

Prelim Exam Transcripts (2012)

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ctrl-alt-m	inserts a comment
ctrl-enter	inserts a pagebreak
ctrl-(0 to 6)	formats the text as a heading that will show up in the Table of Contents
insert (in toolbar)	inserts symbols, horizontal lines, etc
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Thermo

Chu / Balsara

CC

Chu gave me a problem with oil and water in container. At room temperature and atmospheric pressure, do they mix? At what condition do they mix completely? Find the Gibbs free energy of each system (include surface tension of oil in the first system). Then equate the Gibbs free energy of both systems and find how small the water bubble must be to obtain complete mixing. This problem was pretty straightforward and Chu was very helpful when I got a little stuck or didn't know what to do immediately. I felt like this was a typical Chu problem. I think he really likes problems that have to do with surface tension (just judging from my experience in his thermo class).

Then Balsara asked about a distillation column. He told me to draw a McCabe Thiele diagram (once he said that, I thought, crap I didn't study this at all). I didn't exactly remember the axes, so he ended up drawing it for me. What is the temperature profile in column? What variables can you calculate from x_1 and y_1 ? I stumbled through this one pretty badly. I really didn't expect them to ask something so applied. I mean, obviously being a chemical engineer, I should know about distillation columns (especially because my undergrad ChE dept produces tons of engineers who go into the oil industry and my undergrad university is in a state that has tons of oil companies). But I guess that's the way things go. They always question you about stuff you just happened to not study. Both Chu and Balsara were helpful and tried to give me hints, which I clearly needed. At the end, Balsara told me that I said something completely wrong and I thought that might have been an indication that I failed. But it turns out that I did well on the exam. Go figure.

Macarons d'Amiens

First question was about a drop of water in an oil bath. You could either have them phase separated, or you could have all of the water dissolved into the oil. I was also supposed to assume that in the case of the bubble, the bubble was pure water (with no oil) and that no water was dissolved in the oil. I set the G of each state equal, where in the case of the drop, you had to take into account the surface tension, so you had $G = N_{oil} \mu_{oil} + N_{H_2O} \mu_{H_2O} + \gamma \cdot \text{Area}$ for the bubble case, and a similar one of the other case. Then they had me assume that the terms about oil canceled because they wouldn't change much from the first case to the second. So you wind up with $N_{H_2O} (\mu'_{H_2O} - \mu''_{H_2O}) + \gamma \cdot \text{Area} = 0$. Then they had me express both area and N_{H_2O} in terms of R and solve for R as a function of the difference in the chemical potentials. They walked me through this one a lot. I still think that the question was a little fishy, but they made it clear what they wanted and I just went with that (and I passed, despite needing lots of help along the way).

Second question was a McCabe Thiele question. They didn't want to hear about where the lines came from (operating lines, q line). They wanted to know how the temperature changed along the column, assuming constant pressure. Do this with a T - x diagram (and explain the diagram). Then put two points on the mccabe thiele plot and two corresponding points on the T - x diagram to show the temperature change. They were both nice and helpful. Pretty typical Chu and Balsara.

Segalman / Schaffer

BC

Schaffer is ten minutes late, but appears shortly after Segalman calls him. He is running and eating his 'only food for the day so far'. It is 1:30pm on Thursday.

They ask me about my Thermo class and what textbooks I used; we used a homebrew note packet for Thermo and I happened to have it with me, so Schaffer briefly skimmed the table of contents. I suddenly realize I haven't had this class since Fall 2006 (5.5 years ago), which might explain why so much of the stuff I studied seemed so foreign.

Segalman: the Van der Waals equation of state (VdW EoS)

1. write or derive the formula; what does each term mean?
2. draw isotherms
3. where is this EoS accurate? where does it run into problems?
4. derive coefficient of thermal expansion for a substance obeying VdW EoS

Schaffer: you have two reservoirs filled with liquid, at different temperatures; calculate the amount of work that could be extracted from this system. This is just a Carnot cycle problem but with heat reservoirs that are finite.

Segalman: the Clausius and Clausius-Clapeyron equations

1. what are they and what can you use them to find?
2. derive the Clausius equation
I start from the state hypothesis applied to entropy, but she tries to steer me toward doing it from Gibbs-Duhem. I say "no no, I know how to do it this way" and they begin to get suspicious that I don't know the physical significance of the math I'm doing. They latch onto this and slam me with a bunch of definition questions.
3. What is the Gibbs-Duhem relation?
4. What is the definition of chemical potential?
5. What are fugacity and activity, and how are they related?

I crashed through it all pretty decently, and they start to debate over whether they should ask me an additional question. I say "more, please!" and they have time for one more.

Schaffer: 'bonus question' - ice cubes are placed in a glass of water, and the level of the meniscus is marked on the glass. When the ice is allowed to melt, does the level of the meniscus increase or decrease?

Kind of a trick question... the level stays the same!

