)

Peterson: Write a kinetic equation that is valid for all reactor types. Write one for a PFR. What are you measuring and what is assumed in your equation? How would you alter the equations to take into account a mass change? He mentioned multiplying and dividing by density then you get a mass flux which comes out of the derivative and you are left with a concentration over density (moles over mass) which he said you could measure. Is $\text{SO}_2 + \text{O}_2 \rightleftharpoons \text{SO}_3$ endo or exothermic? Why is it important reaction? Used to make sulfuric acid. Plot K_{eq} (ie. % concentration of SO_3) versus temp and explain what is happening. Catalyst does not work at low temperature, what could you do to avoid reversible reaction? He mentioned staging but I didn't know what that was.

Maboudian: Write the 1st law of Thermo. Draw P-v two phase diagram and draw isotherm. Where does gas behave ideally on the graph? What criteria are need for two phase equilibrium? Draw a T-s two phase diagram and an isobar. Draw an refrigeration cycle on T-s diagram. Talked about this for a while. what if replaced turbine with a throttling valve? Why would you want to do that?

Process Design and Control (Keasling & Blanch)

Keasling: How were your design courses in undergrad? I used this to start talking about my senior design project (fuel cells). Jay asked me how a fuel cell worked? Then they looked at each other and said we can't test you on this so what are some ways you can get hydrogen? Do you know what MTBE is and why it is a problem? Draw a process to get it out of ground water? I mentioned activated carbon so they asked why does MTBE stick to it? After naming off every different force in the world, we ended up on London dispersion forces. How do these forces work? Instantaneous dipole.

Blanch: If I have 5% polylactic acid and want to concentrate it to 95% what would I use? I struggled with this one. Answer is liquid-liquid extraction. Draw polylactic acid. What happens when LA is in water? It disassociates. What type of solvent would you use? (strong acid). If I spilled some MTBE on the ground how long until it reaches 10 meters? What is characteristic time? Estimate the value of the diffusion coefficient? Time is like 10^{12} seconds. In the real world would the time be faster or slower? slower because MTBE would adsorb to soil. How would you solve the problem? similarity solution

Jeffrey Nye

Process Design (Prausnitz/Blanch)

Johnny wanted to know about my design project. I walked him through the first few units, stumbling a bit in my explanation of why we ran our reactor at a higher pressure. It turned out to be a LeChatelier thing, enhancing selectivity, but not conversion. Be sure you know the difference. Also be sure not to say "because it's common industry practice" and expect to get away with it. My process had an absorber with organic acids in it, which Prausnitz enjoyed because it let him segue into something he was just itching to ask. How would you reclaim dilute acetic acid from a water stream? Simply distilling out the water isn't cost-effective due to water's high heat of vaporization. Luckily an anonymous test-taker had warned me of this question in advance, so I knew to suggest extracting it with a high molecular-weight alcohol. It has to be a large molecule so it won't dissolve in the water, and the OH group gives it some polarity, helping it hold onto the slightly polar HAc. (A ketone would work too... know your organic groups). I was sure to point out that you could help things along by adding a strong acid to the water, which would shift the acetic acid's equilibrium to the non-ionized molecule, which dissolves more readily in the organic. Harvey then chimed in, saying that since both myself and Prausnitz went to Cornell, he would ask a question pertaining to Cornell's school of hotel management. I was

hoping he would ask me how to fold towels and bed sheets, but alas, he wanted me to design a piece of equipment to pasteurize eggs (which basically entails heating them to a certain temperature for five minutes). I started drawing PI control schemes, which is not what he was looking for. We chatted about different types of heat exchange equipment, and he had me draw some temperature profiles in a shell and tube heat exchanger. I eventually concluded that the best way to do it would be heating in a long, thin tube, which made him happy. John then had me quickly go over how to get 100% ethanol, and I fed him a well-rehearsed list of separation schemes. The context was for using ethanol as a gasoline additive, to replace everyone's favorite prelim chemical MTBE, so he asked me why we could care about removing that tiny bit of water. Having studied the different types of stainless steel the night prior, I started waxing poetic on corrosion issues within the engine. I think they enjoyed my performance, but would have been perfectly happy with me saying "it'd freeze" right from the get-go. This was easily my most enjoyable test. They were very friendly, and lulled me into a false sense of confidence.

