Preliminary Exam January 2009

Compiled by Anton Mlinar

Anthony Conway

Transport - Chu/Radke:

Chu opens the door to Radke's office, grinning ear to ear, he sets the mood for the upcoming 45 minutes. I take a seat and they ask where I went to school and what transport classes I had taken. Radke seemed impressed that I had 4 semesters of various transport classes. He also wished me congratulations for some reason, I first thought he was congratulating me about getting this far…but I realized he meant on UF winning the national championship a week or so back. This led to him and Chu quizzing me on the four teams that were in the NFL playoffs still, which I had no idea. I somehow came up with the answers and he was pleased. They also quizzed me on various other trivia for god knows what reason, like who was the Secretary of Energy – "Steven Chu of course!" I replied. Then I went to the board and he asked me to draw a flat plate moving at constant velocity U that had water on top of it open to air. I had to draw the steady state velocity profile (constant value of U throughout water) and what the power would be to allow this to happen (dWork/dt=Fdx/dt = 0 since dx/dt (velocity) is 0). I had said 0 for another reason but he had me do another case from which then I got that above formula. Then he said the water was evaporating since the relative humidity of the air was only about 10%, the bottom plate is still moving. The height of the water layer is decreasing very slightly with x, but it is decreasing linearly until it is 0 at the front of this semi-infinite plate. You have to do a shell balance on the mass flux of the water going into x – water coming out of x – water coming out of y (at height H(x)). The flux is assumed to be primarily convective, thus write down kc(Ca_s – Ca_infinity) = Nax. Ca_s is changing with x since the height is changing with x, and Ca_infinity can be obtained through relative humidity (have to know partial pressure of water in air at specified temp). Nay is equal to the mass flux of water lost through evaporation which is put into the formula Nay*deltaH_evap =h(T_s – T_ambient). He had me draw the temperature profile in the y direction (decreasing linearly in the water film then curves back up to T_ambient in the air). Plug Nay and Nax into original flux balance equation and you can get H as a function of x (messy solution since T_s and Ca_s are changing with x and y – he told me the next student would have to solve it, "good one Radke!!!!"). Then there was a round of high-fiving and chest bumps, which stopped shortly after Chu's massive frame knocked me down and Radke said we were out of time. Overall very good committee, they have a great dynamic and joked a lot and helped you out as you went. Chu didn't really say much, other than validating my correct answers or pointing out my wrong ones.

Thermo/Kinetics - Smit/Bell:

Terrible exam. Smit does not smile throughout the whole thing and Bell, despite his gentle tone, gives you the weirdest looks when you are up at the board – probably because I was doing things totally wrong. Bell asked the kinetics questions, something about rate laws and the temperature dependence of k and the preexponential factor significance, since as T goes to infinity k can't be 0. I just wrote down all the graphs I could remember, morse potential, Arrhenius plot, that one with the probability vs. energy at various temperatures, which you have to say the probability term is normalized by dividing it by some value of energy so that integrating the equation from 0 to infinity will get you a value of 1 with dimensionless units. He then asked me a PFR question for a rxn of O_2 dissociating into $2O$, he wanted the conversion as function of length down the reactor. Note here that volumetric flow rate is not constant (it is increasing? since 2 moles are being produced from 1 mole – not sure, you should look it up) so that will go into your equation. He stopped me at this point and said we needed to move onto Thermo. Smit asked me about a system of liquid hexane underneath gaseous CO_2. The vapor pressure of CO_2 is 56 atms, the system is at 1 atm. Temperature is 20C. How do you find solubility of one in the other. Do Raoult's Law, I would suggest writing the most general form since I at first assumed it to be ideal and he made me derive somehow what it would be if it wasn't, which shouldn't have been difficult it just tripped me up at the time I guess. If you assume ideal x_{CO2} = 1/56 assuming y_{CO2} is 1. At that point time was up and I proceeded to jump out of the third floor window of Gilman.

Process Design - Alexander/Blanch:
A good duo, I was expecting and exorbitant amount of blinking from Blanch but did not notice any, either because I was doing things wrong or it was too early in the morning. Anyway, I sat down and he asked where I went to school and what my design background was. I said oxidation of ethylene to make acetaldehyde, which was primarily HYSYS based and probably the dumbest class I have ever taken. So we moved onto the board and Blanch asks me what reactor and cooling scheme would I use to make vitamin D, predictable question. Both precursor and D break down with heat so you need to cool it sufficiently. Draw profile of T vs. reactor length. I messed up on this one a lot, but I eventually just said put in interstage heat exchangers to cool the liquid so that the temperature doesn't rise too much and you get a constant increase in D production (assuming you have enough precursor). Draw a T vs. r profile. If you say the uv light to create D is coming from a concentric tube in the middle, and a cooling jacket on the outside the radial T profile would be T almost constant near the middle and dropping dramatically near the outside radius. Of course mention uv has to pass through uv permeable substance (fused silica like in UV spectrometers or quartz I think is the same thing). Say stuff about baffles to increase residence time and promote better radial mixing. Next Keith asked about wanting to separate 2 granular solids, one is worthless one is valuable. Use differences in density, magnetism, charge (like in an air filter), size, solubility. Density you entrain the solids in air and use centrifugal methods to separate it out, for size you use a industrial sieve (like in a garden Blanch compares it to) to scoop out your larger particle from a batch of both of them, and if you do selective liquid

extraction make sure you solubilize your worthless solid so you don't need to recrystallize your valuable particle. Blanch then asked how you separate CO_2 from air (adsorption to activated surface – expensive, absorption tower with water – how do you separate this CO_2 laden water now?, there are also other methods you should look up). And then what is CO_2 used for primarily (not labs since that is a very small amount, think trees!). Keith also mentions something about oil or fuel recovery using CO_2 or something. At that point Blanch was jonesin' for some coffee so he said I could go 15 minutes early so I scurried out of there saying to myself I better have passed since letting me out that early and failing me would be the most unfair thing ever.

Joe Lee

Transport - Chu/Radke:
This one happened in the first slot of prelims. Radke started off with asking for the velocity profile of a plate with a layer of liquid and then air above it. I saw the problem before and blurted out that the velocity profile was constant. Bad move, cause from the boundary conditions alone, you can't determine that, so I proceeded to justify my statement with the Navier-Stokes equation. Along the way, Radke nitpicked at the way I drew my picture and the symbols that I used. I stumbled a little bit when he asked me how to find the power needed to maintain the system at steady state, which ended up being zero. Chu asked about the characteristic time for the system to get to steady state, which I answered (height of liquid)^2/kinematic viscosity. Radke then made the problem more complicated. His explanation was so vague that it took me 10 min just to understand what was going on. He kept asking for how the height of the liquid changed along the length of the plate, but he neglected to mention that the exposure time of the liquid was longer as you go down the plate. The height of the liquid was supposed to drop along the plate as a result of this. Every time I tried to ask if that was the case, he kept interrupting by saying that there is no time dependence because it was at steady state. I had to rephrase what I meant a few times in order for Radke to finally confirm that what I had was right. By the time I got it across to him, the test was almost over. I barely had enough time to write out a balance to explain the profile.
I didn't get a good grade for this one, most likely because they misunderstood what I had meant when I tried to explain what was going on in the second part which wasted a lot of time. Most likely, it would have gone better if I wasn't the first one to go. Radke was a little intimidating, especially when you don't explain what you mean in his mindset. You were also expected to answer pretty quickly; otherwise, Radke would interrupt with a hint. Chu mostly just sat back and looked happy.

