Preliminary Exam January 2008

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Rob Carr

Transport with Radke and Chu:

This was my first exam so as I went into it I wasn't sure what to expect. All in all, it was fairly entertaining. I had it right before lunch so Chu and Radke were a bit tired and didn't have the energy necessary to hassle me too much. The entire session was fairly one sided with Radke asking the majority of the questions. Anyhow, the session started out with them asking me to describe what courses I had taken in transport and the texts that were used. A brief discussion ensued and then I was asked to step to the board. The first problem that I was given was two layers of immiscible liquids, water and mercury, which are in a container with a bottom moving at a speed, v_o. I was asked to guess a steady state velocity profile and for these fluids. I did this by drawing two linear profiles. Next I was asked to solve this mathematically. I started this by doing the Navier-Stokes equation and simplifying. In my final equation I had left the pressure drop term and Radke asked why. I said that I was not sure if it could be neglected. As it turns out, it can be since the top of the water layer is always at atmospheric pressure and the thickness of the liquid is constant. After doing the integration, Radke asked how many boundary conditions I would need. I said two for each layer, which he happily accepted. They were that the shear stress was 0 at the liquid/liquid interface and the liquid/air interface, the velocities were equal at the interface, and the velocity is v_o at the bottom of the container. Given all of this he asked me to adjust the velocity profile I had drawn, which turned out to be uniform. He asked if this bothered me. I said yes. He asked why. I said "intuition" which is apparently not a valid reason. He then led me on a journey to calculate the power needed for this to happen and it ended up somehow being 0. The reason is that there was no dissipation.

Having finished the first problem, Radke then led me into the tear film problem where there is a vertical water film on your eye. He asked to find the thickness as a function of time. I did this successful by using a shell balance (equate the flux to the change in mass). He then asked how I would find the flux. I described it by using a mass transfer coefficient which could be found from the Sherwood number. We quickly went over how to find the bulk water concentration (relative humidity) and the Sherwood number (correlations).

Kinetics and Thermo with Clark and Katz:

Clark and Katz were both pretty quiet during this exam, which provided for some awkward silences and me rambling on about various subjects. The first problem was a simple selectivity calculation for two parallel reactions. I went through the typical Fogler analysis of concentrations and temperatures to run it at. This naturally led to some discussion of the Arrhenius equation and plot. Clark then asked how else could we find activation energy other than experimentally. I shot an arrow into the dark and said transition state theory and managed to hit my target. Little did I know that I my target was a can of worms, because for the next few minutes we discussed transition state theory, a subject that I am not particularly well versed in. The next set of questions pertained to how the selectivity will change if the reactants have to diffuse into a pellet to react. The key was that the concentrations of the reactants change due to diffusion limitations. We did some discussion about the effectiveness factor and the Thiele Modulus and how they relate to each other. Finally Katz talked about "activated diffusion" while I nodded continuously. To be honest I still have no clue what it is.

My thermo question came from Katz in which he has a substance that he is going to put into a thermometer. He then has me draw a P-T diagram where the solid/ liquid coexistence line has a negative slope, like water, and asks why this is a bad material. I responded by pointing out that this

material will expand when freezing. I am asked to prove this based on the coexistence line's slope. This basically consisted of me deriving the Clausius equation and explaining that the entropy and molar volume changes that occur during freezing.

Design with Blanch and Alexander:

Both Alexander and Blanch were quite jovial during this examination, especially considering that it was the second day that they had been doing this. If you receive either of these professors on your committee, consider yourself fortunate because they are very helpful. Blanch started with a question concerning the production of Vitamin D which is produced by shining UV light on some reactant. Too much UV light causes you to degrade Vitamin D, and excessive heat causes you to decompose the reactant. We started with a general discussion of PFR versus CSTR. Although CSTRs are easier to control heat in (since they are well mixed), I chose a PFR since a smaller volume would be needed. After a bit of discussion, we decided on a quartz reactor that had the cooling water on the inside and the reaction occurring in the annular space. We also included baffles to increase turbulence and discussed the effect of residence time on the product concentrations.

Alexander's question was about mitigation of financial risk of a project that may be cancelled. He wanted to know what steps I could take while constructing my process. I said that you would want to design it similar to other processes you have that way if the project gets scrapped, it is easy to adapt and salvage. This was the correct answer, but since there was still another 25 minutes left, Alexander led me in a circle. We talked about the importance of speaking to others that had done similar projects. They can tell you about their successes and mistakes and can put you in contact with vendors. Then if you use the same vendors, you can buy similar equipment, which can be used by the other processes if your project is cancelled. Basically, the same answer I had given 15 minutes previously, but it made him happy, so I was happy.

Maureen Tang

Transport (Radke/Schaffer)

Standard chit chat about coursework, textbooks, etc, then they asked me if I'd heard of the Arnold cell problem. It's in Welty and I'd just done it the day before, so I thought I was fine and jumped into the shell balance for A diffusing up a tube into a stream of moving B. It was going ok but then we got into all the assumptions I made- why do you assume that NB = 0 in this problem? (answer: because if NA is constant, NB must be constant and at the surface of the liquid it has nowhere to diffuse to. If it's 0 there, it must be 0 everywhere). This took me a while and a fair amount of help to get to. I solved for the time to evaporate a given height of liquid, then we had a discussion about why it's ok to invoke the psuedo-steady state hypothesis (answer: characteristic time for diffusion, L^2/D, is much shorter than that for evaporation, $dh/dt/h$). Then we discussed some details about heat transfer through the tube, etc, and where gradients would occur. The final answer turned out to be something I wasn't supposed to know. "It's called little e, energy density. Look it up in BSL and get back to us next week." Uh, next week? "Yes, your remedial exam is next week." I didn't say anything but must have looked pretty pissed, since one of them pointed and said "Ha ha, look at her face!" Which must have meant passing, since making a joke like that to someone who actually failed would be in pretty awful taste.

Thermo/Kinetics (Iglesia/Clark)

I was all over enzyme kinetics, thermodynamics of folding, etc. but of course they didn't ask me any of that. Clark started out with $2A \rightarrow D$ and $A \rightarrow U$. How do we choose optimal conditions for the reactor? Assume elementary reactions, write out selectivity (rd/ru), find that we want to increase concentration. Which reactor would be better? I say PFR or batch, it's pretty much the same thing so then they asked

me to prove that. Why can we assume perfect radial mixing but no axial mixing in a PFR? I didn't know, but it's because reactors are always long skinny tubes. Going back to selectivity, we can manipulate temperature too. Some Arrhenius stuff (it's experimentally observed, but transition state theory shows a near match, except that A is linear with T and not constant) and then Iglesia asked me about thermo. If you put a hot sphere in a cold tank of water and the whole system is insulated, what do the first and second laws tell us about what will happen? Finally we want to find the activity coefficient of water. How can we do that if the vapor is ideal? Use modified non-ideal Raoult's Law. I couldn't remember the exact Poynting factor formula or where exactly it came from but they didn't look too upset and were still smiling when I left.

Design (Blanch/Schaffer)

Was supposed to have Reimer but got Dave again instead. This was the second-to-last exam of the two days and it showed. We started 5-10 minutes late, then spent a while discussing design at CMU. Blanch told me that since he knew I had a strong background in optimization, my problem was going to be MINLP, designing a HEN with 75 hot streams, etc etc. I told him I would remote desktop into the CMU server and plug the whole thing into GAMS. That went over really well. After that, the real problem was that we are making fresh water from sea water. We know we can freeze out golfball size chunks of clean water from the brine- how do we get the fresh water? I said filter them out, then rinse off. Then was a long discussion about how to melt the ice. You can't stick it in a tank and heat it because then you're relying on convection through air, which is weak. Putting the ice in water and heating means that we need to also maintain the sensible heat of the water, which isn't economical. Took me some guidance, but the answer is that you blow hot humid air over the ice balls to melt them to use the latent heat of water vapor. Some little questions about figuring the time to melt an ice ball (mass transfer, energy transfer, Chilton Coburn relation, etc). Blanch: "But those are all highly coupled, messy equations!" Me: "Yes, but we can still solve them, at least with a computer." They laughed at that for some reason. Then was a problem on making decaf coffee which I fortunately had read in a binder. Pointed out that while it's cheaper than ethylene chloride and nontoxic too, supercritical CO_2 requires higher cost equipment. and they told me that I was the only thing standing between them and finishing. I said no, Ashley's after me but I'm sure she'd be more than happy to start and finish early too. This whole exam was just sitting at the table and discussing- no board work.

Jerome Fox

Smit and Katz

Both Katz and Smit are helpful in letting you know when you are right; if you are wrong, they help you further or they stay silent. You definitely don't want them to begin giving you the answers, so keep asking questions if you aren't getting a particular question.

Katz began with chemical kinetics questions. First he talked about a paint can of length L. Inside this can, there was a species A that had a linearly varying concentration throughout the can (0 at 0 and Cao at L). Then species A began undergoing a second order reaction. I was asked to draw the initial concentration vs. position plot (a line with slope Cao/L), and then the same plot after time t (the concentration changes most at high concentrations [curve] and near low concentrations it has changed very little [almost the same line as before). Then I was asked what would happen during a real experiment. I told them that perfect mixing would not occur across the diameter of the can, and they asked what the effects of that would be. This took me a while, but they helped me figure it out: A is consumed even more quickly for higher concentrations than it would be if their was perfect mixing across a particular diameter (draw a curve that goes slightly below the earlier one). At one point—I

don't remember when—they asked me to do a balance around a volume element in the reactor; I started it—they just wanted to see if I could do it—and they moved on.