This was my first prelim, and I left feeling pretty good about how it went. Segalman and Schaffer were both very professional and gave me helpful hints to restart my thinking when I got stuck. They were both very professional and I felt like I was simply demonstrating what I knew, not being electrocuted to death by the Emperor in the throne room of the second Death Star.

I felt like I probably earned a B+ or an A-, so I was pleased when I was awarded a B+.

Smit / Balsara

MS

Smit was late coming back from lunch, inevitably with Chu; Balsara was roaming through Gilman in an attempt to find him. As Smit cleared the board of Will Hunting's scribbles, they asked me about my thermo experience.

Smit was surprised I three semesters (intro, phase equilibria and molecular) but also bashed the fact that my school used in house notes. "I find it hard to believe that they couldn't find a book that was better than those notes." Direct quote. I went to the board that was rancid of cleaner fumes and Balsara asked me what I knew about distillation. After a verbal explanation, they asked me to draw the column and what graphs were pertinent. So I drew a Txy and an xy. They asked how to determine the number of stages and wanted the generic answer of McCabe Thiele or Fenske Equation. Then they asked how the temperature differs between the bottoms and distillate (bottoms are hotter) and how to show this on the Txy diagram (each horizontal tie-line represents a tray).

Smit was next and had me draw the PV diagram of an ideal gas for isothermal compression. He then asked what the change in internal energy was. I said zero because it was isothermal. He said no. Ok, cool I enjoy violating laws of thermo, too. He said pretend it was something like a vdW gas but corresponded to the ideal gas equation, whatever that means. Then he said to calculate the change in entropy. After some staring, I sort of realized he wanted me to prove that the change in internal energy was zero. So I wrote the combined first and second law. I expanded dS into its partials of volume and temperature. The temperature differential is zero because it was an isothermal process. I had to use a Maxwell relation for the partial wrt volume to get partial p/partial T at constant V. I applied this to the ideal gas law and then magically got $dU=0$.

I had ten minutes left at this point: Balsara thought I should be done but Smit had one more crazy question in him. "I found a way to separate CO₂ and N₂ that's cost effective. What do you want to know before applying for a patent." In some convoluted manner, this got to a discussion of properties of mixing. Even though I knew how to derive all of these properties from chemical potential, I still wasn't sure if that was what he wanted. Balsara was not helpful at this point because he was also unsure what Smit was getting at. I rambled for quite some time and then they told me I was five minutes over and I should go. I felt slightly blindsided from my peak into Smit's brain but before I left Balsara said I did very well and should enjoy my weekend. It turned out I did the best in thermo, which was unexpected. My advice for these two is don't let their ambiguity or slightly-awkward stares worry you. They were actually both helpful and did not let me stray far from their anticipated directory.

RL

Balsara started off asking what I knew about a distillation column, which I hadn't really studied cause I didn't expect that to be on the exam. I drew one on the board and then he asked what graphical device we normally use to design one - McCabe-Thiele. I threw a generic x-y McCabe-Thiele diagram up and talked a bit about the different lines (VLE data, x-y line, where the feed bottoms and distillate compositions would be, q-line, rectifying line, stripping line), how you decide how many steps etc. Then he asked about the temperature profile in a column - where is it hotter and where is it colder. I said I thought it was hotter at the top but we worked through the problem together and actually its hotter at the bottom, oops. In order to work through the temperature stuff he had me draw a T-x-y diagram. I drew a generic one and talked about the dew line and bubble line, where the feed and bottoms and distillate components would be. Turns out I drew my T-x-y diagram the opposite way of my McCabe-Thiele diagram (I had $x=0$ to have a lower bp then $x=1$ on T-x-y so needed the VLE curve underneath the x-y line on the M-T). Since I had Smit and Balsara who are pretty difficult to understand and not very good at guiding you in the right direction, it took forever for all of these mistakes to get worked out, but we eventually got to the right thing with them having to guide me a lot. Then Smit asked about the Van der Waals EOS (which btw he pronounces in the correct Dutch way which of course sounds nothing like how we say it so took a while for me to figure out what he was trying to say). He asked what the a and b stand for (attraction and particle volume respectively) then asked why it had a $1/V^2$ term. I had no idea so just mentioned cubic EOS which he said was definition, didn't explain why. We talked about a bunch of random things including what is pressure (molecules hitting the sides of the container) and eventually he sort of told me that you get a $1/V$ term from pressure and another $1/V$ from volume effects which I didn't

really understand but wasn't going to ask for clarification. In the process he wanted me to draw a P-V isotherm with the cubic term in the VLE region, but he didn't say that in so many words so I couldn't figure out what he was asking for and he eventually had to draw it. We talked about that graph for a while, why you draw the binodal curve with equal areas under the cubic (Maxwell-Stefan Equal Area Rule), etc, I couldn't explain everything but came up with a few relevant things to say. At the end he asked about something else but I couldn't really understand what he was saying and time was up so he just told me in passing as I was leaving that you use the Gibbs-Duhem. This is a good standard answer for a thermo question you don't know how to do, but I was too flustered at that point to remember that. In any case, I thought it went pretty badly, but I ended up doing really well so I'm not really sure how to explain that. In summary, you should probably review distillation even though it seems a bit off track, and know the origins of more advanced cubic EOS (which are basically all modifications of the VdW).