Kinetics/Thermo - Bell/Smit:
Bell and Smit seemed to give me a lot of time to think, which I kind of felt was bad at the time compared to how quickly I had to perform during the transport exam. Bell started off with the reaction rate of a simple A -> B reaction. I explained that at the beginning of the reaction you would get a second order reaction at low concentrations of A and a

first order reaction at high concentrations. Then, I proceeded to write out the rate equation to prove it. Bell asked me why the reaction could remain first order at longer times (Because B particles could collide with A and give A enough energy to react). Bell then asked me how to find activation energy theoretically. I honestly had no idea what to do at this point, so I guessed. As soon as I said "transition-state theory" Bell was like "How?". At this point, I realized that I had blundered, and I said "I don't know." Bell then started explaining how you would find it with what seemed like collision theory and Boltzmann distributions of velocity needed to get enough energy to react. I followed along as best I could, but I had no idea what was going on. Finally, Bell said to move on. Next was a simple PFR design equation in which I almost forgot how to write, so I kind of fudged one of the steps to get to the answer. Bell noticed something weird, but decided to leave it alone. Moving on to thermo, Smit first asked about the vapor mole fraction of a tank of pure hexane, which I used Raoult's Law to find. Then, he asked whether it would be different for hexanol, in which I said it would be the same. I explained that it was this case because Raoult's Law assumes an ideal solution in each case. The modified Raoult's Law would be needed to account for the different activities of the two liquids to find the difference. Smit took that explanation well. Then, he proceeded to ask about a tank with A and B in it at constant T and P. After some stumbling, I realized that he wanted me to find the Gibbs free energy change of mixing those two together. I wrote down an equation for that from Smith and Van Ness, but they seemed to want a different equation. I wrote deltaG = deltaH – T*deltaS. Then, he wanted me to derive this. I had no idea what to do.
Me talking to myself too loud: "This wasn't in Van Ness…"
Smit: "But Jhih-Wei explained this in thermo, right?"
(Crap!)
Then time ran out. I thought I had failed because there were a lot of blank stares and quiet moments during the collision theory part and the deltaG part, but I ended up doing the best on this one.

Design - Segalman/Prausnitz:
Segalman and Prausnitz were both pretty nice during the exam. I talked about my research project which was separation of butadiene and production of MTBE. They asked me what these products were used for. Then, Segalman asked about a filtration system for a fish tank to separate solid waste, urea and carbon dioxide. We talked about how you needed to filter out the solids first. It took me a few tries before I could think of using adsorption with activated carbon to get out the carbon dioxide and urea. Then, we talked about having another adsorption chamber in parallel so that you can clean one of them while still having the other in operation. I was mostly lead through this part because I had never heard of pressure swing adsorption. Then, I was asked about desalinating salt water. I first talked about evaporation, but that required a lot of energy. Segalman then asked me to draw out an evaporator system. It took me a moment to realize that she wanted the exact diagram that was in one of the prelim binders. I went back to naming other ways to desalinate water. I answered "with changing osmotic pressure," in which Segalman said, " that's called reverse osmosis." So

then, they wanted to know how most pressure was needed to do this. I said 10 bar, which they accepted. Prausnitz ended with me drawing a diagram of a fuel cell and explaining what it essentially does.
Coming out of the exam, I thought that I did decent, but I had in fact barely passed. Thinking back, it seemed like they docked a lot of points off for not knowing keywords of certain processes. I felt like I had decent conceptual explanations of the processes, but I had trouble using the right terms to express what was going on.


Eddy Kim

Transport - Chu/Radke:
Overall: Radke likes to do these things in a step-by-step manner. You're not expected to go from the starting–point to ending-point all on your own…in fact you probably can't, because Radke will stop you every so often and give you hints and comments to get you to where he wants you to go for the next step, which is good I guess. Was a pretty relaxed atmosphere.

Radke: Tear film problem.
You have a layer of water on your eye that has a thickness H. Will your eye dry out in the 15 seconds between a blink? How is H changing as a function of time?
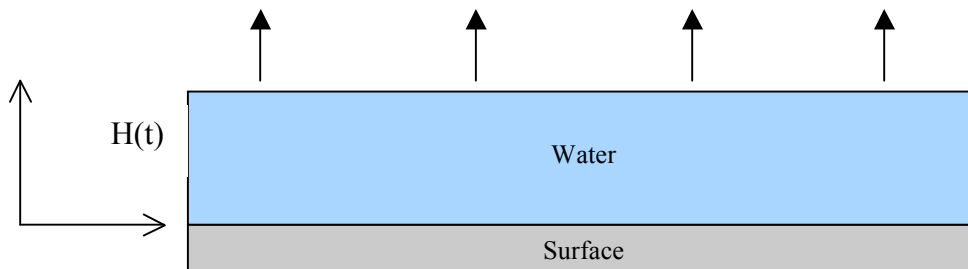
a) We want to model this for any condition, standing, running, etc. What would be the worst condition be? Where you have the most convection, i.e. running.

b) Draw what you think the concentration profile might look like.

   i.   For the thickness of the film, the concentration of water is constant (assume 1 g of water, concentration or $n/V = (1\ g) / (18.0\ g/mol * 1ml)$ or 55.6 mol/L).
   ii.   At H, we now have water in the vapor phase diffusing up into the air. The concentration can be found by p^{sat}.
   iii.   At y goes to infinity, we can find the concentration by the relative humidity of the air.
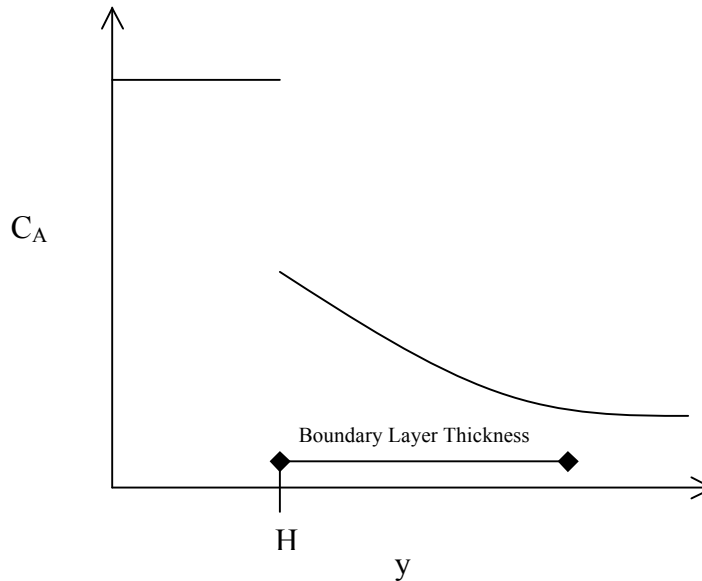
Can you draw on this graph the height of the boundary layer?
Beyond the boundary layer is what we consider the bulk, and inside the boundary layer is where things are still changing. So on the graph, the boundary layer is the region before the concentration reaches about what the concentration is at infinity.

c) Okay, so continue to solve the problem.

$$N_A = k\,(C_{A,H} - C_{A\infty})$$
$$N_A = k\,(p_{A,H}\,/RT - C_{A\infty})$$

You can relate the flux to the change in height by a mass balance.

In – Out + generation = accumulation.
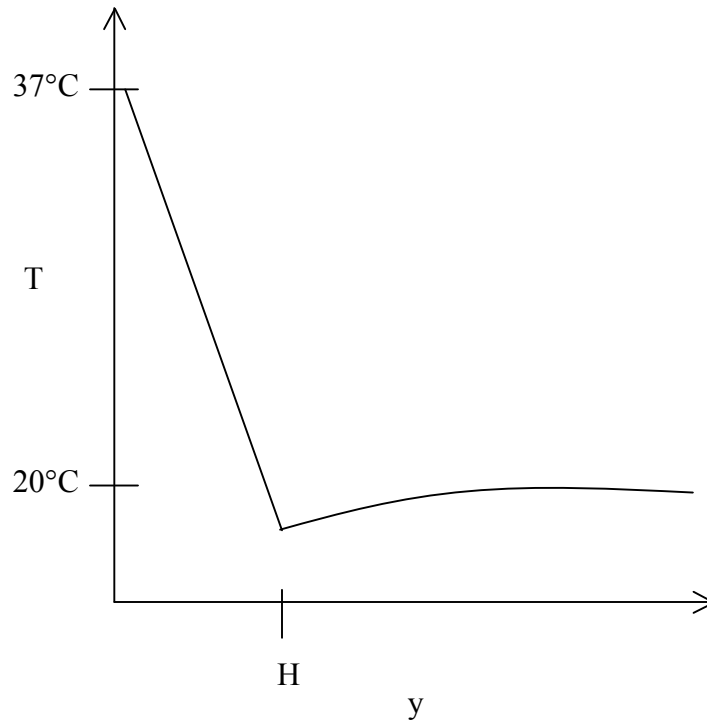$$0 - AN_A + 0 = dN_A/dt$$
$$AN_A = -dN_A\,/dt$$
$$AN_A = -(1/MW)\,dm_A\,/dt$$
$$AN_A = -(\rho/MW)\,dV_A\,/dt$$
$$AN_A = -(A\rho/MW)\,dH_A\,/dt$$

However, back in our expression for N_A, the vapor pressure of water $p_{A,H}$ depends on temperature.

d) Let's say the surface (your eye) is at 37°C, and the air is at 20°C. Draw what you think the temperature profile may look like.