Smit began asking about thermodynamics by asking me to name my favorite equation of state. I wrote the Van der Waals. Then, he asked me to explain the a and b terms (b is for excluded volume, and a is for the attractive interactions between molecules). Next, he asked me to draw a P vs. V diagram for the equation of state. I drew it (this is a classic one), then I drew the arc showing the critical point, then a line for the Maxwell construction. This shows that pressures and temperatures are equal between two phases in chemical equilibrium (obviously, isotherm, and P axis); however, I was not sure how it showed that chemical potentials were equal. This has to do with the area under the curve (look in a thermo book); they helped me, though, and eventually got me to figure it out. Next, they asked me what the equation of state would be for a mixture of A and B assuming that I new what a and b were in the respective Van der Waals equations for both species. This took me a while, but eventually it came out. Both species contribute to a and b of the mixture in proportion to mole fractions for b and, I think, mole fractions times a^2 for a.

Prausnitz and Alexander

They began by asking me about my senior design project. I was an environmental engineer, so it was a green roof. Alexander asked me what the selling points were for such a project. We actually talked about this for about 7 minutes, which surprised me. Prausnitz moved on by asking me how to make ammonia. You don't need fully detailed diagrams for these; in fact, you could probably do it verbally (I drew the one for ammonia, and they said they didn't need it). Than, they asked me how I would get hydrogen and nitrogen (steam and a hydrocarbon, lined process etc.) Know the principles behind the Joule-Thompson coefficient for the lined process (should be positive, below inversion temperature, etc.) When they asked me about nitrogen, they asked me how I would separate the liquid air: rectifying column at a low temperature (nitrogen is lighter, so it boils first).

Alexander began by asking me how to separate two solids from each other: (1) melt both, cool slowly and let one crystallize out, (2) mechanically with a screen, (3) ionize one and pass through charged plates (similar to air purifiers in homes), (4) take advantage of a density difference (floatation). Alexander asked me what I would do if I had a pharmaceutical company that began work on a plant to produce drug C; this plant would take 12 years to build, and I could find out at any time that the FDA didn't approve my drug process. Build the plant, initially, similar to plants that produce drugs A and B (both are currently in production). This got us talking about other reasons to make the plant similar: reduce the learning curve of plant operations. Problems that are encountered will be similar to those encountered in another plant. On this note, we talked about moving knowledgeable workers from plants A and B over, also to reduce the learning curve. In order to prepare plant C to make as much of the drug as possible when the plant is allowed to start selling, parallel assemblies should be set up. Finally, I was asked about getting money today vs. installments. Know time value of money (concept, not equations), and know the rules that the IRS sets for depreciation.

Graves and Chu

Chu began by asking about a volume of water with a particular depth. Suddenly the plate at the bottom of that volume of water began moving. I was asked to draw the velocity profile. As it turns out, this profile is uniform: use Navier Stokes. Know why particular terms can be ignored. Know why particular boundary conditions apply (for example, at the interface of the pool and the air, equate the shear stress from air to that in water).

Graves asked about a drop of water falling in bone-dry air. How high does this drop need to fall in order to evaporate completely before it hit's the ground? This is a simultaneous heat and mass transfer problem (which I had never had before…Hurray for learning….). Draw a force balance (buoyant,

drag, gravitational) on the bubble and explain that the time of evaporation, solved for in the heat-mass part of the problem, could be used in conjunction with the terminal velocity to find a height. For the fun part of the problem (heat-mass) start with the convective mass transport equation (concentration in the bulk fluid [air] is zero). Explain how you would obtain the kc term using Sh = f(Sc, Re). You need velocity to do this, so you need another equation. Heat is being supplied to the drop through convection. The temperature of the air would be given, and the temperature of the drop is the wet bulb temperature (steady state, non-equilibrium temperature of a small amount of water evaporating adiabatically [I think]). Explain how to get h from the Nu = f(Re, Pr). Finally, you need to multiply the equation for convective diffusion times the latent heat of evaporation to link the two equations. Luckily, the Chilton-Colburn relation will still apply. In this exam, I felt like I didn't talk enough to show them what I knew (not that this wasn't hard for me). Several times, my not-close-to-correct answers elicited chuckles. At the end, I felt like I had failed; you can't always tell these things. In the end, know how to approach a wide variety of problems, but, particularly in transport, you will rarely have to solve a problem all the way through.

David Wong

Thermo (Smit/Katz):
    For this exam, Katz asked the kinetics questions and Smit asked the thermo questions. This was only Smit's fourth prelim, so he seemed like he was still feeling his way through the exam. I found Katz to be very helpful: he immediately let you know when you wrote an equation or a statement that did not apply to the problem. You did have to prove why it did not apply before he let me erase it and move on with the problem.

Kinetics (Katz)
- You have an ideal CSTR initially filled with a tracer at concentration c_0, at time t = 0, water is added. Solve for the concentration profile.
    - Since it is an ideal CSTR with no reaction occurring, you can set up a mass balance (in – out + gen = accum). Since there is no reaction, you can eliminate the generation term and just integrate the problem directly.
    - He then asked me to do some concentration profiles of an ideal CSTR and to compare it to that of a real CSTR. Also, I had to draw some concentration profiles for ideal and real PFRs.
- You have a reaction A $\leftrightarrow$ B $\rightarrow$ C. B is a reactive intermediate. Determine the rate of the reaction.
    - For this, you can generate equations for all of the rates (r_A, r_B, r_C) in terms of k_1, k_{-1}, and k_2. Then set r_B to zero because it is a reactive intermediate (using PSSH, know the assumptions for PSSH too). I made the mistake of writing $r_A = -dC_A/dt$, which only applies to batch reactors and he did not specify a reactor type.
Thermo (Smit)
- Name the three laws of thermodynamics.
    - After naming the first law (conservation of energy), he decided to ask me a question about it. He drew a hill and asked me to do the energy balance on a box being pushed from the bottom of the hill to the top of the hill. I wrote dE = dW + dQ, where E = m(U + $v^2/2$ + gh). We neglect dU, dQ (assume no heat loss), and kinetic energy. This leaves dW = (mg)dh. Thus, the work you do on the system is equal to the mgh. This is the part where I got confused – maybe my physics is rusty. He kept asking me if gravity was

doing the work or if I was doing the work. I said that it was me doing the work, but eventually he told me that gravity was doing the work. That discussion about who was doing the work went on for at least 5 minutes.

- Draw and label a P-T and a P-V phase diagram for a pure substance.
  - o I drew the P-T phase diagram, making sure to give the solid-liquid equilibrium curve a positive slope. Naturally, this brought up the question of why the slope is positive (changes in density for solids and liquids), and if I knew of any components that had a negative slope (water).
  - o The P-V diagram proved to be a bit more of a lengthy discussion. I drew out the P-V diagram with the solid, solid/liquid, liquid, vapor/liquid, and vapor regions all correctly labeled. However, I did not correctly label the solid/vapor area and he kept asking me about the unlabelled region that I had on my graph. Additionally (and I have never seen this labeled before), he asked me what the isobaric line between the L/V and S/V regions represents (each intersecting point represents the volume of a single phase – solid, liquid, vapor).

Design (Prausnitz/Alexander):

Alexander asked both of the questions for this exam. Before the actual questions, we talked about my senior design project (gasification of woody biomass to make ethanol) for 10 minutes or so. They asked some questions about how we broke the ethanol azeotrope (pervaporation) and why it is important to not have water in your engine (freezing). They had an interesting dynamic, and sometimes rather than asking you how to do something, they would just have a dialogue back and forth about the question and wait for you to pick up on the answer. This may sound obvious, but be quick. A lot of times they answered their own questions before I could because I hesitated and started trying to talk through it. If I had to take this exam again, I would focus a lot more on the specific names of a lot of separations techniques for all kinds of separations.

Design (Alexander)

- Solid/solid extraction. Alexander said he had a friend who wanted to know how he might separate a valuable solid product from a worthless solid.
  - o Size differences
  - o Density differences
  - o Electrostatic precipitation
  - o A selective solvent (ideally want to dissolve worthless solid so you do not have to recrystallize or anything else to get product back)
  - o I can't remember if there were more
- Temperature control for hydrogenation of benzene to get cyclohexane
  - o Write the balanced reaction (be sure to include catalysts – nickel, and the fact that you need to put in energy).
  - o The reaction is exothermic, so you have to worry about the reactants getting too hot and coking to occur. Alexander is specifically looking for the word coking.
  - o Some different mechanisms for cooling a PBR
    - ▪ Fluidized bed of catalyst
    - ▪ Staging injection points of hydrogen (to slow down reaction)
    - ▪ Break up PBR and put in heat exchangers
    - ▪ Some weaker ideas that I threw out there
      - Counter current heat exchanger shell with a tube going through it (too expensive)

- Spacing the catalyst out more to slow down reaction (really long PBR)

Transport (Graves/Chu):
        This was my last exam and the last exam for Graves and Chu. Graves really emphasizes justifying your assumptions. Both were in a good mood and we went off on a few tangents about random subjects (the test ran 10 minutes long, but nobody was after me). Graves asked me his classic Deal-Grove model problem. Chu threw me a softball Navier Stokes question, which was pretty sweet since I was already thinking about Bear's Lair.

Transport (Graves)
- Deal-Grove model: O_2 flowing over Si and forming a layer of SiO_2. As the SiO_2 layer forms, the rate of growth slows down. Initially, the rate grows proportional to t, but at longer times it grows proportional to $t^{1/2}$.
  - Three fluxes of oxygen.
    - The first is convective mass transport to the surface of the SiO_2 $N_{A1}=k_c(C_{A\infty}-C_{As})$, then there is some known solubility of A into SiO_2, which gives you some C_{Ai} on the inside of the SiO_2 layer.
    - The second is diffusive across the SiO_2, $N_{A2}=D_{AB}*dC_A/dx$.
      - When you integrate, you can use a constant x. You can prove this with a shell balance of O_2 on the SiO_2 layer. It's kind of a quasi-steady-state assumption.
    - The third is the reaction, assumed first order, $N_{A3}=-k_sC_{A*}$
  - Graves has done this problem a lot before and I think the solution is in someone else's prelims description.