Thermo/Kinetics (Reimer/Katz)

Reimer loves flash drums. So I knew right where to start when he told me a story about a pressurized pipe which breaks in two, leaving a puddle of liquid and a plume of vapor. I was doing alright drawing my T-x-y and P-x-y diagrams, but he tripped me up with vocabulary. He didn't like me using the words "vapor pressure" and "pressure at the boiling point" interchangeably. Or something like that... I can't quite remember. What I do remember is that, on my P-x-y diagram he asked me to draw what would happen if he increased the temperature. I stared at that damn dry erase board for what felt like hours trying to figure out if the two-phase envelope would be wider or narrower, and eventually just guessed. I was wrong. It gets narrower, the explanation of which Reimer very smugly said he would leave as an "exercise for the student." He then handed things over to his "good friend and colleague," Katz who asked me about an enzyme-mediated reaction. I threw up the Michalis-Menton whatnot, and talked about how it goes from zeroth order to first order, depending on substrate concentration. He then had me derive a mass and energy balance for a PFR with this enzymatic reaction. I got really flustered and screwed up what should have been an easy test. Rad? No.

Transport (Newman/Graves)

Newman asked me to draw the velocity distribution at the startup of couette flow, which was easy enough. He then asked me to draw the shear at the wall as a function of time for both the top and bottom plate, which was a bit trickier (look at the slope of the velocity distribution). Later, Newman asked about situations where momentum, heat and mass transfer weren't analogous, and I started rattling off things about radiation and electrochemical motility and so forth. "How about flow around a sphere?" he asks. "uhh..." I reply. I fumbled for a bit and he eventually just told me what he was looking for. There's no analogue to form drag in heat and mass transfer. Graves asked me the classic Si-SiO₂ wafer problem, which I thought I was ready for. Apparently, I was mistaken. I was spouting off boundary conditions and so forth, but Graves kept asking me "well how do you know that?" or "is that really true?" which really threw me off. I argued that flux through the SiO₂ layer is constant because everything that diffuses in eventually is reacted away at the Si surface. He wasn't happy with this, at all. He must have asked me "what are the characteristic times of this problem" on three separate occasions, and each time I replied "the time of reaction, and the time of diffusion". The characteristic time of reaction is much faster than that of diffusion, so no O₂ accumulates in the SiO₂ layer. It's an assumption you have to make, I claimed (and I still think I'm right). Eventually he got me to say that the real assumption is that the characteristic time of diffusion is much faster than the time of "SiO₂ layer growth". So the layer doesn't grow appreciably in the time it takes an O₂ molecule to get from the bulk to the Si. We never even got to assumptions about the surface... I got the impression that he would have loved to roast me on this question for another 45 minutes, if given the chance. The whole ordeal was terribly frustrating. Graves was being very condescending – whenever I did something right he quipped "well, of course, you must have seen this problem before" and whenever I did something wrong he would comment on how "elementary" the problem was. So I punched him in the face and asked what would be the characteristic time of me throwing him and his fucking sweater vest out the window. Then I kicked the table over and stormed out. I got my highest

grade of the day on this exam. Then I went to the Bears Lair with Ross and Kevin, and we got our picture taken for their weekly email newsletter.



Sarah Stewart

Thermo/Kinetics (Maboudian & Clark)

Maboudian asked about the difference between open/closed system energy balances, different work terms, the Carnot cycle & graphically determining something from the T vs S diagram. Can't remember what else. Clark asked about a tubular reactor, ended up adding things on to it as we went along. I ended up talking about the Thiele modulus and effectiveness factor. Needed to know about how the order of reaction affects those equations.

Process Design (Prausnitz & Lynn)

Design project. Haber Process. Separation of Air - why do you want to? Something similar to an azeotrope question about a mixture volatilizing.

Transport (Radke & Muller)

Diffusion through a stagnant gas film (BSL) - talked a bunch about the assumptions made. Next I got to choose - I picked macroscopic fluid dynamics - ended up with what I wanted: a Bernoulli problem. It was a big vessel draining into a small pipe - friction factor stuff was big. They were helpful, Radke interrupts alot.

Jessica Ryan

Thermo Kinetics (Reimer and Katz)

Reimer asked me about how i would determine how much of each compound would be in a certain phase of a liquid liquid mixture. he just wanted equality of chemical potential, fugacity, and hence the determination of activity coeff. to get this answer. then he asked about VLE. I drew a bunch of pxy, Txy diagrams, then wrote out fugacity equations. then he asked about deviations from raolts law. Katz asked about a hydrogenation reaction, and the rate being zero order and how this could be. I just wrote up a langmuir type isotherm equation and explained

how the hydrogen dependance can be divided out at certain pressure limits or something like that. then he asked about what affected the slope of the isotherm. I stumbled through talking about surface coverae, and all he wanted me to say was "how much the hydrogen likes the surface" End of story. then he made me do a differential heat balance for a PFR. It was sort of surreal since it was my first one.