CA

Disclaimer: I almost missed this prelim. It was my last one, and I was sure it started at 3:45. I was sitting at home cramming/jamming to some F+M at 2:45, and Nikki says, doesn't your prelim start in 15 min? And I say "No, not til 3:45." "Are you sure?" (I look it up.) "\$^*&%&^\$^\$!!!!!!!" So Nikki, being the best roommate ever, speeds me up to campus and I make it with about 30 seconds to spare. DON'T LET THIS HAPPEN TO YOU. Double check your start times. And have awesome roomies.

So I was a little discombobulated starting off. Smit opens with, I have a paper.... someone says they can separate CO₂ from air... is this feasible? I'm not sure what he's getting at. I tell him that it's energetically unfavorable, but definitely do-able if you pump enough energy in. This is clearly not what he wants. He says, "they say they can do it for XXX kJ/mol (I can't remember exact number)". Is this possible?" I try writing down the composition of air... Boltzmann's equation for entropy (figure I'll do the Gibb's free energy change of mixing or something)... Smit is still asking is it feasible to separate CO₂ over and over and clearly we haven't connected. At this point Balsara starts trying to translate for Smit, which is pretty funny... "Think about ENERGY". At this point I just start writing every Thermo equation I can think of on the board, hoping they'll see something they like. I get to $dU = TdS - PdV$, at which point Balsara says "I'm really glad you wrote that." (I really think he wanted me to pass.) Then Smit launches on a description of some carbon capture technology and at this point it is getting late so we move on.

Balsara then asks me to draw a McCabe-Thiele diagram for a distillation column. At this point, I accept the fact that I'm failing this one (I figured this would be the one I failed anyway) because this is not something I studied. But he took it pretty easy with the questions... asked about the axes (y-mol fraction v x-mol) and which end is the hottest (bottom - to which Balsara replied, "I'm really glad you said that"). Then where the equilibrium points are and how to step off the the stages.

What I didn't know is that Balsara often teaches 154 (the Unit Ops lab) so if you have him, you might want to review some of the more classic ChemE unit operations stuff. Don't go overboard, but spending 20 min looking over distillation would have helped. Anyway, for all that I was dreading this one, they were both pretty nice and ended up passing me (B).

Prausnitz / Smit

SH

First, Prausnitz began with his typical intro question about gas liquefaction except this time instead of O₂ he was interested in making liquid H₂. Initially he asked how it would be performed (Linde cycle) and he asked me to draw the cycle and explain what was occurring. This led to a discussion about the Joule-Thompson

coefficient and the inversion temperatures of He, H₂, and N₂. After describing how to make liquid H₂, Prausnitz wanted to know why we might be interested in it (fuel source). This part also included random discussion and side notes about engineering applications for very cold liquids.

Smit then asked me to "draw an ideal gas." After pointing to the empty board since an ideal gas doesn't account for molecules, he clarified that he meant to draw an isotherm on a P-V diagram for an ideal gas. Then he asked what an isothermal compression would look like on the diagram and what the change in internal energy would be for that process. I drew the two points and said that the ideal gas would not experience any change in internal energy ($dU = C_v dT$). He asked me if I was sure and then asked me to define kinetic energy, internal energy, and potential energy. After that he asked me again if an ideal gas would experience a change in internal energy for an isothermal compression, and once again I said no because there was no temperature change. He asked me to draw a solid lattice and pretend the molecules interacted like springs. And he asked if one performed an isothermal compression on this solid would there be a change in its internal energy (yes). Then he asked what was the difference between the two cases. His next question was to calculate the entropy change if the process was an isothermal, reversible compression. Up to this point I had been getting confused looks from Smit the entire time, and I thought I was missing something (but really that's just how Smit is).

After an awkward 15 min conversation with Smit, Prausnitz jumps back in and asks me what the third law is and why it is important to chemical engineering. He followed this by asking how to calculate the change in entropy for a reaction (entropies of formation). Then he asks how to experimentally determine the entropy of formation. This was followed by a couple more random conversation topics from Prausnitz.

Eventually Smit entered the conversation again and asked how to separate N₂ and CO₂. I said maybe you would cool it and have the CO₂ fall out of the gas phase as a solid at atmospheric pressure. He seemed to think that was reasonable and asked me what I would do if I developed this technology. I replied with checking the energy usage and economics compared to other processes for the separation. He said to pretend my process was the best, what would I do next. I replied apply for a patent. That wasn't what he was looking for, he wanted me to say I would calculate the entropy change and make sure it did not violate the 2nd law. I told him that if I saw the separation performed how could it violate the 2nd law. He then said that he meant the process was shown to me by a colleague and I did not perform it personally.