Transport (Chu)
- Water on a flat plate. The other side of the water is exposed to air. What is the velocity profile? The plate is moving at a finite velocity v_0.
  - The velocity profile turns out to be that the water is moving at v_0 across the thickness of the water.
  - There are two boundary conditions.
    - No slip condition on the plate, so at y = 0, $v_x=v_0$.
    - At y = h (water/air interface), $dv_x/dy = 0$.
  - Navier Stokes simplifies to $d^2v_x/dy = 0$, which you can integrate twice and apply BCs to get that $v_x=v_0$.

Michael Nigra

Kinetics\Thermodynamics (Doug Clark/Enrique Iglesia)
1.   Drug added to the stomach (isothermal CSTR).
2.   Pure Substance: If I set the pressure, why is the temperature set (Gibbs Phase Rule)?
3.   Derive K = exp(-Delta(G)/RT) from first principles using chemical potentials?

Process Design and Synthesis (John Newman\Harvey Blanch)
1.   How do you make synthesis gas from coal?
2.   How do you recover CO2 from the air?
3.   How do you melt ice in an energy efficient manner?

4.   How do you separate a large equimolar mixture of two solids?

Transport (Clay Radke\Nitash Balsara)
   1.   Determine the diffusion coefficient through a membrane between two concentration cells?

Hannah Murnen

Design: Blanch/Alexander
First they asked about my design background which is pretty minimal. I mentioned that Dartmouth is really small and doesn't even have a chemical engineering department (just engineering) to get them to understand how minimal my background was. I mentioned that we had a small design project about a manure digester on a farm. That got Blanch to ask about cheese whey which I said you could add to your digester to increase your gas yield. He asked how you could change the liquids/solids ratio in the whey mixture, particularly the lactose part of it. After a bit of fumbling he got me to say a molecular sieve. He then turned it over to Alexander who asked about solids-solids separation. I said dissolve one of the solids in something, preferably the one you don't want. I then said exploit density differences. Have one settle out. Next, use the difference in size of the particles to sieve them. Then I ran out of ideas. Alexander said those were all great, you could also do electrostatic separation based on their charges. Then Blanch asked about freezing water out of saltwater. I had read this one so described ways to do it. He then wanted to know how you would melt it. After a bit of fumbling, we settled on using air which has water vapor in it. (Not steam because the latent heat of condensation is about the same as the latent heat of melting) We spent the next 10 minutes doing transport of melting a spherical piece of ice using the air mixture. It felt very much like a transport problem which we didn't actually solve. They seemed happy and easygoing. Blanch winked a lot. They let me out about 10 minutes early.

Transport: Chu/Radke
Everyone always says Radke is aggressive and asks a million questions but I really liked him. They asked me what books I used and how much transport I'd had. Then we moved on to the question which was the Arnold cell. I didn't know it was called the Arnold cell but it's basically a capillary tube that you fill with some liquid and then measure the height of the liquid as it evaporates. Air is passed over the top of the tube to move the stuff away as it evaporates. Basically you're trying to get the diffusion coefficient as a function of the change in height. This problem is in BSL so I won't write out the equations. Basically they just wanted me to go through all the equations with them. Radke would interrupt to ask about assumptions as we went along. All in all he was quite friendly and laughed a lot. Chu hardly said anything unless I seemed stuck or confused about what Radke was saying at which point Chu would try to reword it. This sometimes worked and sometimes I had no idea what Chu meant. They are a great pair.

Thermo/Kinetics: Clark/Katz
It was 3:45 on Friday and they were visibly sick of doing this. We started with a kinetics question. You have a membrane plug-flow reactor performing A→B. As you react B it is immediately removed through the membrane. Write out the concentration of A as a function of volume as you go down the tube. The key for this was just not to assume constant volumetric flow since B is leaving. You find the flow of B and then plug that back into your A equation. That was fine. Then they asked if I wanted to stick with kinetics or move to thermo. I said stick with kinetics. So we started talking about diffusion into a catalyst particle and how it changed with temperature. At one point I wrote down the Arrhenius equation and Doug asked where that came from. I thought I had read a derivation during studying, but couldn't remember. So I paused for a second trying to remember and finally just said "I think there's a derivation but I can't

remember it". Doug laughed and told me it was empirical. Katz asked about Knudsen diffusion inside the pore and had me draw a graph of lnK vs 1/T. All this was pretty straightforward. Then we moved to thermo. They asked me to write up deltaG=-RTlnK and we then talked about Van Hofft and how you get delta H's at different temperatures (use Cps). They had me draw a refrigeration cycle and do the first law for each of the steps and figure out how to find temperature drop across the condenser (I think it was use Cv's, but they worked through the equations with me). Finally there was about 15 seconds left and I thought I was done, but no….Clark asked me what Raoults law was. I slowly started to write it on the board and he said just give me an example of when you'd use it. I said if you have ethanol and want to know how much is in the vapor phase. He laughed and said, "great example for 4:30 on a Friday. Go have some ethanol." And that was that.

Brett Loveless

Process Design (Alexander/Blanch)

A jolly group, these two offered me a seat and some water before we started. They were amused at the fact that I did my undergrad at the University of North Dakota, so we talked a little about the weather, isolation, etc. Next we moved on to my senior design project (citric acid via microbial fermentation), and Harvey asked a few questions about how we isolated the product.

Harvey then tagged in Dr. Keith, who proceeded to fall right into his (predictable) spiel about the hydrogenation of benzene to cyclohexane in a packed-bed reactor. The first question was whether the reaction was exo/endothermic. I drew the reaction on the board, and pretended to think about the answer. I justified exothermic by the breaking of pi bonds (higher in energy) in benzene to form sigma bonds (more stable, lower in energy) in cyclohexane. Dr. Keith was impressed by my shoddy picture of pi orbitals and proceeded to comment on the 'new chemist in the room.'

Proceed to the actual design portion, where Dr. Keith asked about the consequences of this highly exothermic reaction. I drew a typical temperature vs length down the reactor graph, and mentioned thermal instability of the reactor, etc. He then wanted to know how to control such a reaction. Buzz words here are staged feed, inert packing, diluting the feed, and heat exchange.

It was now Harvey's turn, who wanted to purify ocean water in Saudi Arabia. Here we froze the water to form ice, and drained the tank to isolate our new drink-sicles. Harvey wanted to know how to melt the ice, so I mentioned the sun, burning some of the oil surplus, and steam heating. The latter two were unfeasible according to Professor Blanch, and after a few winks, he led me to the obvious answer…air! The concept is quite simple, as you pass the partially-humidified air (although we are supposedly in the desert) over the cold ice. The water in the air condenses, supplying enough energy to melt the ice in a 1:1 ratio (think heat of vaporization). This also washes away any residual salt left on your ice cubes.

Conclusions – Very relaxed committee, be thankful if you get them. And don't fear Harvey's winks, they will be the source of your knowledge when you get stuck.

Transport (Radke/Chu)

I walked in the Radke's office, sporting a tie for the final day of prelims. It went like this

Chu – Oh…nice tie
Me – Thanks; look good, feel good right?
Radke - …We'll see…

I went on to tell them about my background in transport (very limited, I could tell Radke was not impressed) and we were off. Chu had me draw a thin film of water on a solid surface, open to air. This is like the 2 plate problem in BSL, except the top plate is gone. He started pulling the bottom plate at a constant velocity v and wanted to know the velocity distribution in the liquid as a function of time. I gave the whole spiel of how the x momentum (in the direction of motion) of the plate is transferred in the y direction (vertical), and drew some profiles. Clay then wanted to know what the profile would look like at long times. I stated that the liquid would have the same constant velocity v as the plate, eventually. Although I was wearing a tie, those fellas weren't going to take everything I had to say as truth…I had to prove it. Pretty simple, used Navier-Stokes in Cartesian coordinates, cancelled terms, etc. Clay doesn't like writing the entire thing out and then crossing out zero terms, so he told me to just "write the answer already."

Next, we time-traveled to Arizona and our liquid film is evaporating. Clay wants to know the film height as a function of time. This consisted of me setting the flux of water into the air equal to the rate of evaporation, and solving. We then jumped into how to find the flux of water (he previously said that we knew, he was just interested in the film height). I threw mass transfer coefficients out there, and wrote the equation. He wanted to know where my temperature dependence in that equation was, and, after some squirming, he got upset and told me the answer. He then proceeded to hold my hand for a 10 minute journey into the world of relative humidity, where I stumbled on some of my definitions but did remember the ideal gas law. The point he was trying to make is that at the liquid/water interface, there is a sudden drop of concentration from the bulk water (pure) to the equilibrium concentration of the water in the air at your temperature. The concentration then decreases to the bulk concentration of the water in the air (very small related to the pure water). Think mass transfer through a film, and make sure you use your mass transfer coefficient in the fluid that has the concentration gradient (air).

Conclusions – Not a bad committee, don't let the lore of Radke scare you. He interrupts and questions a lot of your moves, so the key is to keep your composure. As for Chu, be surprised if he says more than 10 words.

Thermo/Kinetics (Clark/Katz)

This one wasn't pretty…it was the very last exam on the last day, and Doug Clark was not the happy man I once visited with Clark bars in his office. They asked me what books I used (Fogler, Smith/Van Ness), and Katz started with a Kinetics/Thermo problem. We had a reaction A → B in an adiabatic reactor with pure A feed, with the exit conversion known. Our problem? We didn't know what kind of reactor it was! Resisting the notion to "interrogate" the reactor like my good friend Colin about its functionality, I started with the good old first law of thermodynamics for an open system. Clark and Katz nitpicked every symbol, integration limit, and term in the equation. I was tripped up on Katz's wording for a while, and Clark looked like he was going to smash his head into the table in disgust. We spent a lot of time on this problem, as apparently its "fundamental" and the answers are "right in front of me (you)." Nothing difficult here, just remember that enthalpy is a state function and you can go from there.