Sort of ran out of time so not sure if this was entirely correct. But, for the layer of water, it goes below 20°C because as the water evaporates, it requires heat to do this.

Kinetics/Thermo - Smit/Iglesia:
Overall: By far the most unpleasant exam I've ever taken. Know your kinetics/thermo because you're not going to get any help at all. Watch out for trick questions.
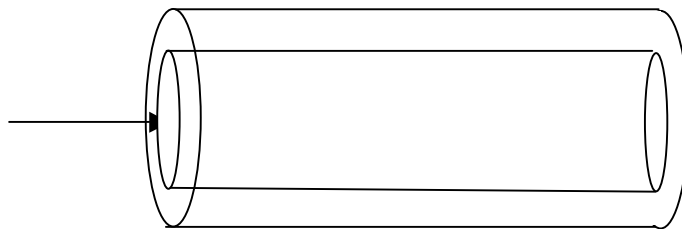

Kinetics: Iglesia
You have a reaction A → 2B occurring in a membrane reactor, the membrane is permeable only to B.

So as soon as B forms, it will go out of the reactor. So, derive the design equation by doing a balance. But since B diffuses out as, C_A will be constant throughout the reactor.

Thermodynamics: Smit

Draw two points on a PV diagram, one near the top left at T_1, and the other near the bottom right at T_2. What is the work required to get from T_1 to T_2?

P

T_1

T_2

V
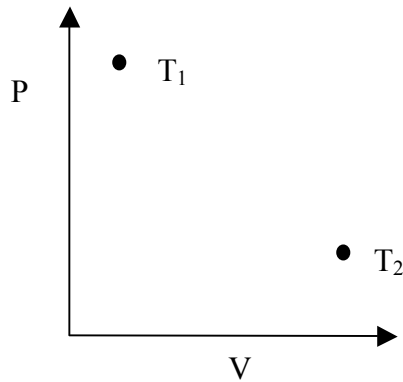
According to the energy balance, should just be - ∫ PdV, or area under the curve. I still didn't know how to answer this question, so I stared at the board with a puzzled face, and started drawing isotherms and talking about other random things which didn't get me anywhere. In the end, I wasn't able to answer the question. So what was the answer? There is no answer. You can't do this problem. Not without knowing the path you take from point 1 to point 2.

Thermodynamics: Smit
Derive the ideal gas law.
We had done this in statistical mechanics the past semester with Chu, so I started writing down the partition function for a canonical ensemble. Smit said I didn't need stat mech to do this. Not that I remembered how to anyways.

Process Design - Segalman/Alexander:
Start out talking about your senior design project, 5-10 min. It's a good idea to try explaining your design project to your peers for practice.

Segalman: Fish tank
Started with a short problem. Let's say we have a fish tank. Design a system to clean the fish tank. We want it to be a continuous process.

First, figure out what you have to clean. We have solid wastes (I refrained from saying poop), and liquid wastes, urea. So I said you'd want to use filtration first to separate the solids, and that you'd need a pump, since you'll have a pressure drop from the filtration. Then, use adsorption to remove urea. I was asked what are some common materials used for adsorption, and what properties they had to make them good. I said activated carbon, which is good for adsorbing organics and has high surface area.
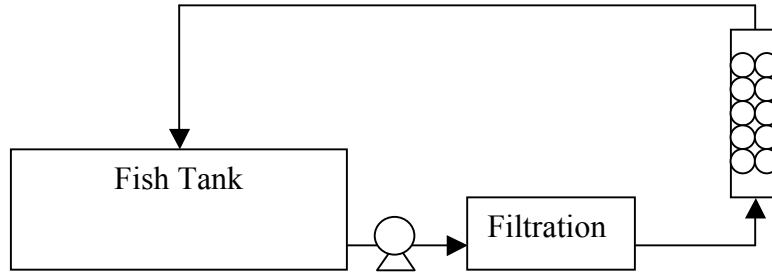
Segalman: How can we get drinking water out of seawater?
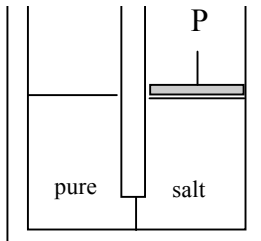
I answered with reverse osmosis. I was asked to explain this process, so I drew a picture of two cells connected by a membrane, one side with salt in it. Then I was asked how I would find the pressure needed. After drawing a blank, I was given the hint, what conditions are required at equilibrium. The chemical potentials have to be the same. So, I wrote for equilibrium:

$$\mu° = \mu° + RT \ln(x_i) + P$$

Segalman: Can you think of another way?
Evaporation. I was asked to draw this, so I drew two in series to show how you could utilize the heat from the vapor phase of the first evaporator. Then I was asked about pressures. For multi-effect evaporators, the units down the line need to be at a lower pressure because the liquid will become more and more concentrated, meaning its boiling point will increase.

Segalman: Can you think of a third way?
Ice. Remove enough heat, and you will get ice (pure) and concentrated seawater. After washing off the ice, you need to melt it. You can do this by blowing humid air over the ice. As the water vapor in the air condenses, it will release heat that will melt the ice.

Segalman: Can you think of another way?
I ran out of ideas, but with some hints, I said ion exchange.

Alexander: Looking at how M&Ms are made. M&Ms are milk chocolate that are covered in a hard candy shell. Start with liquid chocolate.
Thank you Food Network and Marc Summers! Start with pouring the liquid into molds. I was asked what they would look like, so I said something like ice cube trays, and they asked me to draw how it would look. I forgot about surface tension, which they pointed out.
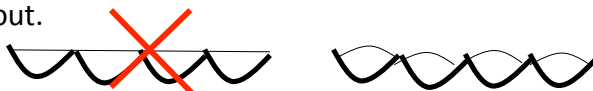
The next step was to cool the liquid chocolate using refrigeration, and then the chocolate insides are pretty much done. Alexander asked how I would get the coating on so that it was evenly coated on all sides, and I said use a rotary drum (I think that's what How It's Made told me how they get cheese coating onto cheetos…was all I could think of at the time). But I said that I thought this was wrong because I felt like the candy coating would just clump everything together into one giant mass. But, they said the rotary drum part was right, and asked how I would get the coating on so that this didn't happen. I came up with spraying it on, which they said was right. And because the candy shell has a higher melting temperature, it would just melt the chocolate if it were to be just poured anyways.

The question that got me was, how do they get the m's on the M&Ms? I guessed it was spraying through a nozzle that had an 'm' stencil on it, but that wasn't right. After given the hint "how are newspapers printed," I drew something on the board they accepted. An array of M&Ms moves down the line under a rubber cylinder that stamps on the m's.
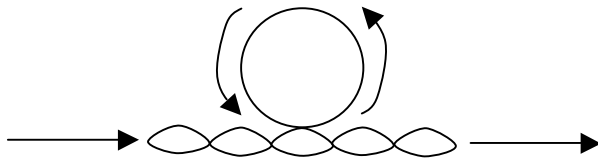
Victor Ho

Thermo/Kinetics - Schaffer/Iglesia:
Schaffer did the thermo. He started by asking what is constant in an adiabatic process. The answer is the product of the pressure and the volume to the ratio of the heat capacities (γ). Then he asked to see the derivation, which can be found in any thermo book (start with the first law; plug in what you know; chug along). After that he asked the question about a hot metal block in a constant temperature cold bath and asked about the ideal amount of work that can be extracted from the system. Then he wanted to see the derivation of the efficiency for a Carnot cycle starting from the Second Law. Then he just asked about how an ice skate works. And that was it. It was straight forward, and he was pretty helpful.

Iglesia asked the kinetics question, which had to do with a tubular reactor that has walls that allow the complete removal of the product from the mix. He wanted to see a derivation for a PFR and what assumptions can be made about it. He asked about why you could assume plug flow in general and asked about axial dispersion. Then he just wanted to see the solution for the composition profile. I bombed this part, so you should probably read someone else's account if you want to know how to do this problem. Iglesia gave me a pretty hard time, but in his defense, I was flopping around

for about twenty minutes and saying really dumbass shit (can I drop the "S" bomb?), so I deserved the new hole that he tore for me.