Overall, this prelim was extremely awkward and left me questioning if Smit and I were both talking about the same subject. On the other hand, Prausnitz asked similar questions to the past years and I did ok.

AH

I was nervous going into this one, since Smit's such a wild card and Prausnitz is a giant in the field, but I tried to stay positive and it turned out just fine.

Prausnitz was the first to ask a question - what's the third law of thermodynamics? (A perfect crystal at 0 K has $S = 0$). Why do we as chemical engineers care about that? What's it useful for? I tried to explain that we can use it as a reference point to calculate the entropy of various substances at different temperatures. Fine, what about CO₂ gas, how can you find the entropy of that? I wrote an equation showing that you can integrate the C_p/T of solid CO₂ from 0 K to melting point, then add the ΔH of melting/T, then integrate the C_p/T of liquid CO₂ from melting point to boiling point, etc. Prausnitz counters with, well how do you experimentally find the heat capacity of solid CO₂? Half joking, I say, well you'd need it to be very very cold and then you could use a calorimeter or something. P - How do you get something that cold? Me - liquid helium? P - But that only gets you to 4 K. How about colder than that? Me - Magnets! (Knew this from reading past prelim write-ups). Prausnitz seems impressed at this point and also starts with his Berkeley history facts (that they came up with using magnets here in Giauque Hall). I already knew this, but I pretended it was new info and completely unintentionally go "Oh really, that's cool." To which Prausnitz counters, "No, it's super cool" and everyone laughed. (Puns - great way to cut tension).

Now it's time for Smit to get started. He says something like "Can you write $jkahgksj$ equation of state?" Oh, did you say van der waal's? He gets huffy that I'm not pronouncing it like a Dutch person, but I write the equation out and it's fine. Then he asks me to explain what a and b mean and I explain that. Then he asks me why

there's a V^2 in the denominator of the second term. Uhhh... I have no idea? I'm scrambling so he says, let's think of a wall of a container containing a gas - what's the pressure? Force per area, of course, where the force comes from the collision energy of the particle against the wall. Then he asks, now what if the particles were much smaller? How would that change the pressure? I still don't really understand what he means but keep trying to guess things. I think the answers we ended up settling on (with much help from Smit) were that the particles would take up less space, so more of them could hit the wall (one volume term) and that with smaller particles (but the same total mass) there would be more actual particles in the box (another volume term). This is still sort of confusing to me, so maybe check on this.

Moving on, he asks me to draw the PV diagram, which I do, but I make the mistake of drawing both the cubic and a straight line under the two-phase envelope. He immediately zeroes in on that - why did you do that? (Oh, well when I draw the cubic, I know the areas under the curve need to be the same so the straight line helps me). Nope, not good enough. We keep circling this for a while. I explain that there is a straight line because in the two-phase region, the pressure does not change. He asks for the equilibrium conditions (temperatures, pressures, and chemical potential are equal). He has me write the Gibbs Duhem equation. He asks how I find the area under the curve, and I say integrate over PdV where you substitute VdW EOS for P . He's still not satisfied with my answers. Eventually we hit upon the fact that the chemical potentials must be equal ($du = 0$) and he says we should move on. I thought I was answering his question, but he was never really satisfied with what I said. I would suggest to just try not to get flustered with him and bring in other thermo facts to help you so that you can show you do know some things.

Back to Prausnitz for a bit and it's a mixture question. If you have a ternary mixture but only have data for each of the binary combinations, how can you estimate the ternary? You have the T , P , and compositions. I start with the equations for binary - $gE = RT\ln(\gamma)$, $gE/RT = A_{12}x_2^2$. I then say that often times for mixtures, a good approximation is linear so gE (ternary) = $A_{12}x_1x_2 + A_{23}x_2x_3 + A_{13}x_1x_3$. P is happy with that, but now he comes back to the first two and says, fine well how do you get the activity coefficient? I write down definition of activity coefficient (a_1/x_1), then activity ($f_1/f_{1\text{pure}}$). Fine, now you have fugacity, now what do you do? What if you assume ideal gas above liquid? I say something along the lines of $f_{1\text{pure}} = y_1P$ and $f_1 = P_{1\text{sat}}$ and we're done.

If you have Prausnitz, you need to look at his past questions - he's pretty predictable. I also looked at the one hw he assigned us in CHE 240 and that definitely helped the last question. Smit is totally unpredictable so just try not to get flustered and hope for the best.

Verdict: Passed

Segalman / Maboudian

AML

Segalman asks me about how to determine the entropy of mixing two equal volumes of ideal gases A and B adiabatically. I start with the first law $dU=dW$ (no dQ) and sub in for U and W $C_vdT=-PdV$ then sub in for P (ideal gas). We talk about van der Waals a bit and ask me to sub in using that equation instead. They then asked me to solve the equation, which I wasn't sure how to do. They then ask me to write up what the entropy of mixing is (sum of $-R(x_i)\ln(x_i)$) and to plot T vs. x . They then wanted ΔG vs. x . I forget the second question.