Next up was refrigeration, and Clark gave me two minutes to explain it. I whipped up a quick vapor compression cycle and drew a pump where the expander was supposed to be. Doug was not happy

with this, and suggested I think about what happened between the condenser and evaporator one more time. Also, I had my heat reservoirs backward, and finally straightened things out…that the evaporation absorbs heat from a cold reservoir and the condenser rejects heat to a warm one. The astute reader might say, "Hey…doesn't that violate the 2nd law?" Well my friends, no, because you input work to the system via the compressor. I was then asked how to calculate the heat absorbed into the evaporator, and I drew an overall energy balance. Strike one. I then related the heat absorbed to the mass flow of the refrigerant times the heat of vaporization. Doug said we didn't know the heat of vaporization, which I thought was a ridiculous comment. Strike two. I never got to strike three, as we moved onto one more questions before they kicked me out.

The last problem consisted of two reactions, one angry Clark. The first reaction was second order in A producing the desired product, and the second one was first order in A. They had me write the rate laws, and wanted to know what kind of reactor to use to maximize A. I said PFR, because you want to keep your concentration of A high to push the desired rate. We then discussed why a CSTR is bad, and then we came to the batch reactor. I scratched my gross prelim-beard in contemplation, and Doug reminded me that we were almost out of time. I spit something out about how a batch reactor works, but I think he was looking for that the batch and PFR for a constant volume would be the same.

Conclusions – This one was rough, as I made some silly mistakes on a straightforward problem. Katz may confuse you on his wording, and apparently Clark is usually a nicer guy during the whole ordeal. This one was definitely the most uncomfortable of the two days.

Megan Hoarfrost

Transport: Radke and Schaffer

They had me sit down, and asked me about my background in transport (what undergrad school, which classes, length of classes, which professors, which texts, etc.). We chatted a bit about the professors, and then I went to the board. Schaffer asked me the initial question (which he admitted was the same one he'd been asking to the people before me, but was too uncreative to think of a new one), but Radke did more than his share of the talking. Like you've probably read, he likes to ask you little conceptual questions, or have you clarify your variables, or correct your negative signs, or whatever along the way.

Schaffer asked me the stagnant film question (it's in BSL on pages 545-50 - basically there is liquid A at the bottom of a capillary evaporating into gas B above it, and you need to measure the diffusivity based on the change of height). I set up the mass balance for the liquid substance A, explained why we could use the steady state approximation (diffusion time is much quicker than the time for the height of the liquid to change…you can arrange for this experimentally by increasing the length of the capillary with gas in it, and making the liquid height small), justified why the flux of the gas B is zero, solved for the flux at the interface, and then equated this to the change in the height of the liquid. They had me plot the height versus t, and explain why the height decreases more rapidly (rather than linearly, which is the solution you get) at long times.

Then they asked me about the temperature at the interface. It is lower than the bath, which apparently surrounds the capillary tube to keep the temperature constant, because of the energy needed for evaporation. Then I had to set up the energy balance, explaining the various types of heat transfer going

on: conduction through the liquid and gas (I had to reason why there was conduction and not convection based on there being a very narrow capillary tube), and the heat of vaporization.

That was it – one problem. It took the whole time since they asked me a lot of conceptual questions along the way. But they're plenty nice, and if they asked me a conceptual question I didn't know right away, they led me into how to reason it out. Don't be worried if either of them is on your committee.

Thermo/Kinetics: Iglesia and Clark

Clark asked me kinetics questions first. He described two parallel reactions, and asked me how to optimize the formation of one of the products. (Write out the selectivity equation, and describe how increasing/decreasing temperature or maximizing/minimizing concentration of A will maximize the selectivity.) Along the way, he asked about the concentration profiles in batch and PFR reactors, what factor affects their exponential decay, leading to the proposition that they will have the same concentration profiles plotted versus t/tau, about the Arrhenius dependency of the rate constant (and compared it to transition state theory), and for exothermic reactions, if you would want to cool the reactors (no if increasing temperature increased your selectivity, and vise versa). He then proposed running the reactions in a PBR, and how that would affect your selectivity. He wanted me to talk about diffusion into the catalyst particles, and how the diffusivity of the particles affects the concentration of A (if the diffusivity is high, you will have a constant concentration of A in the particles, equal to the outside concentration, which maximizes the concentration of A…if the diffusivity is low, you will have some exponential decay in the concentration of A, meaning your concentration is not maximized). I definitely needed a lot of leading from both Clark and Iglesia to get through this conceptual stuff.

Iglesia moved on to thermo. He asked me a simple first law question that I pathetically stumbled through. Q: If you drop a metal ball at some starting temperature T1 into a water bath at some temperature T2, what is the steady state temperature of the ball/bath? You calculate dU = 0 = Cv(T-T1)mass (ball) + Cv(T-T2)mass (l) or something like that. Then I had to calculate the change in entropy of the ball: dS = dQ/T = CvdT/T and integrate. Should have been way easier than I made it. He then asked me about Gibbs phase rule (Q: Why, if you have a container with water in equilibrium between gas and liquid phases, can you specify only the temperature or only the pressure, but not both? A: degrees of freedom = 2-phases +components = 1). And finally, he asked how you would describe the system with water and another component (set fugacity in each phase equal for each component), and how you would calculate the activity coefficient, assuming the liquid phase is not ideal (just had to set up the equation for the fugacities equaling each other).

They were both pretty nice, and helped when I was stuck. There wasn't a ton of positive reinforcement, though, so don't just think you're wrong if they don't smile and tell you you're right, haha. You're still probably right.

Process Design: Blanch/Schaffer

Professor Blanch asked me where I did my undergrad. I said Stanford, and he said, "Oh so you don't know anything about design?!" Ouch. He asked me to design a PBR for the exothermic benzene to cyclohexane question (a popular question of the day…think of ways to cool – interstage cooling with heat exchanger, create a catalyst gradient by packing in inerts, feed reactants into the reactor little bits at a time down the length of the reactor, etc.). Then he asked me to think of lots of ways to separate two solids (by density (gravity), size (filter), magnetism (magnets), solubility (solvent), etc.). I listed

several, but he didn't let me stop until I got what he thought was the big one – density/gravity. Professor Schaffer then asked me how to decaffeinate coffee. I gladly answered – using supercritical CO2. But then he asked me, okay, how would you do it with water? I stumbled through the process with a lot of help – dissolve everything in water, use liquid-liquid extraction to put the caffeine into dimethyl chloride, then dry out the coffee that is left to remove the solvents (and separate dimethyl chloride and caffeine to reuse dimethyl chloride). It caught me off guard because I was expecting the coffee question and so had prepared my supercritical CO2 answer. Oh well. Both Blanch and Schaffer were nice, and gave me lots of hints as to what kind of answer they were looking for.

Most important thing: be confident, enthusiastic about your answers, and never self-deprecating. It's really all about the attitude. If you've studied, you're going to be fine with the material (trust us, you will be), so focus on attitude on the day of.

Ting-Ying Chung

Transport (Radke/Chu)
The first question asked by Chu is two layers of immiscible fluids (mercury and water) on a plate, which moves in a const velocity v. The thickness of each fluid is L. The fluid is in contact with air on the top. This problem is somewhat like the one in BSL. However, the example in BSL is in contact with two plates on both sides. Don't be constrained by the examples and questions you have seen before. (I was, so I had a really hard time fumbling to the correct answer they want.) They asked me to draw the velocity profile of the fluid before solving the differential equation. It turns out to be a plug flow in steady state, which both of the fluid has constant velocity v as the bottom plate. (Surprising!) Then Radke asked how to determine the time needed before it becomes steady state. I said it must be related to the viscosity of each fluid. The correct answer is for each fluid, the characteristic time equals to the thickness of the fluid L^2 / υ. (square of the thickness / kinematic viscosity).
The second question is classic Radke question, dry eye. Assume it's a thin film and simply calculate the mass flux of the water vapor and correlate the mass flow rate to the volume change of the water film. Bear the mass transfer coefficient in mind because Radke want it in the equation instead of mass flux. This one was much better than the previous one.
Transport was my first exam, and I was really nervous. I think I was too nervous to clearly understand their questions. Radke walked to the board several times to help me out and give me clear hint. He is very pushing but still in jovial emotion. Transport is my favorite subject but I still messed it up. My hearty advice, be confident and be calm! Think hard and prove them you can think!

Thermodynamics/Kinetics (Clark/Katz)
1. Describing the melting behavior of water and deriving the Clapeyron equation.
2. Discussion of Arrhenius' law, which is the only temp dependent factor in a reaction. I said it is pure empirical, then Clark asked if it can be derived from any theory. Follow their directions, I drew a lots of reaction coordinates diagrams, exothermic and endothermic, struggling to figure what they were seeking. Finally, Clark told me that the hump on the reaction coordinate diagram called "Transition State" and Arrhenius' law can be derived from "Transition State Theory". That's the "magic phrase" they are looking for.
3. How to find the relationship of reaction constant k and temperature. Plot lnk vs 1/T and the slope is just –(Ea/R).
4. The final question was asked by Katz. The experimental result shows that for a heterogeneous surface reaction, the slop of lnk vs 1/T diagram flats out at high temp, acting like activation energy is

zero. Why is that? Compare the temperature dependence of diffusion and reaction. Both of diffusivity and reaction constant increase with temperature, but k increases exponentially, which is much faster than that of diffusivity. Thus, at high temperature the whole process become diffusion control and the slope of lnk vs 1/T diagram flats out.

Process (Blanch/Alexander)

Process is hard to prepare because there is no good textbooks for it. One rumor is that you should memorize all the processes of top 20 chemicals, which you could find in your prelim binders. None of those processes are related to my process questions.