Transport (Newman and Graves)

Newman was not so nice as you may have read. He was not very helpful, and graves was antagonistic when he told me that he didn't tell me that i could make the assumptions that i wanted to make. But the asked me about a wire wrapped in insulation. they argued about whether i had made a math mistake for a few minutes, then i finished...and graves said "i think she's taken long enough...it's your turn." So Newman asked me about flow through a packed bed, which is the one section of BSL that i skipped over. After not taking the hints well, Newman said "you don't know much about this now, maybe you'll learn about it in my class" and he proceeded to pull out a piece of dental floss and start flossing his teeth. I thought i had failed due to this bad omen, but they didn't fail me.

Design (Keasling and Blanch (wink wink))

I was last of the day. I talked about my design project. I answered every question they could have possibly asked while presenting this. Then they asked me how i would decaffeinate coffee beans. They were pretty surprised when i knew the answer. It's a long story, but use supercritical CO2 or hot coffee water. then they asked me how to purify some sort of polutant from ground water...activated carbon. I thought keasling was going to break out controls. Instead it was a bottle of wine, since his group was having cookies, so it was time for me to leave early and it was all over.

I storngly suggest getting hypnotized if you panic easily. I've never been so calm in my entire life as i was during these tests...I think it may have worked.

Ross Eppler

Design (Keasling/Blanch)

What was your final design project? (the separation of cheese whey) Various questions about the process stream composition, temp, pressure, membrane thickness, etc. In my design project I was given a spray dryer to do the separation. I had never looked at the specs on it or thought about how it worked. That being said I somehow stumbled through this part. For the second question I was asked about tri-chloro-ethylene contamination of groundwater. How is it removed? is it on the top or bottom of the aquifer? and so on. I think this one is in some of the older notebooks.

Transport (Graves/Schaffer)

Graves: Wet-bulb problem what is it? what does it measure? lumped model or gradient? how do you measure mass transfer, diffusion, heat transfer coefficients. What sort of analogies could be used to simplify this process? (Reynolds/ chilton-colborn)

Schaffer: Basically, derive the Hagen-Pousille Law for flow in a tube. His question was how to measure the viscosity of a fluid?

Thermo and Kinetics (Arup/Peterson)

Peterson: A strange question about convoluted design equations based on mass/density and not concentration. (multiply by molecular weight?). I'm not sure I answered this question entirely correctly, but I passed.

Arup: The question was about bubble formation draw a G vs. density graph. what accounts for the barrier. (interface formation), and a question about spinodal decomposition. I was a little miffed at Arup and these question because it was all grad level thermo.

Mahendra Chhabra

Transport (Schaffer & Graves)

Schaffer asked me to draw a oil drop in a pool of water and tell him about various forces acting on the drop (gravity, buoyancy & drag). He asked me to draw velocity profile of fluid in oil phase (oil layers move upward in the outer regions and comes back down from center of the top portion of the drop). Then, Graves asked me his standard question about SiO_2 formation on a silicon wafer with O_2 flowing over it (rxn. takes place on the surface of the wafer). He asked me to write mass balance and state boundary conditions (1 of the boundaries is moving with increase in deposition of SiO_2). He also asked to identify extreme conditions (diffusion and rxn. limitation).

Process (Iglesia and Lynn)

Lynn asked me to come up with a process to separate H_2S (1 mol), NH_3 (1 mol) and water (98 mols). I suggested membrane separation since we required high purity and discussed about membrane types to be used. He preferred to use distillation. Then we discussed how good will be distillation (NH_3 having a high solubility in water, would have less volatility as compared to H_2S so H_2S would come out at top of the column). Then, he told me write equilibrium rxn. between H_2S and NH_3 (forming NH_4^+ and HS^-). He mentioned that ions will have less volatility than gases. Iglesia asked me to design a process to make H_2 in an automobile. I suggested him to get H_2 by steam reforming using hydrocarbons. He asked about various rxns. which will occur. Reforming needs very high temperature which can be reached by burning part of the hydrocarbons. He was expecting me to consider issues to do all these on a small scale, but the time was over so we stopped in between.

Kinetics & Thermo. (Katz & Chakraborty)

Katz explained me about a system where $\text{A} \rightarrow \text{B}$ zero order gaseous rxn. was occurring over a Pt surface. He asked me to draw a graph of $\ln(k)$ vs $1/T$ (a line with negative slope). Then, he asked me about diffusivity dependence on temp. for gases ($T^{3/2}$). Then, he asked me to see the effect of diffusivity dependence on previous graph (diffusivity is a weak function of T than rate constant so curve will flatten out at high temp.). Chakraborty asked me about splattering when water is put on heated oil (it involved drawing gibb's energy vs specific volume graphs and explaining that there is a free energy barrier for water to go from gaseous state to liquid state though energy is less of gaseous state and as temperature is increased, it reaches spinodal temperature at which there is no free energy barrier). Water splatters if it goes above spinodal temp. Then, he asked me why there is energy barrier for transition even though energy is less of gaseous state (surface tension). They seemed to be very satisfied after this and they let me go.