DO

Started with a box with a membrane separating water on one side and toluene on the other. Asked me what would happen when the membrane was removed. I had seen this problem before, but for gases, and was a little thrown off that they were liquids. I started by talking generally about how I would expect this to be a non-ideal solution and how there would be changes in enthalpy, entropy, and Gibbs free energy. They asked me about the signs of these changes and also wanted the formula for change in entropy. Next they wanted a T vs. x diagram for a binary liquid, eventually I got it and also was asked to draw a G vs. x diagram and explain the conditions for stability. They asked me what a spinodal and binodal region were and to label them on the G vs. x curve.

Next they moved onto a calculation where I knew the volume and temperature of an ideal gas at one point and wanted to calculate the volume at a different point given we knew the temperature. This was a simple first law calculation. They asked me what I would change if I was using VdW equation of state. They wanted to know what a and b were in the VdW equation too. They also asked me to draw VdW isotherms on a PV diagram. Maboudian asked me if I knew what a throttle valve was. I talked about throttle valves and the Joule-Thompson coefficient. I recalled that a throttle is isenthalpic because it is adiabatic and there is no shaft work. We had a little time left and Segalman asked about evaporators for juice. She basically wanted me to explain how evaporators could be put in series with a lower pressure in each successive evaporator to better purify juice. Overall, this was my best prelim. They were laughing a lot, but in a good way and that helped to loosen me up and perform better. You may read that Maboudian always asks about cycles and fugacity, I studied those things a lot and none of it was tested.

CS

I really found myself lost during this prelim, and I don't remember much...

The first question was about the ΔG of mixing. They asked me to calculate that for a system of A and B, and then asked me to draw how composition of A vs. ΔG would look like. The next question was about expansion work and how the internal energy changes with it. The third question was about the p - v diagram of a van der Waals gas. There were many, many mini questions in between, and I could only answer a handful of them. The committee was nice and helpful, and patient, in spite of my poor performance.

AB

First they told me to draw a box with a partition with toluene in 1 half and water in the other. Asked me to calculate the ΔG for mixing and how do you get ΔS . They wanted me to move from ΔS to ΔG but I did the reverse. Asked me about the assumptions of the eqn $g=g_o+RT\ln x_i$ (enthalpy of mixing is zero). Then they asked me to draw the T vs x diagram for the system (which I had no idea).

Then Maboudian asked me about deriving the relation $PV^\gamma=c$. Asked me what would change if we have a Van der Waals gas. The significance of terms a and b in the eqn. Also why there is a $1/V^2$ in the eqn. Then Segalman asked me to draw a plot of P vs V for a substance. Asked about the unstable region, Maxwell construction and show it on PV plot. Asked why VDW was a significant achievement (you can predict

critical behavior). I was then asked about how to liquefy a gas. It's done by throttling and they asked about JT coefficient and what sign of JT can you liquefy. Segalman asked me about a pit where temp is the same throughout and find the relative humidity variation with height. ($dp/dz = -\rho g$). Asked me what assumptions are there in this eqn (like ρ is a combination of water vapour and air density). Maboudian then asked me about a gas phase rxn $A + 2B = C$ and whether increasing/decreasing the Pressure will favour product formation.

Prausnitz / Maboudian

NS

Prausnitz starts by asking what book I used (Koretsky) which he has never heard of but Maboudian has. We start by Prausnitz asking what the third law is and how it is important. I say it is used a reference state but Prausnitz isn't satisfied with this answer. He tells me to write a simple $A + B \rightarrow C$ reaction on the board and asks me how I would find the change in entropy from the reaction. He tells me that the reaction is done at a low temperature and this goes on to a discussion about the Linde Process and then using magnets to get the temperature of the system really cold. We get back into a discussion of the change in entropy. I say that we have to use heat capacity to find the entropy of the each species. Prausnitz agrees and then he tells me how do I do it. I write the equation on the board and he says aha this is where the third law comes into action. To find the entropy you have to integrate from 0 to the desired temperature and something like that. I write out the equation for the change in entropy but Maboudian then says the reaction is cold so wouldn't there be changes in phases. I say yes and write out the change in entropy from phase change. We then go on to finding the equilibrium constant. I write it in terms of concentration first, and Prausnitz says something is missing. This then goes into a chat about fugacity, activity, and activity coefficients. Eventually we get to a point where I am missing a pressure term when defining the equilibrium constant in terms of concentration. Maboudian then asks about how you account for the fugacity of a non-ideal liquid. I didn't get what she was asking for a while but then she says something about a correction factor and I'm like oh yeah you use the Poynting factor.