1. Tell us about your undergrad design project. (5min)
2. Benzene + $3H_2 \rightarrow$ cyclohexane, occurs in a packed bed reactor. Is the reaction exothermic or endothermic? Exothermic, because breaking pai bonds would release lots of heat. Plot the temperature profile of the reactor. What would happen towards the end of the reactor? Temperature and pressure build up. Why does pressure increase as well? High temperature would crack cyclohexane and produce coke. Coking blocks the flow channels between catalyst particles and thus the pressure of reactor shoots up. What can we do to cool down the reactor? Use multiple smaller reactors rather than a big reactor and thus can apply inter-stage cooling. Use multiple supply of feed as coolant.
3. I have a big chunk of ice and want to melt it as a fresh drinking water. Provide an economical way to melt it. (Blanch) I first proposed to use waste steam, but Blanch was not satisfied with my answer. He said that steam is dirty and we cannot direct contact with steam and ice. The answer he wanted is that we can simply blow humid air around the ice. The water condenses and releases latent heat on the surface of ice, and thus melts the ice. The melting rate of the ice can be related to the mass flow rate of the humid air.

Joanna MacKay

Design (Blanch and Alexander)
I was the first to go. They asked me about my design background (which is nonexistent, I didn't even take a separations class, oops). I told them about a mini-project I had in which we tried to remove CO2 from the atmosphere to reduce global warming by bubbling air through a solution of Ca(OH)2, and how that was an awful idea. They didn't ask much more about it. Blanch started out by asking me about the hydrogen economy since I brought up global warming. He asked me about ways to make hydrogen. I said steam reforming and partial oxidation, and showed him the reactions. We then talked about whether hydrogen fuel is a good idea since you obtain the hydrogen gas from hydrocarbons anyway and make carbon dioxide in the process. He then asked for other ways to make hydrogen. Me: ummm… separate water with electrolysis? Then they wanted me to draw it out with the cathode and anode and write the reactions. They then asked for other sources of hydrogen. I had no idea so I mentioned how when you form double CC bonds, you get hydrogen, or maybe you could pull off protons from acids. It was obvious I had no idea what I was talking about. Then we moved on and Alexander asked about a fixed bed reactor in which we were making cyclohexane from benzene and hydrogen. He asked if it was exothermic or endothermic (exothermic since you are breaking double bonds). He then wanted a temperature profile down the length of the reactor (T increases, then k increases, T increases more etc, runaway problem) and we discussed problems such as coking, explosion. He then wanted ways to prevent runaway. I mentioned a cooling jacket and feeding reactants through the side (he wanted a T profile of this). He still wanted more ways so I mentioned a gradient of catalyst packed with inert packing towards the end of the bed. He said those were all good ideas, but what else. I mentioned

gradual feeding of cold inert gases or using catalyst that cokes less (They laughed and said yeah that would be nice). Alexander then wanted to know how I would determine the weight of the catalyst. I wasn't really sure why he asked this. I said just weigh some and test it out in a pilot scale reactor. He seemed okay with that and threw out the term "bulk density". Back to Blanch, he asked about an HCl absorber with water if we had a waste HCl gas stream. Blanch seems to ask about this a lot, so know it. When HCl dissolves in water, it dissociates and therefore the HCl concentration in water is always 0. We first talked about bubbling the gas through a tank of water: sizing the reactor, how you would know the mass transfer surface area, why the water heats up, boiling problems, what happens when the gas flowrate increases, etc. I stumbled through all of that but eventually got to the answers they wanted with some helpful guidance from Blanch. We then talked about an absorber. He asked for how to find the dimensions, which I never actually told him. I drew a picture with water falling down and gas going up, and talked about the mass transfer, and he had me draw a y vs x diagram with the equilibrium line and operating line. I had studied this question a little before so I knew it required just one stage, but I didn't really know what I was doing on the diagram. I drew a vertical line at x=0 (since the concentration of HCl in water is always 0) and he asked about the operating line. I said that was the operating line, and he said no, so I drew another line diagonally and he was okay with that. He seemed to be wanting more from me, but I wasn't really sure what to say. I forget if we talked about anything else, but they did let me go a few minutes early instead of asking more questions. Both guys were friendly and helpful. While Blanch left me hanging awkwardly once in awhile, if you make a few guesses, it's easy to read his expression and figure out if you are heading in the wrong direction or not.

Transport (Chu and Radke)
So Radke did all the talking. He started out by saying so I have this problem, that I don't know the answer to: I have a sphere of ice in a column of hot water, how do I know the distance it travels up before it melts away? Well, he had asked this question in previous years, and I had conveniently gone through it the night before... I started with a force balance (weight-bouyancy-drag) to find the terminal velocity of the sphere as a function of radius (which is changing due to melting). I set the force balance equal to 0 and he asked what it would be if it wasn't 0 (I said m*a, he asked what m was, I said m of the sphere, he said no it was a superficial mass that accounted for the water that would move, or something). Anyway, we set that to 0 and found v(r) using stokes law for the Fdrag. Next I did an energy balance around the shrinking solid ice (which is always at T=0C, so lumped capacitance). Since the temperature in the ice isn't changing, I said dE/dt=0=q"*area+deltaH_fusion*N"*area. The first term is the heat to the sphere from its flow upwards, q"=h(Twater-Tice), and the second term is the melted ice that is leaving the sphere as a mass flux, N"*area=rho*dVdt. From the energy balance, my goal was to get r(t) and plug that into my equation for v(r), which is dz/dt, then solve for z when the ball is completely melted. To get h, he wanted a Nu correlation which I said was 2+a number*Re^1/2*pr^1.3. He then asked me why it was to the ½ and 1/3. I of course had no idea, but he said something about a flat plate was Re, but folding it around made it Re^1/2, and then the Pr is to the 1/3 because the thermal boundary gets lost in the momentum boundary layer... I didn't really follow but pretended that I understood. He also asked me what the 2 was for (conduction), and then we dropped it out. So I used that correlation for h and started manipulating equations and solving for r(t). By that point Radke said he was tired of watching me do math on the board, and we moved on to talking about the moody diagram which came up with stokes law earlier. He asked me to draw it and talk about the linear area and the flat area, and what I thought various values were. I guessed, and he was fine with me guessing. (Don't worry, he didn't expect me to know details about the various regimes or anything too complicated.) We talked about form versus skin drag, and talked about how a car has most of its drag behind it as wake. Also, with stokes law he asked me what fraction was skin drag, what fraction was form drag. (2/3 form and 1/3 skin.) Overall it was a good exam for me. (I highly recommend going

through past test questions from recent years.) As for the people, Radke tends to talk the whole time and basically tells you how to do everything if you seem stuck. He's randomly picky at times about writing variables a certain way. Chu was his usual jolly self. He didn't say much but did pipe in once in awhile to correct my math. Both guys are very friendly and nice, and kept the mood light with plenty of jokes, mostly making fun of something I said, but in a good way.

Thermo/ kinetics (Clark and Katz)
This was my last exam so I was in a pretty good mood despite how awkward and painful this one went. Katz seemed like he was in a decent mood too, but Clark was not very happy and seemed tired of quizzing us. Katz started out with a reactor of unknown type with A flowing in, A$\rightarrow$ B in the reactor, and then stuff flows out at conversion X. We know Tin, but we want to find Tout and it's a liquid. So I said I was going to model it as a CSTR because it was liquid. He stressed that we didn't know what kind of mixing was going on, but let me continue with my assumption. I wrote the design equation for a CSTR, and then said I was going to assume first order kinetics. They didn't like me assuming this, but let me write it on the board as an assumption. I then wrote an energy balance as: $dE/dt=$ Fin*Cp*Tin-Fout*Cp*Tout+deltaH*r_a*V. Katz said I could assume steady state, and then both of them proceeded to pretend they had no idea what was going on in that equation and asked me every little question possible. We spent at least 20 minutes on this energy balance. They asked me questions like: What is Cp? Is it the same for the flow in and the flow out? (Cpin=Cp_a, Cpout=Cp_a*(1-X)+X*Cp_b) Why did you use Cp and not Cv? (huh? Because we always use Cp? I said we didn't know if we had constant volume.) We don't know the reaction kinetics, how are you going to deal with that? (r_a*V=X, so we don't need the reaction order and can just use conversion) What is deltaH? This was a long discussion on how if we had deltaH at STP, you could follow different paths of cooling your reactants to STP, carrying out the reaction at STP, then heating back up to T. They asked what T my deltaH was at and what would happen if we followed a different path, if I would get a different composition of products. It went on and on, and there were many awkward pauses, because really, it's just an energy balance, who thinks about this stuff? In the end he had me revise my energy balance to be: 0=Fin*Cpa*(Tout-Tin)+deltaH*X. 20 minutes just for that. And when these two ask you questions that you don't know the answer to, be prepared for some awkward silence before they say anything else to clarify. And they don't really give you hints, they just seem to ask more and more questions and let you struggle. So finally we moved on to another question, which went worse. Clark: we have a reversible reaction A$\leftarrow\rightarrow$B, how do we find the equilibrium? I wrote down K=k_f/k_r. He asked for it another way, so I wrote lnK=-deltaG/RT, and he wanted another way so I expanded that into H and S. He then asked, what is that deltaG? I said gibbs free energy for a constant T and P. He asked but which T and P? I had never thought about this before, it's just one of those equations you write down. He said, well isn't deltaG=0 at equilibrium? Wouldn't that make K=1? Me: yes, that's true but K isn't always 1… Clark: so how are we going to fix this? I had no idea what he was trying to get at. He had me write down an equation for dG and I fiddled with some of that for awhile. I brought up fugacity because I really had no idea what he wanted. He didn't seem to want to go down that path, but had me put up fugacity for a liquid and for a vapor. I put up some other random equations that also were useless. There was a lot of him staring at me, and me staring back looking very confused. Eventually he told me that the deltaG was deltaG_o at STP, and let us finally move on to something else. They discussed whether they should go on to a kinetics question, but Katz decided not to mix things up too much and just to continue from there. So more thermo… He had me draw a PT diagram and focus on the solid liquid boundary. Katz: I'm concerned about the slope of that line, how do I find it? Me: oh you want dPsat/dT? I then proceeded to derive the Clausius equation. I had written dG for each phase, and was about to subtract them when he realized I knew what I was doing and stopped me. Then Clark said we have water in a box, if I give you T can you tell me everything else about it? Well he just wanted the phase rule, so I did that out and showed dof=1. Then they dropped a

hot ball in the water, Katz asked what happens with the entropy? I said it increases and derived $dS=Cv/T*dT$ for constant volume. Clark then asked what's happening with the internal energy of the vapor? (What? What kind of question is that?) I didn't know what he wanted so I started writing that $dU\_total=0=dU\_vapor+\ldots$ and then he stopped me and time was pretty much up. Thank god.