Transport - Balsara/Graves:
This one went surprisingly well. Balsara started by asking the familiar thin film flowing down an incline problem, but instead of having a Newtonian fluid, it was ketchup (a Bingham plastic). He gave the equation for the shear stress as a function of the shear rate and the coordinate system on the ramp at angle theta with the ground. I must have looked really lost because he handed me BSL open to the page for the general equation of motion. After copying that down and canceling out terms that aren't relevant, there was just an equation for the shear stress with boundary conditions of zero shear at the interface and no slip at the wall. I don't really know what happened after this, we just started talking about the equation and the system. Basically I think all I really said was that the velocity profile will appear identical to a Newtonian fluid near the wall until it decreases below its yield stress, at which point the profile will flatten. They were both really helpful (in fact I think Graves answered more of the problem than I actually did), and I just had to nod my head and say something that appeared insightful but in reality was just a reiteration of the definition of a Bingham plastic.

Graves then described a system where a gas flows through a tube and reacts, and the composition of the effluent is analyzed by placing a thermocouple coated with a catalyst that reacts immediately with one of the components in the path of the stream. This just boiled down to convective mass transport to the thermocouple (a sphere) and setting the flow equal to the amount that reacts at the surface. Then plug that value into a transient energy balance using a lumped capacitance model. He asked about how to get the values for the mass and heat transfer coefficients, and he was happy with me just saying that they're just functions of the Reynolds and Prandtl/Schmidt numbers (has anyone noticed that Prandtl and Schmidt have the same consonant to vowel ratio [6:1]). These guys were cool and not awkward at all, so the whole thing was actually quite a pleasant experience as far as prelims are concerned.

Process - Blanch/Prausnitz:
I don't think anyone cares about this one anymore, but just in case they don't axe this one in time for the next year students, here's my experience. Blanch was late, so Prausnitz started by talking about how to separate isomers of xylene. Crystallization is what he was looking for, so he wanted a solid-liquid phase diagram of a solution of ortho and para xylenes. Then he just asked a bunch of questions about "Well what if we started here and cooled?" or "What if we start at this eutectic point? (I don't know if there's a eutectic point in reality, I just drew it because I think that's what he wanted)" and stuff like that.

Then Blanch showed up, and he wanted to know about my senior design project. They didn't want a PFD, just a basic outline of what the process was and what the "deliverables" for the project were. Then Blanch asked about this process for making

water by towing an iceberg from the North Pole to "SoCal" and getting fresh water from it. So he wanted to know how to get the ice to the plant and how to melt the ice. He really wanted to hear that you blow moist air over the ice chunks and the vapor that condenses on the ice will provide the energy to melt them. You can find a more detailed analysis somewhere else, but he wanted to see a transient energy balance that was very similar to the one that I wrote for Graves.

Then they both proceeded to ask about clean energy stuff. I don't remember the exact questions because this was more of a chat with the professors than anything else. There was something about removing carbon dioxide from a waste stream; something about making hydrogen; something about if I were to be inaugurated on Tuesday (which was Barack Day 2009) what I would do about the energy crisis. Most of the time it was just chatting about stuff, and Blanch finally just started talking about Quantum of Solace. After that it was over. Prausnitz was pretty quiet and Blanch was friendly, so the whole thing was agreeable for the most part.

I'm sure this has been written like a hundred times by now, but don't let a poor performance in an early exam have an effect on your next one(s). I flipped a shit after thermo/kinetics, but the rest of the exams went smoothly. So my advice if you screw up your first one, flip a shit for like ten minutes or so. Break stuff, cry, throw things, be inconsolable, do whatever you feel like. But after about ten or fifteen minutes, kick yourself in the ass and calm down. You only need to pass two out of three (unless they change that) so just forget how you did and go into the next exam confident.

Anton Mlinar

Thermo/Kinetics - Balsara/Reimer:
Reimer went first and gave me the kinetics portion of the exam. The way he phrased the problem was awkward and he seemed to be changing the problem constantly so I felt lost most of the time. The problem started off with a reaction occurring on a catalyst surface. He asked me to plot the reaction rate as a concentration of A; seemed simple enough but I had a few questions before I drew up the answer, mainly, did it follow a first-order Langmuir-Hinshelwood reaction mechanism. He seemed to not understand my question so I drew a plot on the board. He looked confused so he then explained to me that the reaction I was looking at was between A and B on the surface (in other words, a second-order Langmuir-Hinshelwood mechanism). This changed the problem so I changed my plot to show a decrease in reaction rate at high concentrations of A (no B can adsorb on the surface). This sufficed so we moved on. Next he said I wanted to load this catalyst into a CSTR reactor. He then asked me to plot $CA(0) - CA$ as a function of CA. I drew a line with a negative slope but again he seemed puzzled. We wrote out the CSTR material design equation on A and put $CA(0) - CA$ on one side of the equation and the reaction rate term on the other side. I plotted the reaction rate side of the equation on the same plot and had three intersection points with my previous line

(basically solving the equation graphically). We went through which points were stable and unstable both on the plot and in the equation. Finally, we thought about where we would want to operate the reactor and how we would start it up.

Balsara had enough with kinetics at this point so he asked me a thermo question. Basically, I was supposed to prove the equation for osmotic pressure (P(osmotic) = mRT). I started by drawing the basic setup of an osmotic pressure apparatus with a semi-permeable membrane separating the pure solvent from the solvent + solute. I then explained how the device worked. Balsara seemed pretty happy so far but then he asked me to find the osmotic pressure. I started by saying that the chemical potentials on both sides of the membrane must be equal since the system was at equilibrium. We discussed that the chemical potentials on each side were at different pressures and that the chemical potential of the solvent + solute was non-ideal (this took into account the solute concentration). At this point I got stuck so I wrote down the definition of the chemical potential and the equation for dG. Finally, I just wrote down the answer because I knew what it was (he didn't mention it previously) and he seemed very pleased that I knew what it should be.

General Consensus: Toughest prelim I had. Reimer tried to help me when I got stuck but his hints only confused me more. Balsara was not as intimidating as I made him out to be; he was actually quite nice and mentioned a few times that I was doing very well.

Transport - Chu/Radke:
This was a really fun prelim. We started by talking about what classes I had taken related to transport, current events, and the origins of my last name. Surprisingly, the discussion lasted something like 10 mins. Eventually, Radke had me go up to the board and had me start the problem. The first part of his question was the moving plate question he had asked in previous years (water is sitting on top of a plate moving with a velocity U; the top of the water is exposed to air). He asked me what the velocity profile should look like so I mentioned what the boundary conditions were and this led me to a flat velocity profile. He then asked me how much power is needed to move the plate at steady-state (none) and what would be different if the fluid were non-Newtonian (no difference since viscosity cancels out). Radke then modified the question to make the plate really long in the direction that it was moving such that the height of the water was a function of the distance. He then asked me perform a mass flux shell balance on a differential length of the plate. Basically, we determined that the height was changing because of evaporation. This conclusion led to the height changing linearly with distance (we used a mass transfer coefficient). Chu asked me about the wet-bulb temperature and then what the temperature profiles would look like in the fluid and gas since evaporation makes the interface cooler. The energy balance led to a linear temperature profile in the liquid and a heat transfer coefficient relation with the air. The conclusion was that the two equations were now coupled so that the height was no longer linearly changing with distance. Finally, Radke asked me how I would solve the problem. After numerous wrong answers, he got me to mention using Runge-Kutta numerical methods.

General Consensus: Really fun group. On numerous occasions, all three of us were laughing pretty hard. Definitely go into this exam light-hearted and you will do well. Oh, but just don't give Radke the answers to his problems right away – justify what you are thinking and then give him the answer or he will steal your thunder (and thus make you look bad).