MD

This was by far my most pleasant prelim. Prausnitz and Maboudian were both extremely friendly and relaxed, which made for a very calming environment. Prausnitz started off by asking me if I knew the reaction to make ammonia (combine hydrogen and nitrogen gas). I wrote this out on the board. He then asked how to experimentally calculate the ΔG , ΔH , and ΔS of the reaction. I knew you could use calorimetry to determine the ΔH of reaction, and I knew you could look up everything from tables using energies of formation. I struggled for a long time on coming up with how to experimentally determine ΔS of reaction. In the end I don't know if I ever even came up with the answer. Eventually the question just morphed into 'what would you need to know to calculate it', which from $dS = Q_{rev}/T$ led me to say 'heat capacity', which they were satisfied with and decided to move on. Maboudian built on the ammonia reaction by asking how I would write out the expression for K_{eq} , deriving it from activity coefficients, assuming the ideal gas law applied. This was a pretty straight forward derivation, and I got through it pretty quickly so they decided to move on from the ammonia reaction. Next Prausnitz asked me about excess gibbs energy for a binary system. I don't recall exactly how he framed the question, but I remember it involving the relation to margules parameters and mole fractions of the two species. He also had me relate them to activity coefficients. Maboudian then asked about fugacity and how to calculate/measure fugacity (via Raoult's law). The explanation involved also getting the activity coefficients from the excess gibbs energy relations I had just gone through as well. Finally Prausnitz asked me about a tertiary system, and how to estimate the excess gibbs energy (assume it can be approximated by summing the binary excess energies). Then we went through a few random trivia questions - what's the acentric factor, what does it correct for, how can you calculate it? (accounts for non-sphericity of molecules, there's a relation you can calculate it from). What's the compressibility factor? (Z - adjusts ideal gas law) how do you make liquid oxygen? (compression/cooling/throttling multiple times. first cooling can use

water, later coolings will need to use other liquified gases) How do you get to 4-5K temperature? (same process and then use magnets/lasers at the end to get the final temperature that low). He also asked me the uses of liquid oxygen, which I didn't have any idea about, but at that point he didn't seem to mind. Overall it was very pleasant and Prausnitz and Maboudian did a good job of helping push me in the right direction when I wasn't figuring out what they were looking for.

Kinetics

Bell / Katz

CC

You have an internally diffusion limited reaction. Talk about the Thiele modulus. I explained the Thiele modulus first in just words. That is, Thiele modulus is the ratio of the rate of reaction at the surface to the rate of internal diffusion. I was about to write down the formula, but then Katz wanted me to derive it from what I had just said. So, I wrote out the rate of reaction and rate of diffusion. Next he wanted to know how changing the radius would affect the overall rate. I started talking about effectiveness factor and explained it in words again as the ratio of the observed rate to the rate if there was no internal diffusion. He helped me a bit to relate the Thiele modulus to the effectiveness factor because I couldn't remember. At high Thiele modulus, effectiveness factor is inversely proportional to the Thiele modulus so decreasing the radius increases the effectiveness factor, which increases the rate. Next he asked me about how increasing temperature would affect the overall rate. I talked about the rate constant's Arrhenius dependence on temperature and wrote the Arrhenius equation. At high temperatures, the overall rate is diffusion limited, so increasing the temperature doesn't affect the overall rate much. Then Katz asked how I could predict the rate just from knowing the concentration profiles in the catalyst particle. I kinda got stuck here and was fumbling around for an answer. Katz tried to help me a little, but I still didn't really know what to say, so he said we'd move on to Bell's question.

Bell asked about a series reaction in a PFR and what the optimum residence time would be. I wrote the design equations for the PFR in A and B and wrote them in terms of $dc_A/d\tau$ and $dc_B/d\tau$. I set $dc_B/d\tau$ equal to zero and found the concentration of B, which is the conc of B at the optimum τ . Then I totally forgot what to do next. I was clearly having a brain fart and there were some awkward moments of silence (with me thinking, "They must think I'm really stupid right now"). They tried to help out me and eventually I wrote down the design equation for C. They wanted to get to another question, so I just quickly explained how I would find the optimum τ using that equation. For the last question, Bell asked about a reaction occurring on the surface of a catalyst. He told me to write a Langmuir-Hinshelwood reaction. Then he asked about how changing the number of

vacant sites affects the rate. He asked about the activation energy and to compare that with the activation energy for a gas phase reaction. I really didn't know what he wanted and was about to guess an answer for his question, but I didn't since I thought it was wrong and I'd look stupid. Turns out what I was about to guess was close to the answer. That kind of goes to show that if you can make an educated guess about something, don't be afraid and say it, because you might right.

Coming out of the prelim, I thought I had done pretty badly, but this was one of my higher grades. I think what helped save me was that I explained the Thiele modulus and effectiveness factor in words first instead of just writing out a formula. They

seemed to like that and it does show that you understand the concept. Both Bell and Katz were actually pretty nice. Yes, there were some awkward silences (probably more my fault because I forgot how to solve an equation with two unknowns), but they were very helpful when I got stuck. Some of their questions were kinda unclear and confusing. Just make sure to ask for clarification or reword their question and ask them if that's what they're asking.