Adrianne Rosales

Thermo/Kinetics – *Katz/Smit*
This was a friendly committee. They asked me questions using a "conference style" – we sat around a table and I used paper/pen (not a marker board) to answer their questions. Katz was very helpful and often rephrased Smit's questions so that they made more sense to me.
- PSSH/QEA assumptions & which is more general; qualitative arrow diagrams to describe reaction rates
- Mass balance/design equations for a leaky PFR
- Describe what happens when a hot metal ball is dropped into a cooler tank of water to high school students. Now describe it using the 1st and 2nd laws of thermodynamics. How can you find the final temperature of the water? What assumptions do you have to make?
- Describe chemical potential. What is an equation of state? Give an example of an equation of state. What is the theory of corresponding states? What is the dependence of potential energy on distance for two molecules? Relate potential energy to the van der Waals equation.

Design – *Alexander/Prausnitz*
Again, a very friendly committee. I think Alexander asks the same questions every year, so make sure you know them.
- Describe your senior design project (~10 minutes)
- You have 2 solids in a vial. How would you separate them? (Sieves, selective solvents, electrostatic precipitation, etc.)
- Hydrogenation of benzene – how would you control the temperature? What does the temperature profile look like for a PFR with feed added along the length of the reactor? Why does a fluidized bed have better temperature control?
- How would you find the bulk density for catalysts of different geometries?

Transport – *Graves/Chu*
I was the second to last person for this committee, so I think they were being particularly nice to me. They let me out 20 minutes early, and they only gave me one main question.
- Imagine you have a layer of water with a moving plate underneath and air above. What does the velocity profile look like? What does the shear stress profile look like? Set up the governing equations.
- Now say that you have a layer of a polymer melt underneath a layer of water. There is still a moving plate underneath the polymer layer and there is a fixed plate on top of the layer of water. Now what is the velocity profile? What is the stress profile (this ended up being a vertical line)? Set up the governing equations to prove it.

Sean Dee

Transport (Schaffer and Radke)

I walked in and Radke made a comment about how tall I was and that I need to do my prelim on my knees. What's your background – at CWRU, we had heat, fluids, and waved our hands at mass transfer and said it's just like heat with different nomenclature. Clay and Dave joke that they'll have to give me a mass transfer problem. We all laugh as I go to the board.

Radke then asks, "Do you know what an Arnold Cell is?" and in my head I wanted to smack him across the face. Arnold Cells are used to measure the mass diffusion constant with a T pipe, liquid A in the bottom, vapor B blowing across the top. I said yes, I know, and I know this is a mass transfer problem. I set up the problem and started by writing Ficks second law of diffusion. I wrote it in terms of Ca, Clay was displeased and wanted it in a "more correct form" so I wrote it in terms of xa. Clay then said he didn't like xa, use ya instead.

I then started making assumptions and crossing out terms. Every term I crossed out was an excuse for clay and Dave to grill me on why I could cross things out. I wrote continuity on the board and showed dNb/dz was constant, 0 at the interface, therefore 0 everywhere. They clay and Dave wanted to know why the problem was at steady state. They led me by the nose to compare the rate of change in the height of column A compared to the rate of diffusion of A through B to show verify my assumption.

Clay then took a step back and said "where are you going with this problem?" I said I wanted to solve the Fick's eq for Na, plug it into continuity and find Na as a function of position. "I thought we were trying to find Dab," Clay then scolded me for not knowing where we are going, told me to write a mass balance and "get out of the weeds so you can see the forest again." Dave said "I'm going to be a picky mathematician, are those partial or total differentials?" I said partial, but we've neglected all the other independent variables, which makes them "pseudo" total. So then I had to change all derivatives to totals, and I had a mass balance, ficks equation, and continuity.

I solved the series of equation and found Dab. At the end I was out of board space, and got on my knees to write on the bottom of the board and said "Well I guess you saw this coming…" and Clay laughed a lot harder than he probably should have. I solved the 2nd order diff eq by separation of variables. Then they said I could leave and they could tell I was disappointed I didn't get tested on heat or momentum. Clay said not to worry, for someone who learned mass transfer over the past 2 weeks, I did fine. Very helpful committee, but I was really nervous (first prelim). I don't think they want to see you squirm, but I think they find it much more entertaining if you are squirming. I passed, barely.

Thermo (Clark, Iglesia)

I walk in, asked background and books. I said Fogler and SVNA. Iglesia picks both books up off his desks and says if I need to look anything up, they're right there. I knew in my head that was a bunch of BS and told myself to just forget Iglesia said that.

Clark starts with kinetics. 2A → D and A→ U (desired and undesired products), in parallel. What are the kinetics? I assumed first order, clark jumps in and asks what inherent assumptions I've made. I said first order, he wanted something else. I talked about collision theory, he wanted something else. He starts saying something and I cut him off and say "elementary reactions" before he can say it. He asks about maximizing D, what parameter is it. I said I was going to maximize rd/ru and use Arrhenius rate law. He said "well yes, that has a specific name…" and I again cut him off to say selectivity of D,U. Clark then let me write the Arrhenius rate law on the board and asked what I was assuming, I talked about the

frequency factor, and said it modeled collision theory. Clark asks if Arrhenius derived collision theory, I give him a blank stare and said "I honestly don't know what Arrhenius did besides give us this equation for kinetics." Clark remarks that its agrees with collision theory, but its more derived from experiments. Back to the question, I show ultimately what I need is a difference in activation energy between the two reactions, Iglesia says EaD is higher, so I have an exponential to a negative number over T. I fumbled saying if you increase T, the selectivity gets bigger because your exponent gets less negative, which is bigger than a more negative exponent. They were as confused as I was with the math, Iglesia makes me draw an ln K vs. 1/T plot. I said since the larger slope is more sensitive to temperature, we want to move to the left on the graph and decrease T, (they reminded me it was 1/T and I wanted to increase T). Clark asks if a CSTR, Batch or PFR is better (PFR or Batch, higher concentration of B, but again, I had the right reasoning, but muttered the wrong answer). If the reactions are exothermic, should I use isothermal or adiabatic (again I gave the right reasoning, muttered the wrong answer, back tracked with clarks help).

Iglesia asked me a question about dropping a ball into an isothermal/adiabatic constant V container with liquid. I wrote the first law and second law. He said he wanted temperature changes. I started wrong and was writing entropy changes, restarted, and got to an equation with temperature changes $(mc*cpc(T-Tc) = mb*cpb*(Tb-T))$. Iglesia asked me about entropy changes, for the system, ball and liquid. I said "My intuition says…" and Iglesia cut in and said "We don't care about your intuition, we care about the right answer." So I politely told him that the ball loses entropy, cup gains entropy, and since no heat is lost to the environment, the overall change in entropy for the isotherm/adiabatic/constant V system is 0. I did some more deriving, and got an increase in entropy for the ball. I immediately said that wasn't right, the ball is losing entropy. Clark asked for a "physical" explanation and I talked about decreasing T puts atoms in more stable states with lower entropy. I then realized I had switched the levels of integration on dS and I had actually found –Delta S. They were happy I caught my mistake and let me go.

Design Blanch and Schaffer

Talked about my senior design project for about 10 minutes, Blanch liked that because he worked in a penicillin plant a long time ago. Went over everything for how to penetrate the market, to design issues, to how the course was set up. Talked about my co-op experience and internship background (they thought I had taken two years off between undergrad and grad, but I had just co-op and worked every summer). Blanch asks me his classic vitamin D question. UV light reaction, use a PFR with a lamp in the middle. What do you build the lamp casing out of? I said glass, they said it absorbs UV (they asked if I get tan in a car with the window up, I told them I don't tan , I burn, and I can easily become burned in 15 minutes of sun exposure so I didn't really know. I said to use some polymer that wasn't going to absorb UV light, they didn't like that either. Quartz was what Blanch wanted, and he told me outright I should use quartz.

We then talked about cooling the reactor, put another shell of quartz and flow water thru it. We talked about what to do if the length is too long (make a multiple pass PFR). They asked about getting a 15 minute resonance time, I wrote pass*length/pass * 1/velocity on the board, strictly because it had units of time. Then they asked would I want turbulent of laminar flow. Turbulent so its plug flow and you can maintain no gradient of reaction in the r direction. Then they said I couldn't change the v or D and was stuck in laminar flow, how do I mix it. I said you could decrease the roughness of the pipes, not good enough. I said baffles, blanch leaned back and smiled satisfied.