Design - Segalman/Prausnitz:
As per all design prelims, we started out talking about my senior design project. After explaining the main purpose of the project and defending the feasibility of actually implementing it, Segalman began asking design questions. Segalman began by asking me how to clean the water in a fish tank (basically, the rocks filter out the solid material and an adsorbant like activated carbon removes the organic compounds). This led to a discussion of how it would be done industrially (multiple columns so that they can be recharged periodically) and led to the all-important term "pressure-swing adsorption". Prausnitz then asked me how I would make helium (from natural gas). My first answer was to use a membrane to separate the natural gas from helium. Prausnitz acknowledged that was one way to do it but wanted to talk about using a Joule-Thompson process to do it. This led to a discussion of inversion temperatures and that we need to make liquid hydrogen before we can make liquid helium (use liquid hydrogen to cool helium below the inversion temperature). This led into a discussion of the Haber process. Nothing too tricky except that the hydrogen feed might contain some carbon dioxide which is poisonous to the catalyst. This could be fixed by implementing the reverse of the steam reformation process to make methane, which does not react with the catalyst (becomes an inert in the system). Finally, this led into a discussion of how we could make hydrogen without needing fossil fuels. I mentioned that you could use light to make steam (more efficient than electricity/electrolysis of water). I described how water is heated up residentially to warm things such as pools (tubes painted black put on top of the roof) but Segalman pointed out that the water wouldn't become steam. I countered this rebuff by talking about focusing light onto tubes filled with water inside of parabolic troughs. Segalman nodded approvingly and then challenged me to give another method. I mentioned the solar tower that had been recently built outside of Seville, Spain (only knew this because I was there a few months earlier). In a last ditch effort to stump me on this problem, they both asked me questions about the problems of using a lot of mirrors (need to keep them clean) and what happens when the sun moves across the sky (the mirrors can be tilted to follow the sun). Segalman seemed oddly disappointed that I had answered all of her questions so she said I was done.

General Consensus: Very easy-going prelim. It certainly helped that I like process design. Both professors were incredibly nice and gave plenty of time to answer their questions.

Ben Hsia

Process - Blanch/Alexander:
1) Alexander: Benzene → Cyclohexane in a PBR. What's the reaction called? Hydrogenation. Is it exothermic? Yes. What happens if it gets too hot? Hot spots/runaway and coking. What happens if there's too much coking? High local flow rates, material failure, catastrophic explosions. What would you do about it? Cool it down. How? Staged feed, dilution of feed with an inert, inert packing, cooling jacket (this apparently is a bad idea since the reactors are really large). Alexander seems to like this question a lot.

2) Blanch: How do you melt icebergs to make fresh water? First break it up into small chunks. Heating it up would take a lot of energy. Running steam over it would be dumb because instead of making the steam, you could've just heated up the ice. Running moist air over it is the best because you use the latent heat of condensation to provide the heat of melting. And not only do you get the water from the ice, you get the water from the air. Blanch then asked me to write a transport equation for it. I wrote the heat transfer one first, but the heat from heat transfer is small compared to the heat of condensation from mass transfer. Blanch also seems to like this question a lot.

3) Alexander: How do you make M&Ms? A new one! I had to figure out how to get the shape, the coating, and the nice color and stamp done. The shape is from pouring molten chocolate into molded trays (muffin trays) and letting surface tension create the symmetry. After hardening, the chocolates can then be dumped into a rotary agitator thingie that sprays on colored candy coating (when Alexander was trying to help me with this, he kept rotating his hands in a circle. I'm not sure he realized that he was sending me signals). Finally, you can pour the almost completed M&Ms into another tray and roll them underneath a rolling stamp press (kind of like newspapers) to put the M on.

Both guys are really nice. Blanch might make your ideas sound dumb sometimes, but try to beat him to the punch and say why they are dumb. Watching "How it's Made" might be a good idea. I got out 10 minutes early and got an A on this one.

Thermo/Kinetics - Schaffer/Iglesia:
1) Schaffer: "Let's start with a softball." Eek. In an isobaric process, P is constant; in an isothermal process, T is constant. What's constant in an adiabatic process? I was trying to figure out something with Q or S but nothing seemed to be quite right, so he said, "What about P, V, and T?" I was super confused and replied, "none of them?" So then I had a light bulb moment and realized that he meant some combination of the three. So I did an energy balance and started equating things till he told me to stop because I was taking too long.

2) Schaffer: "What's the maximum work you can get from a hot piece of metal?" Since I heard this question before, I quickly did the whole efficiency of a Carnot cycle business with changing T_h and integrated over the temperatures. "Can you derive the formula for efficiency?" I started out well by talking about energy being a state function but I had a hard time getting from Q's to T's until he basically told me that "Something else is a state function." So I plugged in $dS = dQ/T$ and got the efficiency.

3) Iglesia: If you have a PFR with A→B and B leaving the system instantaneously through a membrane, write the governing equations. State your assumptions. So I wrote up the mass balance for A and then proceeded to find conversion as a function of V. And then since the molar flow is decreasing through the tube, you have to do an overall mole balance and find density as a function of V. (Ask him if you can assume ideal gas; hopefully he says yes). He then asked me how things would change if I had axial dispersion. I didn't know what that meant so I said, "what do you mean by 'axial dispersion?'" He replied, "Whatever it means to you." So I turned back to the board and looking at it for about 10 seconds and then said, "I don't know what it means." Iglesia: "Why didn't you just say so?" Instead of snapping back that I did say so, I stayed quiet and he told me that it would be a CSTR. He asked me to compare the conversions and some other stuff, but I don't really remember much after that.

Both guys are pretty quiet. Iglesia can be a bit mean, but don't let him get you flustered or it'll all go downhill. I got a B+ on this one.

Transport - Graves/ Clark:
1) Graves – "Imagine you have a flat plate immersed in a fluid. You begin to raise the plate at some velocity and the fluid forms a region of width h that gets pulled up with the plate. What is the velocity profile in the fluid region? Do a momentum balance. Use Navier Stokes and cancel. Both Graves and Clark hated shell balances (I'm not sure Clark even knew exactly what they did). After I was done, Graves said, "You seem like a clever fellow, so I'll ask you something we haven't asked yet. How do you calculate h?" I was not as clever as he thought and he proceeded to walk me through some rigmarole about the properties of the fluid.

2) Clark – Fluid flowing over a flat plate. Viscous shear stress (tau) is known. How do you find the heat transfer? I wrote down Newton's law of cooling and he asked me about the Nusselt number. So I said to use some empirical correlation with Re and Pr. But he wanted something to do with tau. I wasn't really sure how to do it so he asked me about Reynold's analogy which I had never heard of, but the word "analogy" made me say something about the Chilton-Colburn analogy which thankfully was an okay thing to say. So I guess the whole thing was about getting h from the friction factor. <Shrug>. So then he wanted me to derive the "2" from the Nu correlation for a sphere. I barely got started on that and then he wanted me to do something with hot air flowing through a tube to heat it. And then he asked me to write Fourier's law. I wrote down the 2nd derivative version and he was aghast and exclaimed, "Is THAT Fourier's law? That is NOT

Fourier's law." At this point, Graves muttered, "Well actually, that is Fourier's *second* law." And at some other point in this run-around, he asked me about the Biot number. I wrote it down faithfully and he said it was wrong and that the Biot number was for mass transfer not for heat transfer. So in short, it was a confusing time.

Eh. These guys are tough cookies. Clark was also a bit all-over-the-place and occasionally wrong. I got flustered a few times but still managed a B.

Melissa Bartel

Process Design - Prausnitz/ Segalman:
This was my first exam, so I was really nervous because I didn't know what to expect.
- *Tell us about your senior design project.*
  My project was about glycerol conversion to liquid fuels. After a couple of minutes, they realized that I had reviewed my project before the test and knew what I was talking about, so they didn't really want to hear very much about it and we moved on to the next question.
- *How would you purify oxygen from air in a process that is portable enough to be used in a small oxygen tank for patients that need oxygen?*
  You need to find a way to adsorb nitrogen and allow oxygen to pass. I first suggested passing the gasses over a surface, but eventually stumbled on the answer they were looking for – a PBR-like tube that the gasses can flow through. The adsorbate will only adsorb so much nitrogen, so you will need to have at least two tubes so that you can use one while you are regenerating the other. To regenerate the adsorbate, you should run a small amount of the oxygen-rich product stream back through the tube, which will cause the nitrogen to desorb.
- *How do they typically purify oxygen (or nitrogen) from air?*
  Cryogenic distillation. Make sure you know how this works.
- *Describe the Haber-Bosch process.*
  This is one of Prau's favorite questions. Make sure you know the operating temperatures and pressures and why these conditions are used.

In general, if you are confident, you will be fine. Sometimes, the comments they made came off as a little condescending, but they were still helpful when I was stuck.

Transport - Radke/Chu:
This panel was very friendly. Radke did most of the talking, and Chu just sat there and smiled. We started off with some small talk (what courses I've taken, what textbooks I've used) and a quiz on Berkeley history.
- *Draw the steady state flow profile for a fluid (height H) sitting on top of a plate that is moving at a constant velocity U.*
  I said that this is similar to the problem of flow between parallel plates, but since there isn't a plate on top of the fluid (and therefore no resistance to movement), the fluid will flow with the same velocity as the plate.