Macarons d'Amiens

Katz first asked how I could get activation energy (E_a). I wrote down Arrhenius equation ($k = A \exp(-E_a/RT)$). I plotted $\log k$ vs $1/T$, and the slope winds up being $-E_a/RT$. He said, now imagine that instead of that being linear (as it is often drawn and how I had drawn it), and say that at really high temperature, k levels off. What could cause this? I didn't really know, but he had me think about a catalyst particle, and eventually led me to think about external diffusion limitations. They had me write down Fick's Law, and it turns out that diffusivity has a different dependence on T than k does, so at high T , diffusion to the catalyst becomes limiting.

Bell asked me a question on $A \rightarrow B \rightarrow C$. First, he asked if E_a of the first were higher than the second reaction, would I want to increase or decrease temp to get more B . I couldn't remember the answer from Fogler, so I wrote the Arrhenius equation for both reactions, and divided them. Then, depending on which E_a is bigger, you wind up with a positive or negative exponent and can decide from there. He then said that we just have a $A \rightarrow B$ gas phase rxn. And it is observed that at low partial pressure of A , the reaction was second order, but at high partial pressure, it was first order. What's going on? We talked about collisions and how they transfer energy. We talked a little about vibrations. That didn't help me answer his question, so he had me write out the reaction. I wrote:

$A + A \rightarrow A^* + A$ (where A^* is high energy, and this reaction is really just a collision)

$A^* \rightarrow B$

$A^* + A \rightarrow A + A$ (also a collision)

I made pssa for A^* because it's high energy and won't last long, and solved for dB/dt . It gives you something with a form that if you assume $[A]$ is large then things cancel and it becomes 1st order and otherwise it's 2nd order. Bell then tried to ask me about adsorption. He asked me to write out some rate laws but then we ran out of time and I don't really know where he was going with it...

This was a good combo of examiners. They both gave enough time to think out loud and derive stuff that I needed without letting me flounder for too long.

CS

First question was about the degradation mechanism of SiH_4 to SiH_2 and H_2 . Bell asked me why the reaction was 2nd order when the vapor pressure of SiH_4 was high/or was it small? And 1st order when the vapor pressure of SiH_4 was high/small. So, with a lot of help, I wrote down the reaction mechanism and the reaction rates. And the rate order depended on which reaction mechanism step was limiting. The next question was about a consecutive reaction from A to B to C and how maximum concentration of B can be achieved. Is it the same for a CSTR and a PFR? The third question was about the residence time of a CSTR and a PFR, and how a contaminated reactor's contaminant concentration changes over time.

Katz / Reimer

BC

Katz starts out with a question about Michaelis-Menten kinetics:

1. at low concentrations the reaction rate is first-order with substrate concentration, while at high concentrations it is zero-order. why is this?

I write the Michaelis-Menten kinetics and point out which terms are most important at high and low

substrate concentrations.

2. When the reaction is zero-order, which reactor configuration is the best choice: CSTR or PFR?

My initial thought is that the PFR will be preferred, but I am stuck in a first-order reaction mindset. They ask me to write out the general reactor mass balance, and ask me to explain exactly what a design equation is. They then ask me to simplify this general equation to arrive at the CSTR and PFR design equations. I see immediately that, for a CSTR and PFR with the same mean residence time, the conversion for a zero-order reaction will be identical. They seem pleased that I arrived at this quickly and with very little prodding.

Reimer asks a question about a gas-phased homogeneous reaction that he encountered while working at IBM, which was second order with substrate concentration at low concentrations and first order at high concentrations. I used the pseudo-state-state hypothesis (PSSH) to write out balances for the transition state and the products, but I saw immediately that my equations did not explain the observed reaction order. I pointed out the term in the product equation that would need to change to give the desired behavior, and Reimer dropped a big hint: "does the transition state simply decay on its own into product, or does something need to happen?" They basically dragged me to the conclusion that the transition state must require an additional collision to fall apart into product, and with this change the equations looked how I wanted them to.

Katz now asks me to draw a spherical or porous catalyst and describe the reactant concentration inside in terms of the Thiele modulus. I throw down a quick plot and start talking about the relationship between Thiele modulus and the Effectiveness Factor. Katz pulls me back and asks me to write out the expression for the Thiele modulus. Initially I just write out the ratio of diffusive and reactive timescales, but he prods me through the dimensional analysis until I have all of the terms correct.

At the very end we got into a brief discussion of the meaning of 'activation energy' and the temperature dependence of the components of the Arrhenius equation. I knew they wanted to talk about transition state theory, so I began hashing out that derivation. Halfway through they look at each other and say that I can go.

I felt super-great about this prelim, because they jumped quickly to a new topic every time they seemed convinced that I knew what I was talking about. Both my first and second prelims went very well, and at this point I felt like an enormous weight had been lifted. I walked out feeling A/A- and I was happy to receive an A.