Dave says "lets ask another question," with his wry smile. Blanch didn't think we needed another question, but we had time so Dave brought up decaffeination of coffee. Since he was on my transport committee the previous day, I thought this was a low blow since he knows I don't know anything about mass transfer. I said I wasn't sure how the process thing worked, said I'd probably use extraction to try to coax the caffeine into some other solvent. He asked what solvents to use. I gave him a dear in a headlight look and said "supercritical CO2" because I read it in a previous exam question. He then grills me on what's so great about supercritical CO2. Do I know the Temperature of supercritical CO2, no. Do I know the viscosity of supercritical CO2, no. What dimensionless number describes what we're looking for in this mass transfer. I said Sherwood, Dave says no guess again. I said maybe Schmitt if we're worried about heat transfer, he says we're not. I ask if caffeine is leaving via reaction and we're worried about the Thiele modulus (whose pronunciation I completely butcher and Dave and Harvey laugh). He said no, he was looking for the Nu number, and my brain was so focused on getting out of there so I could start drinking, I didn't realize I could have told him that the mass Nu number is the Sherwood number. We talked about problems running with CO2, particularly Pressure. I talked about pressure drops in extractors, cost of having pressure rated vessels, and safety concerns with exploding equipment and injured employees. They let me go, and I swore if I failed transport and process, I was going to make my job to explain the Sherwood number to Dave before I had to retake prelims. Lucky for Dave I knew the UV question and passed.

Georges Siddiqi

Clark/iglesia – thermo/kinetics

Started off with a question about kinetics. You have take a drug, and in your stomach it undergoes the rxn A -> B+C. you can model your stomach as a cstr. First they asked me what the RTD (or conc profile (forget which)) looked like. Started by deriving the governing equations and grilled me on all the terms in there. Apparently, even though they told me it's a cstr, we don't have any flow in, because once you take the drug, it's in there's no more coming in. So we have an unsteady state cstr with no flow in and a rxn. Some more grilling about IC's. apparently at t=0, the concentration is Cao, because you can assume at t=0, the drug is fully dispersed through your stomach but reaction hasn't started. Some more grilling, asked to sketch RTD for pulse of inert material in CSTR, then sketch what it would look like if there's a rxn. I just drew it as dropping off faster.

Then onto thermo. They started out with sone arbitrary rxn at equilibrium, and me how I'd derive the Keq fom fundamental values (or something like that). Stumbled around a lot, eventually figured out that μ(reactants) = μ(products) at equilibrium. To make things easier, I drew up an arbitrary rxn aA +bB -> cC + dD. Then from there μ(react) = μ(A)+ (b/a)\μ(B), same for products. Managed to remember μ= μo + RT ln (PA/Po),plug all that stuff in. don't worry about solving exactly, but notice that once you combine terms etc you get something like μoA + μob- μoc- μod = RT ln (all the P's /Po raised to the exponent of their stoich ratio). Then they pointed to a equ I had written in previous stumbling delta(G) = RT ln (keq). So the P/Po junk looks a lot like Keq, but what about the μoA etc. isn't the delta G supposed to be 0 at equilibrium? After A LOT of wrong answers, I finally got that I had written the original equation wrong, it's delta Go that little circle means a lot apparently, and means it's NOT 0 at equilibrium.

All in all, they were both very helpful, and gently pushed in along in the right direction. Iglesia was a lot less scary than I expected lol.

Blanch/Reimer(Reimer was replaced by Newman tho) – process

Two very nice, very helpful people. Started off asking me about my senior project. They nitpicked it for 5 min, then moved on. Newman started it off saying he wanted to get CO2 out of air. After listing off random ways, I suggested absorbing it onto a solid. They asked what solid, I guessed CaO, cuz I remembered u can form CaCO3. they seemed to like it. Asked for balanced rxn, and all that good stuff, got it wrong a few times, but eventually got it. Next they asked what kinda reactor I'd use. I said a pfr packed with pellets of CaO. They seemed to like that too. Next they asked what do you do when all the CaO is reacted and ur left with a pfr full of caco3. I figured it's bad to toss it out (newman mentioned something about wanting to be frugal), so I said let's regenerate it. They then asked how, with some rxns. I remembered that when u pour acid on caco3 it bubbles, they seemd to like that too, so something with HCl on caco3 (I've reforgotten wtf it was), regenerates it. A few more random q's about the design of the reactor then we moved onto blanch.

Blanch set up a series of rxns (making vitamin D or something), A -> B -> C, and these were driven by UV light, then A -> D which is driven by heat. You want to maximize the production of B, and minimize all the rest. I kicked it off by choosing a PFR b/c it'll allow you to make the reactor just long enough to maximize the prod of B and minimize C. Now, how to make the reactor so that UV light can get in? ->> clear reactor! Now, what type of material allows UV light to get in. Not glass apparently, and not plastic, he hinted something about UV vis spec and what type of container you use, and a random memory from an ochem lab got triggered and I guessed quartz. Blanch winked joyfully. Now how to control the heat so that you minimize D? I went through the usual junk with cooling the inlet, spacing out the feed through the length of the pfr, putting in a cooled recycle. They seemed to like that. Next blanch asked to draw the velocity profile in the tube, it's a maximum at the middle of course. And he pointed out the fact that in the middle, the fluid's moving the fastest and also receives the least light, so the rxn wont be that good. How to fix that? I suggested putting a tube in the middle, but what he was looking for was baffles (wanted to keep the flow laminar too). Then I was done.

Balsara/Radke – transport

Usual chatting about which book/profs u had. Then up the board I went. Balsara kicked it off with one hellova question: what is the density profile of air in the atmosphere. Wtf??? He told me to assume earth is flat, neglected heat difference, and apparently neglect the diff in gravity from the surface to the top of the atmosphere. Again wtffff. I tried to bullshit my way through this, but they nitpicked the hell out of anything I said, and after some amount of time that I'm not sure of (I still hadn't gotten it), they saw I wasn't getting anywhere near the answer and had me move on. Radke asked I have a falling ball in air, how would I find the time for it to reach the ground. Started off with a good ol force balance, mass * accel = Fgravity + Fbuoyant – Fdrag. Or something like that. I guessed at of stokes law, the walked me through the units to see if my guess was correct, then once that was done (took some time), they asked what I would do next. I said we know all the F's, we know the mass, m = dv/dt, v = dx/dt, solve that shiz. So we moved on. The ball was now heated to a certain temp, what would its temp be when it hits the ground. Ball was copper, so I approx temp profile in ball as being uniform, blah blah. Then I set up a heat balance. More awkwardness with the units and the equation (I suck at memorizing), then I said we get heat loss per time, we know the time from before, voila! Well not quite, asked B.C.s and other shiz. Then balsara asked another question (GAH!), have a tank, perfectly stirred, separated in 2 halfs by a porous membrane. One side at t=0 has a conc of Co, other side has a conc of 0. set up a mass balance around just the membrane, worked through it, lotsa nitpicking, then they asked me about the BCs (and

ICs). Man did I mess that up. The bcs were a function of time, and other stuff. Then time ran out, in all I solved the problem decently, but with a LOT of stumbling. I felt the best about transport going in, but felt the worst coming out. I did pass it tho.

Ashley Fritz

Transport – Graves and Muller (First Day)

I was the last of the day, and both seemed to be in a pretty good mood. They asked who I had and what books I had used. Muller started off with a problem I guess Graves had been giving throughout the day – A wire with current running through it. I wrote down the governing energy equation (i.e. they never made me do a shell balance). Assumed steady-state so all that remains is a generation term and the conduction term. Went through that math, and used boundary conditions to determine the constants in the equation – one boundary condition was the convection term at the outer radius. They asked about what was usually in the empirical relations for forced or free convection: Nusselt as a function of Prandtl (forced), Reynolds (forced), and Grasholf (free). Talked about the Nusselt number and the Biot number – what h and k was of in each (Nusselt is the same material, but the Biot is the external and internal resistances so the h and k are of different materials). This also led onto a tangent of French people liking dimensionless numbers along with other tangents. Like I said, they seemed to be in a good mood. The next problem was a diffusion boundary layer problem with a homogeneous reaction occurring throughout the layer, A -> B (I don't think it was reversible, but I can't remember). I wrote down the general equations again, assumed equimolar counterdiffusion for the flux term, steady state, and the reaction remained since it was within the control volume. There are two of these equations because you can write them for both species. However, the fluxes are related, so you can substitute them into each other (which leads you nowhere, everything cancels). I think they took most people down this path. You can go back and solve one of the equations for one species and you'll get what you were looking for. Boundary conditions, starting concentrations at the outer layer and no flux at the solid boundary. They asked me what would change with the boundary conditions if a reaction was occurring at the surface. Then a little more random discussions (about the name Ashley), and they let me go. This was surprisingly fun, and both helped me work through the problem. So, essentially I was never stuck staring at the bored. If only I could say that about my other prelims.

Thermo/Kinetics – Iglesia and Clark (Second Day)

I was pretty nervous about this one, and their demeanors didn't help too much. I was the last person before lunch, and I think they were already tired on their second day of quizzing. Asked me to talk about what I've taken which was relatively short (and I think I was their only Levenspiel person for kinetics, and I don't know if that changed my questions any). We started with kinetics with Clark doing most of the talking. Parallel reaction of 2A to B and A to C. Want the formation of B – what do we maximize (the rate of formation of B over C), which leads to the fairly common question of how temperature affects the problem, activation energies, and concentrations affect the problem. Want a high concentration of A (want PFR/Batch) which led into a discussion of how PFR and Batch are similar. They were a little thrown off by me just writing the general design equations down. Asked me about the derivations of equations – which led into the aspect-ratio discussion of PFR and why we can assume there is radial mixing, and no axial mixing. I didn't fully understand the way Clark asked it so they probably had to ask it about three or four different ways. Eventually, Clark gave up and just said the key phrase he was looking for: "aspect ratio". Oh, there was also a discussion on finding the activation

energies, which I also struggled with. I did a great explanation on how to find the heat of reaction (cause I was really looking for anything at that point), but I'm pretty sure you can just take a lot of data points, and using the Arrhenius relationship, you can find it. Possibly. Anyway, Iglesia took over thermo stuff with about 10 minutes left. Closed system, a hot ball is in a fluid – wrote down the first law. How to find the final temperature – used heat capacities with mCdT (after messing up my differences of temperatures, which I at least caught before they did). Then a solution thermodynamics problem with modified Raoult's Law. Then some discussion on how to find the activity coefficient (measure everything and find the deviation from ideal Raoult's Law). Then there was a question on how the activity coefficients were related for the two species in solution. I didn't know. Iglesia said I ought to go get lunch. Got some consoling after that, and prepared myself for my last one. I did manage to pass this one, even if I did feel I spent a good twenty-five minutes staring at the board.   A lot of this was just plain basics, I expected a little catalysis or something that relied on the basics, but it was pretty much a thorough look at the basics, and I wasn't too prepared for that… nor did I study solution thermodynamics. This was a pretty painful prelim.