- *Prove that the flow profile is correct.*
  Use Navier-Stokes. Radke doesn't like when you start from the beginning and cross out terms, so try to only write what you need on the board.
- *Now the fluid is evaporating as it is moving. What is the fluid height as a function of position in the x-direction (direction of motion)?*
  I did a mass flux balance on a differential part of the fluid. The flux out of the fluid in the y-direction is a convective mass flux. He asked me how to find the concentrations needed to find that flux.

I thought that this panel was very nice, and they provided a relaxed environment. Whenever I was stuck, they would give very good hints to help me out.

Thermodynamics/Kinetics - Bell/Smit:

Smit asked all of the thermo questions, and Bell asked the kinetics questions, but they both gave hints and talked to me during the whole exam. They also asked the usual questions about courses and textbooks at the start of the exam.

Thermodynamics:

- *Develop an equation for entropy that is a function of temperature and pressure.*
  They wanted something in the form of $S = (dS/dT)dT + (dS/dP)dP$ and then to find relations for dS/dT and dS/dP that transformed those expressions into variables such as C_p.
- *What is the constant pressure heat capacity for an ideal gas?*
  I said $C_v = 3/2*R$, but they asked why that was only valid for a monotonic gas. I don't think I ever said what they were looking for, but we had to move on to kinetics.

Kinetics:

- *Bell gave me some equations for a Langmuir-Hinshelwood mechanism. I don't remember the exact reaction, but they asked me to solve for a concentration.*
  You need to use the pseudo-steady state approximation and a balance on the total number of binding sites.
- *Draw the concentration profile of various molecules involved in the reaction.*

Alex Teran

Transport - Chu/Radke:

These guys were jovial from the minute I walked in, which helped break the ice and put me a little more at ease. They told me to sit, asked what sort of classes I had in undergrad, what book, and who taught them. Then they asked me if I knew who would be swearing in Obama the following week and then some other random politics questions. Then it was to the board. My first (and only) question was as variation of Radke's thin film on the eye. He wanted me to write an equation that would take into account any activity a person was doing, and how that would affect the rate of evaporation from the eye [$N_A = k (C_{Ainfinite} - C_{As})$], this way the k will change based on whether the person is sitting, running, riding a bike etc. At one point they asked how I'd

find that k → use Sherwood number, which you find from a correlation using Re & Sc. They basically had me do mass and energy balances and draw concentration and temperature profiles through the film and into the air. They made a big deal about whether the concentration in the equation is in the vapor or in the liquid and what the temperature at the surface is. Turns out the temperature at the surface is lower than in the film or in the bulk because of evaporative cooling → took a lot of prodding for me to get that. It makes for a very non-intuitive temperature profile.   That's mostly it I suppose - I got sort of flustered at the board at one point and couldn't figure out how to put all of my equations together, but they were pretty nice about it and sort of prod you in the right direction. Basically, be thankful if you get this pair.

Design - Segalman/Prausnitz:
They stuck to the book the whole exam, which was nice. First, senior design. Hopkins didn't really have a traditional senior design project, so I spent only a few minutes telling them about that. Then Segalman asked about desalinization. I ended up having to draw some flash evaporators in series and recycle their heat and talk about how pressure would decrease in each one. Then at some point they asked me about making oxygen so I talked about the Linde process and they asked me a bunch of questions about how the initial cooling would be accomplished and a few other things. Then Segalman asked about portable oxygen, and I tried to talk about pressure swing adsorption columns, but think I sort of had it backwards. Eventually they asked me the standard questions about fuel cells . Finally Prausnitz started asking me about some practical concerns with regard to hydrogen cars, such as storage, problems with having fuel cells on board, etc. Nothing I couldn't reason out. Overall, not bad.

Thermo/ Kinetics - Bell/Schaeffer:
The first question was about the Arrhenius equation and transition state theory. For whatever reason, Bell was on a real TST kick this year, and wanted me to calculate the pre-exponential factor with pen and paper, not by plotting experimental results. He seemed to be under the impression that we learned TST in kinetics with Smit, which was far from the truth. Ultimately, I was told him I had no idea how you could do that and finally he let me move on. Next question was a PFR reactor with a gas reaction where the number of moles is changing. Then it was time for thermo. Schaeffer asked me about getting the max work out of a hot object → have to use differential form of Carnot's engine equation. Then he wanted me to prove that for an adiabatic equation PV^γ=constant, which I had a hard time with. There was one more question at the end, but I don't really remember.

Matt Dodd

Kinetics/Thermo - Bell/Smit:
From what I had figured before going in, Smit would be handling the Thermo questions, and Bell would be asking the Kinetics. I was the second person to go on the first day.

Alper went before me, and I saw him walking down the hall between sessions and I asked him how it was, and he had this little smile on his face which was hard to interpret and he just said, "you'll do fine." So I walk into the Gilman offices, and the door is still shut so I figure the testers were still wrapping up and grading Alper's performance which I'm sure was top-notch. The door opens finally and Bell walks out to get more coffee and Smit invites me into the room and I take a seat. They ask where I'm from (UG inst.), my first name (it's only surnames on the schedule), how much thermo and kinetics I've had, and then they tell me to go to the board. I was pretty nervous at first, but, as with all the sessions, once I started writing and thinking, it wasn't bad at all; I almost can say it was fun. Smit starts in with his thermo, he asks me to draw a closed system, he tells me the pressure and the temperature. It's hexane in a liquid with CO_2 above it. He tells me the vapor pressure of CO_2 at this temperature is 56 atm or something like that. He asks me to figure out the solubility of the CO_2 in the hexane. I fumble around and start talking about Henry's law and saying you need to have the Henry's law constant. I wrote out the equations. I got stuck a little, didn't know where he was trying to go, and then he asked me what was happening physically. I said at equilibrium, CO_2 is hitting the surface of the hexane and going into the liquid phase and CO_2 on the surface is going into the gas phase and these two rates are equal. He said this was good, and I wrote this sort of equation down like a kinetics equation and used the ratio of the rate constants as the equilibrium ratio. He liked that I knew that. He said that I could get the solubility from this. I fumbled around and basically manipulated the equation like he asked and then somehow the solubility appeared; I still don't really get it. We then talked about what if it was hexanol and not hexane. I talked about how these models assume ideality and don't really account for specific molecular interactions and that CO_2 hexanol/hexane interaction would be accounted for in activity coefficients and things like that. He seemed pleased with that. Then we got stuck, I didn't know where to go and he had me draw a new system. He said there was A and B in a closed system, and started drawing liquid and vapor phases and he told me to forget about that. He asked me how much they would mix or something. I got excited cause I thought I knew what he wanted and I started talking about the delta G of mixing for ideal solutions (I basically started explaining stuff that his question might not have warranted but I wanted to go into something in detail that I was pretty confident with so I just went with it). I talked about entropy of mixing and said the enthalpy of mixing was zero. He asked why, and I said for ideal solutions, there is no energy interactions. Bell looked pleased when I said this. I then talked about S = kb ln(omega) and talked about permutations; when I did this briefly, Bell looked very pleased but I think Smit got annoyed cause I was going in directions he wasn't interested in. He asked how would I know if the system was at equilibrium and I drew a delta Gmix vs. composition curve (like you'll see a lot of if you take Segalman's polymers class). He asked "why G?" I said, "that's the variable that is minimized at equilibrium" Smit says "why not F, or Z...?" I'm not sure what he was getting at and then he had me look at the original system (the A and B system) and Smit says "ok, lets say it is at constant T and V and not T and P"... this is when I remembered that G is for constant P and T systems and then I say... "oh, then the Helmholtz energy is minimized" (which I thought was right, and then my brain made

me think enthalpy is minimized for some reason and I said that, and then I changed it back to Helmholtz).