Process Design – Blanch and Reimer (Second Day)

I was the last one again. Blanch and Reimer were both in a good mood. Schaffer had replaced Reimer for this round of testing, but had to come back for me, since Schaffer is my advisor. Asked about my background, during which I said that my design class wasn't very intensive – it was during the summer before I came to Berkeley. Mentioned that involved syngas conversion to ethanol of cellulosic materials from a pulp mill, but that's about as far as I or they cared to go. Reimer started off with my one and only problem which involved absolutely nothing I studied about design. A drug company has extra drug sitting in a warehouse and finds that the concentration has increased, and they want to build a process to recycle the drug (something expensive like human growth hormone). He had a sheet with solubilities, melting points, densities, etc. I could ignore any metal backing, but there was a plastic pouch, sugar packed with capsules filled with drugs. First, I washed the drug off, said I could use some kind of robot to punch the hole and get the drug out to which Reimer suggested shredding the entire pouch, which is what I changed my design to do, then could do a density separation where the plastic would float and the capsule would sink, sugar would dissolve. He had messed up the units on the density, but basically water would work. Fractionate off the plastic, fractionate the majority of water and sugar mixture – put it through evaporators and then a crystallizer (oh, a crystallizer, how about that… I totally blanked during the prelim), then you can take the fractionated drug + capsule and put it back through the original process. We talked about economics of building this process vs. tossing out the drug (I brought up environmental concerns, but I don't know if they were as concerned with that). What if it was something like aspirin? (i.e. the economics would greatly change, the hormone would be much more expensive than aspirin) Blanch talked about the FDA a little, they'd have to reapprove the process. Talked a little about costing and what kind of data I'd have to give to a shredder manufacturer in order to price it. That was it, and I headed off to the Bear's Lair. I think these two grade a little harder than they let on, I felt that I picked up on things quickly enough, but I got the same grade as I did on my horrible thermo/kinetics prelim. Oh well, it was a pass.

Wei-Cheng Lien

Transport
1. How to make the airplane fly? What is streamline?

2. You have to parallel plane, the bottom one is move with the velocity Vo, and the upper one remains fixed. Draw the velocity profile from time = 0 to fully develop. Find the expression of the velocity profile.

Thermal and Kinetics
1. Find the temperature profile of the non ideal reactor for Steady-state, no shaft work, adiabatic condition.
2. What is the enthalpy unit? What is the carnot cycle? Give an example using carnot engine.
3. Do the mass balance of the ideal plug flow reactor.

Process design
1. How can we separate the two solid particles?
2. What is the lactic acid? How to separate them from the water? Liquid-liquid extraction is not economic. The answer is electrodialysis.
3. PBR question. How to control the temperature inside the reactor? Pretty much the same with last year.

Jo T.

Thermo-Kinetics (Clark and Iglesia)

Clark first asked about the refrigeration process (know P-V and T-S diagram, process flow diagram, how they are correlated, efficiency, how is it useful, how does it work). I stumbled initially by labeling the axes of my T-S diagram incorrectly, which threw off several of my other answers. Iglesia asked a very basic question about the derivation of a PFR mass balance equation (perform a differential volume on a PFR to get the design eqn. for PFR, its one thing to know an eqn. but another to understand how one derives it).

Process Design (Newman and Blanch)

Blanch asked how I could separate $Na+CH3COO-$ sodium acetate (with $H2SO4$, for example) and extract acetic acid (know the full balanced equation). Since the anion of interest is in salt form, we can use a form of ion exchange separation using ion exchange resins with tethered functional groups, which can substitute the functional group from the incoming feed. (There are multiple answers to this separation, so know more than one for how to make a specific compound.) You'll need to also know how to extract the resulting acetic acid. Newman then asked about how to remove $CO2$ from air. ($CO2$ composes very little air and can form $H2CO3$ flue gas)

Transport (Radke and Balsara)

Balsara asked the question about a square system divided by a membrane, permeable to salt, with the upper half consisting of pure water and the lower half consisting of salt and water. They wanted to know the eventual diffusive profile of concentration over time. Radke asked about the derivation of the shear stress associated with a air-liquid-flat plate system with the flat plate moving at a velocity Vo and wanted to look at the solid-liquid and liquid-air interfaces (look up what makes the no-slip condition at the solid-liquid interface true).

Sam Maurer

process design
reimer/prausnitz

First one, for me and for them. We spent about 5 minutes on my design project, which was absorbing CO2 from scrubbed flue gas using an aqueous K2CO3 solution. Papa Prau asked if there were any other ways to remove CO2. I said that you could also use aqueous monoethanolamine, which has a similar mechanism but is more toxic. He then asked if I could think of a way to do it other than "AB-sorbing." The first syllable was about 20 times louder than the other two, so I took the hint and started talking about AD-sorbing to a solid in a packed bed. When the packed bed gets saturated, switch to a clean one, and regenerate the one that you're not using. They didn't want to know about the chemistry of the packed bed, which is good, because I had no clue.

Then Reimer gave me his problem. You have a ready-to-sell drug, which consists of capsules (drug encased in polymer) suspended in a tablet (sugar) which is surrounded by packaging (polymer). You found out that each tablet contains too much drug, so you want to separate every component so you can reuse it. How do you do that? I started with the easier task of separating the capsules from the sugar tablet--dissolve the sugar in water and filter the capsules out. Then you can just reuse the capsules without having to extract the drug from inside of them. For separating the tablet from the packaging, I proposed putting it in a shredder, then adding water (plastic floats, tablets sink), but I wasn't sure if you could effectively chop up the packaging this way. Reimer went off on a delightful tangent about how there was a plant in Richmond that used a giant "cuisinart" to chop up refrigerators, but then a lot of dust got into the air and clogged up some pipes, and then the plant exploded and killed several people. But he said a shredder would be fine for my process. After I messed up the final step of removing sugar from water (apparently filtration is cheaper/easier than crystallization?) Papa Prau said, "okay, you did very well, you can go."

I never stopped talking for more than two seconds throughout the entire prelim. When I didn't know something, I proposed a method that I knew wouldn't work and described why it would be bad. Reimer seemed to like that. Overall, the test was a lot of common sense, brainstorming, and relating Reimer's open-ended problems to things I already knew how to do.

transport
balsara/graves

Yeargh, this did not go well. After exclaiming, "Radke lab? Whoo, transport city!", Balsara started off by asking "a very simple problem" about the force involved in couette flow between parallel plates. I should have known it right off the bat from definition of viscosity, and I think that's what they expected, but instead I went all crazy deriving the velocity profile from navier-stokes, and then I got confused between tensors and vectors, and because I had assumed infinite plates in my navier-stokes analysis, but eventually I got to it by relating shear stress to the velocity gradient. Then they wanted to know something about what if it weren't a fluid, but a perfectly elastic solid? I suck eggs at solid mech, so I just babbled for 5 minutes and said nothing worthwhile. I think the answer is that the solid is deformed as the top is dragged along by the moving plate, and then it eventually stops, because F=kx.

Then Graves asked the silicon dioxide growth question (see BSL), which I had just looked at last night, but still screwed up. He got kind of mad because I was implicitly assuming the mass diffusion equation

instead of writing it out. Turns out mass diffusion is your diff eq, the surface rxn is your boundary condition. HINT: Don't say something like, "intuitively, I know the concentration profile is linear" because it ends up making you look stupid instead of making you look like some awesome transport badass to whom answers are intuitively obvious. Anyway, I passed, so I guess I got far enough to satisfy him.

Both seemed a little bit grumpy, but that was probably just their disappointment in my poor performance, because they were in a good mood before I started. These guys were not helpful, though, and there were a lot of awkward silences as I dug myself deeper and deeper into an abyss of transport. Did you know Morton M. Denn used to have Balsara's office?

kinetics/thermo
iglesia/smit

This wasn't so bad. Smit asked me about a hot sphere that you put in a mass of cold fluid. What happens, based on the first and second laws? Blah blah, say that entropy increases, heat goes from hot to cold, eventually T1=T2. All stuff from my 240 notes. It was weird, because sometimes we were talking about a gas and sometimes we were talking about a liquid, and I was never sure which. Then he showed me a PV-diagram and asked me what the observed pressure would be as you compress a gas very slowly. It took me a while to figure out his hints, but I eventually said some stuff about the first and second derivatives of the pressure that I believe was accurate.

Iglesia asked me about two reactions: 2A => D and A => U. How do you maximize selectivity for D? I rock at selectivity, so I was pretty happy. My big mistake was forgetting some terminology. If you can look at 2A => D and write down $rD = kA*cA^2$, the reason is the "law of mass action" which works for "elementary reactions." He also drew a plug flow reactor and wanted to know why you can neglect diffusion/backmixing in the direction of flow, but assume perfect mixing in the axial direction. I talked about how transport due to the flow is much larger than transport due to diffusion, but Iglesia was looking for the fact that the length scale in the z-direction is much larger than the length scale in the r-direction. Other questions: what happens if the activation energy of 2A => D is higher? Should I run my reactor isothermally or adiabatically? Which is better: PFR or batch? They are the same.

I have a habit of repeating the question I'm asked to stall for time, and Iglesia did not like that at all. Smit was fine with it. They were both pretty helpful when I got stuck. With Iglesia, it's better not to assume anything and to ask a lot of questions early in the problem (what are the kinetics? what are the activation energies?). And don't BS anything, because he can stare into your soul.