He had me erase everything and then Bell stepped up to the plate. He asks me to write the rate equation and then write out the long form of the rate constant. He has me explain what all the terms mean. I thought I knew pretty well, but I rambled on and don't think I got it exactly right. He asked how you would calculate the pre-exponential factor. I talked about collision theory and drew two molecules flying at each other and talked about their size and orientation. To explain when they react and activation energy. He asked what factors were important. I talked about a critical radius and stuff like that. I really just made stuff up on the fly after thinking what would be important. I mentioned the Boltzman distribution so they asked me to write it down. I couldn't remember the form but I knew the shape of the curve so I drew that and talked about velocities needing to be high to get over the threshold energy. I said "I think it's like e to the kinetic energy over temperature or something....." (which is basically right) but they seemed to really want me to know the exact equation. They asked what shape is it... I said parabolic (which was me just misspeaking) and then I corrected myself and said Gaussian which they seemed skeptical about (I don't think it is Gaussian but it is a symmetric distribution of similar shape). He then had me erase that and he asked, I have a tubular reactor with A + B -> P, how do I know the concentration at some point along the reactor? I wrote down the design equation (no derivation) and then I said I would write everything in terms of the limiting reaction which needed to be know. (I nailed this question and Bell seemed pleased and nodded throughout) I said, for now, I'm going to assume equamolar feed. I wrote how I would keep track of A and B was written in terms of A and I made sure to include the volume change term (I learned a specific way of doing this; it varies depending on how you learn it). I really think he was trying to get people who leave it out, but I made sure to include it. So i had the design equation and all the math ready to go and he said that was good enough. I didn't say anything about isothermal conditions; In retrospect, I would recommend at least mentioning how this would affect your equation or the happenings of the reactor. Last, he asked me if there were any other ways to calculate the activation energy. I thought "bingo, this is the TST question"; I pretended to ponder and then replied.."um...Transition state theory..." and he asks "explain that.." and I think "ok, wikipedia, don't let me down" I generally explained it well I thought and I drew some diagrams and he asks me what the key assumption is... I didn't quite know and I thought for about a minute looking at the board, and then Smit says .."we are running out of time..." and then I say "the products and reactants are in equilibrium with the transition state" and Bell liked that... and then i shook their hands and left.

Honestly, I felt really good after leaving. I thought I had done well. I was thinking at least a B+ if not an A, but it turns out I barely passed. I'm still a little confused by this grade. It must have been the fumbling around Smits thermo questions in the beginning or maybe my oral explanations of things to Professor Bell weren't as accurate as they had sounded to me. Overall this committee was nice. Smit will kinda leave you hanging.

Bell reworded a few of Smits questions when I didn't know where to go. (not a language barrier thing, more like Bell doesn't like to leave you hanging like Smit might do).

Process Design - Blanch/Alexander:
Everything I read about these two suggested it should be a fairly straightforward exam. I got to the room early and Ferrese was still finishing up. I could hear the conversation through the door, and everything sounded jovial. Tony walks out and tells me that the exam was fun in some ways and he seems pretty confident. One of them peeks out after a few minutes and I walk into the room at sit down. They ask about where I went to school and what my design experience is. I talk to them a little about my senior design project. After all that, Harvey asks about freezing seawater to make fresh water, and "how would you melt it?" Of course at this point I'm very confused because the profs know we have access to previous year's question and Harvey asked this exact same question a year ago and everyone seemed to fumble around until he told them the answer he wanted of using humid air to melt the ice. I didn't want to just come out and say the right answer. It seemed sort of perverse. So (like I sort of did when Bell asked about TST) I pretended like I didn't know the answer. I said "well, you could stick it out in the sun but would probably take too long." and Harvey says "yes, you have to process lots of ice" or something like that... I couldn't take it anymore so I just said "well, you could use humid air and condense that to liquefy the ice." This is where I figured out what was up. Harvey asked, "how would you do that...?" So I figure he just took his old question and added on to it. I said stuff like you'd probably want to crush up the ice mechanically to increase surface area to help with the time of melting. and you'd have to collect the first bit of condensate and throw it away cause you're washing off the salt and then fresh water would come off, so at some point, you switch the trays collecting the water, you'll just have to figure out when that is. They asked how to design the system. I said some sort of conveyer belt with a grated tray. At this point Alexander asked me "what does this look like, can you draw it on the board" I turn around and there's the board (I didn't see it at first and was wondering if there was one in the room). I go up and attempt to draw something that looks like what I'm saying. Then Harvey asks "ok, how long does it take to melt the ice..." I said something like "well, the latent heat of vap is about the same as the latent heat of fusion...so you need as much water vapor as ice..." and Harvey agrees reiterates... "How long would this take" and I'm a little confused (cause this seems like a transport problem) and he asks me to zoom in on a piece of ice and i still can't figure it out. I say things like "there's a certain amount of vapor hitting the ice per time and it hits and melts the water, and this goes away..." (basically this seems like a transport problem so I'm a little perturbed at this point) Harvey asks me to zoom in even further, so I give him a molecular explanation of water vapor molecules hitting the surface and melting the ice. I still can't figure it out. The whole time Alexander is just staring at me. Harvey is just staring at me. Awkward..They decide to move on.

Alexander is next and he says he has two solids in a vile, one is very valuable and one is worth nothing. "How can I separate them?" I delve into my solid/solid sep knowledge...I

say first, well you can leach one with a solvent.. and you want the worthless one to go into the solvent so you don't have to further separate it" he says.." but were going to be processing tons and tons of this stuff... is that a good method"...I ponder and guess no and then realize he wants to hear that the solvent could be very expensive so this is not a good idea. I then make sure to mention that the solvent can be processed and then recycled. He asks why would you do that...I said it could a very specially designed or produced solvent that is very expensive... "Ok, what else"...he wants more techniques...I mention melting the sample and then crystallizing one out based on melting points.... he says "you don't want to fuse them together more than they already are...this is the opposite of what you want". (I think the problem here is that I thought these two solids were like an ore of some kind, i later realized he meant little pebbles of A and little pebbles of B so more mechanical means of separation were desirable) I remember and mention you could look at the magnetic properties and possibly use a magnet to separate. Also, one could look at the electrostatic properties and maybe apply electric fields as in electrophoresis. I also mention suspending the particles in a medium and centrifuging to utilize density differences. He asks "could you use air?" I said you could blow air from the bottom and the lighter (less dense) particles would escape out the top of the container at a certain critical velocity and I drew a force diagram on a particle. Lastly, Alexander asked me, in my solvent recycle scheme, "what would that look like" i drew some streams with the solvent + B stream leaving the A/B tank and going to a distillation column and then solvent came out the top and was recycled back to the A/B mixture. I guess that is what they wanted. I heard good things about this committee before hand, but I guess I just got a few questions I wasn't really comfortable with. Alexander wasn't that helpful when I was out of ideas; he sat, starring at me a lot. Blanch was better, letting me know if I said something that was of use.

Transport - Graves/Balsara:
This was my last prelim and my best subject and I figured I had passed at least one of my previous exams so I was pretty laid back. This was the very first session on the Friday morning and then I was done. I go up to Balsara's office, and wait about a minute and when it was time I knock, they let me in, introduce themselves. They ask what my transport background was; what textbook/s i used. Balsara asks me to go up to the board and says we are going to look at a system of a fluid flowing down an inclined plane at an angle theta.....(at this point, I have show tunes going off in my head and I'm thinking "Welty and Wicks, chapter 8, example 2"...I became very familiar with that book as an UG and even more while studying for prelims) Balsara reiterates very carefully that he wants to look at the general case and not just the Newtonian fluid situation. I think he did this so that the student doesn't start with just writing down Navier-Stokes and crossing out terms. You'll see why he didn't want this in a second. (so make sure you know the general fluid equation before substituting in the Stokes relations for the fluid (aka. know the Cauchy eq. of motion)) I start with the shell balance cause that's how they do it in Welty and have a hard time just cause it's a lot easier when you have the book open in front of you. Balsara says, (because i'm going kind of slow), "I have BSL here on my desk if you want to look at that" which you could

take to think he was patronizing me, but he wasn't at all. He really wasn't too concerned with the derivation (but if you can do it, it's worth points of course), he was more concerned with analyzing the equation and figuring out the velocity profile for fluids with odd stress/strain rate relationships (i.e. non-Newtonian fluids). But I got through it and he said "good." He said "good' or "very nice" or "that's right" after all the steps that were correct. So I got the general equation using the BC that tau at the fluid-air interface is zero. Graves chimed in and asked why that was. Balsara asked me to show the velocity and shear stress profiles for a Newtonian fluid flowing down the plane. I used the equation for tau and substituted in the Newtonian fluid relationship and the no-slip BC at the solid/fluid interface. I got the velocity profile equation (another "good" from Balsara) and then I drew the shear stress and velocity profiles qualitatively on the diagram. Balsara says that we now have ketchup flowing down the plane, and he has me write down specific shear stress relationship (he gives it to me to work with and analyze, you don't need to know how ketchup behaves)... it was something like this. $\tau <$ tau_critical.....$dVx/dy = 0$, $\tau >$ tau_critical $dVx/dy =$ normal Newtonian behavior...he asks for the velocity profile... I look and think for a minute.. write down the velocity profile (not too difficult to figure out) and the shear stress profile. Last thing he asks is for me to figure out how to calculate tau_critical... i look at the equation is and say something about substitution and he says that's generally how you would do it.. I can't remember exactly what I did; this was the only confusing part of the problem.

We move on and Graves says that that was the difficult problem and his question is much easier. I think he was being serious. He tells me we have a plasma and chlorine radicals are being created and destroyed and we want to know the transient behavior by using a thermocouple in a stream or something... how would you do that? It was daunting at first but then I figured it out. I write $d(\rho c_p V T)/dt =$ mass rate * (delta H reaction) - Area h $(T - T_{bulk})$ ....So i wrote that and I was confused if that was right. Graves says after 30 seconds or so "what are you doing?" (not as in "hey, idiot what the hell are you doing" but more like "so..lets think about this, what does this equation mean") He asks "are you doing an energy balance?" I say "yeah, an energy balance around the thermocouple" and he says "oooh, this looks promising then" he tells me to write the equation out in words so I do. rate of accumulation = heat in - heat out.....he says he likes my equation except for the 'mass rate' part. I knew that wasn't right but I was just writing it knowing that I needed to figure out how to get that.   Then i realized it was just a Kc(Cbulk - Csurface) and then i said Csurface was zero. He asked why. I said because there's a reaction there and so it immediately disappears... he liked that. (I'm using this equation to get Cbulk...ie. using a thermocouple and T to figure out the concentration of radicals in the stream) So i got my equation and he asks how I would get Kc and h (convective heat transfer coeff) and I say, correlations (I write the general form out) or the Chilton-Colburn analogy would be useful if you just wanted the ratio of kc and h. (I realized later on that this problem is basically the same as Example 6 in the 4th edition of WWWR except it's transient and the energy is from a reaction and not a latent heat of vap.) I talk about Nusselt number and Sherwood, what they are (he asks

what D is in those numbers)   He asks as an aside, the difference between convective and conductive heat transfer. He asks what the equation looks like at the surface...I know what he is getting at..I write k dT/dx @ surface = h (Tbulk - T surface).. he asks what k is... we run out of time here. I knew I did well in this exam... and I got a good grade. This was a good committee even though I was worried about it. I may have gotten lucky that I knew the answers to Balsara's problems, perhaps it would have been much worse if I didn't, not sure how much help he would give. Graves was very nice and helped me through the problem with just the right amount of encouragement.

Anthony Ferrese

Process Design - Alexander/Blanch:

As this was my first prelim, I was nervous, but these two put me at ease quickly. The first few minutes were taken up my me explaining what my process background was and what my project was about. Alexander first asked me the Benzene problem that he had asked in previous years so I knew the answer right away. Basically the problem is that you are turning benzene into cyclohexane with the addition of hydrogen. I wrote the reaction on the board and then he asked if it was endo or exothermic and I replied (just as I had read in previous answers) that it is exothermic because you are breaking pi bonds. Then he asked which kind of reactor I would use and I said PFR because of kinetics. Alexander then asked what would happen and I said a runaway reaction and threw out his favorite buzz work 'coking'. The we talked about how to control it. I pretended to think about it for a little and then said: smaller residence time, interstage cooling, adding in the h2 along the reactor and adding inert packing material in the catalyst.

Then it was blanches turn. He said that we wanted to remove CO2 from a gas stream using algae and he wanted me to dry the flow diagram. I assumed a couple things like that the gas stream was the exhaust from a coal power plant and we worked through it together. I ended up bubbling the gas through water and having the algae eat it that way. Blanch then asked how deep the water should be and I talked about the characteristic length from the diffusivity of the CO2 into the water and how you can get a time from that and using the terminal velocity get the height. I definitely didn't get it all right all the time, but I just kept throwing out ideas even if I knew they were bad and said why they were bad.

Finally Alexander asked how to make M&M's and we worked through the process together. It ended up being, squirting the chocolate into a mold and letting in harden then passing the hard chocolate through a rotating tube with the candy coating in it. Then Alexander asked how you get the M's on the candy. I suggested that you could do it like they sort pills and get them into an organized matrix then spray on the M's, but Alexander told me before I left that they shake them back into the molds then print the M's on with edible ink.

All in all, thee two were very helpful and really nice. I actually had a really good time in that prelim. The only process that I had any prior knowledge of was the Benzene question which was only about 5 minutes of the total exam. The est thing to be able to do is to think on your feet and come up with as many ideas as possible. I really didn't study at all for this prelim other than looking over some processes and remembering how to think critically and practically about how to make something.

Transport - Chu/Radke:
This was a very interesting pair with Radke asking almost all of the questions and Chu chiming in every once and a while with a clarifying question. Radke asked lots of questions and really didn't let me complete a thought without asking another question. He also really led me through the problem and at points I had to cut him off because he was basically telling me what to write to solve the problem. This kind of annoyed me because the problems were pretty simple and I felt like Radke was leading me to the answer because he thought I couldn't answer it myself. So on to the questions. It started out with Radke asking about what Transport background I had which led to lots of confusion, but that was mostly due to my inability to accurately describe what I had done. Then Radke told me to draw a line. Eventually we got to the problem, which was the same as in previous years, where you have an infinite plane moving with a constant velocity with water above it and air above that. Radke wanted to know what the velocity profile was. I immediately said that the profile was uniform velocity without and Radke asked me to prove it. I fumbled around a while, but was eventually led to an acceptable answer which had to do with the fact that the the boundary condition was that there was no sheer stress at the interface between the air and water and therefore the change in momentum was zero and the velocity profile was the same throughout. Radke then asked about the work needed to keep the fluid going at that velocity and I answered that it would be zero and whipped out my definition of the force exerted on the fluid which was the sheer stress (which was zero) multiplied by the area of the plate.

Radke then put the plate in a room with a relative humidity of 10% and said that the water was evaporating. I started writing some governing equations, but he starting asking what the mass flux was going in and what it was exiting at x+delta x, so I ended up doing a shell balance instead. I fumbled around a while and Radke helped me through, but eventually I got an equation for the height of the water with changing x. During this whole process, Chu asked a couple of questions that I had already answered. It went sort of like this:

Chu: and what is m?
Radke: it's the mass flux, he already answered that.
Etc.

I was a little disappointed with this prelim because I spend a long time learning all sorts of dimensionless numbers and remembering all of the equations of change in both rectangular and cylindrical coordinates and I only ever used a shell balance.

Thermo/Kinetics - Shaffer/ Inglesia:
I was the most nervous about this prelim of all of them for the reason that I spent the least amount of time studying thermo which meant that I still had no idea how to do anything with fugacity or activities. My hope was that they would ask me something about Carnot cycles and then go on to the kinetics question, which I felt much more confident about. Last minute the location was changed to Stanly hall. I could see that they were trying to throw me off by changing locations, but I was determined to stay on top of my game. I got in there and it was in Shaffer's office. I said hi and we talked about what kind of classes I had in the past for a minute or so and then went onto the questions. The first one was about thermo and was about an adiabatic system. The asked me some definitions and then asked about the Carnot engine which excited me because it was one of the few things that I had studied. After a bit of deriving and answering of questions Shaffer told me it was time to move on to kinetics. Inglesia, then proceeded to say that I has a tube reactor and wanted me to set up and solve the equations. He also mentioned that I didn't have enough information to solve it and that I needed to ask clarifying questions if I needed them. I then asked weather this was adiabatic and if it was well mixed (the assumptions tat I usually made when solving the equations).

Overall, the prelim went well, and I felt that I got lucky and was asked questions tat I actuality knew the answers to more or less. I definitely didn't breeze through the exam, by any means and fumbled around for a while, messing up equations and getting definitions wrong. The one thing that I really remember about this pair is that unlike the other exams that I had, if I was stuck, they would let me sit there and flounder for a while before helping me out. When it happened it seemed like I was staring at the board forever, but it was probably only 10 seconds or so. They would let me know if I did something wrong though, but they definitely gave me a chance to correct it myself first.