Bell / Reimer

AH

After the introductions, Reimer started with a question about a batch reactor. Constant volume, constant temperature. Series reaction $A \rightarrow B \rightarrow C$. Start with only A. How do you maximize the yield of B? I wrote the rate equation for A and for B and explained that I would solve for [A] from the first equation, plug that into the second and solve for [B] as a function of time. Then, find $d[B]/dt$ and set it to zero to find the time for the optimal concentration of B. They seemed happy with that answer and then asked me to draw a plot of how the concentrations of the three components changed with time. I initially drew [A] as half an upside-down parabola which was wrong. They eventually coached me to an exponential. [B] and [C] worked out fine. Then Reimer switched it up. Same batch reactor, now with an exothermic reaction $A+B \rightarrow C$ and a cooling jacket (temperature T_a at inlet and exit). At what temperature will you get a runaway reaction? I started by looking at the heat of reaction. I knew I needed to multiply something to get to become a rate, so multiplied by $r_a V$, where $r_a = -k[A][B]$. They didn't tell me it was elementary or irreversible - I wrote that reaction out and I said, "Here, I'm assuming it's elementary and irreversible" and they agreed that was a good assumption. Then, we addressed the heat exiting into the cooling jacket. I had just looked at this material so I knew that it was $Q = UA(T_{\text{reactor}} - T_a)$.

Ta). Now, back to the original question. Well, at steady state, the two values would be equal, but for a runaway reaction, the heat from reaction would start to eclipse the other value. $Q_{\text{excess}} = Q_{\text{rxn}} - Q_{\text{jacket}}$. The last step (which I didn't get) was to identify that you needed to differentiate Q_{excess} with respect to T to find the T where the reaction would start to run away. When it looked like I wouldn't get it, Reimer told me the answer and we moved on.

Next question came from Bell - reaction taking place on the surface of a catalyst. $A + B \rightarrow C$. How would you determine the rate of disappearance of A? I wrote out a mechanism $A + S \rightarrow AS$, $B + S \rightarrow BS$, $AS + BS \rightarrow CS + S$, $CS \rightarrow C + S$. I asked if I could assume a rate limiting step (and explained what it meant), but Bell said no. Then I started writing the rate equations for each component and explained that you would have to solve coupled equations in order to find the disappearance of A. You could use the pseudo-state assumption to make this easier (Bell suggested this, I explained what it was). I also wrote a balance on the surface sites $S_{\text{total}} = S + AS + BS + CS$. Bell asked me then to look at the reaction step and write the rate for that step. $-r = k[AS][BS]$. He asked what the rate depended on. I wasn't sure what he meant, but I mentioned the rate constant would be a function of temperature from Arrhenius equation (not what he wanted), and that $[AS]$ and $[BS]$ would depend on $[S]$. We looked again at the surface site balance and he asked what would happen if you divided through by S_{total} (you get the sum of fractional coverages = 1). Using fractional coverage, we changed $-r = k\theta_A\theta_BS_{\text{total}}^2$. At this point it got weird. Bell asked, so if you double the number of total sites, you'd expect the rate to increase by 4? That's not experimentally observed - how can you explain that? I fished around - are all the surface sites the same energy? (Yes). The fractional coverage is the same? (Yes). He said, what if it's just $A \rightarrow B$? Then $-r = k\theta_AS_{\text{total}}$. In this case, you do see the rate double for a total site doubling. I wasn't getting to what he wanted, so he ended up telling me that you do not see the rate increase by 4 because the rate actually depends on θ_A and the probability of having B in proximity to A (which is not the same as θ_B). I'm still not totally clear on this point.

I thought that because Bell had to give a lot of hints in the second part, that this wouldn't go as well, but I ended up just fine. I think this is because I stated and explained my assumptions and tried to define things even if I didn't end up using them. Show off what you know!

Verdict: Passed

MS

This began with Reimer setting up a clock on his iPad and Bell making a snide remark referring to its lack of necessity. Reimer posed a question from his IBM days that his co-worker, who is now two men below CEO of IBM. The details were much more than I cared for but I knew the problem would be the silicon processing one from previous years ($\text{SiH}_4 \rightarrow \text{Si} + 2\text{H}_2$). This takes place in a generic PFR with horizontally stacked disks where the reaction takes place. It was found that the deposit was thicker around the outside than at the center of the disks. How could I correct it? Well it turned out that it was mass transfer limited. After working through design equations and assuming equilibrium, I realized lowering the pressure is the answer. This way only the intrinsic kinetics mattered and the diffusion to the center was no longer the rate-determining step. Reimer further asked how was the overall rate affected (it decreased because we're running at a lower pressure) and was there anything else I could do? I suggested increasing the temperature as long as it was not an exothermic reaction so that the rate constant would increase from Arrhenius. Apparently that was what Barney (his friend) did.

Next up was Bell: he told me that I have cyclopropane (CP) isomerizing to propene (P). First he asked me what the transition state might look like. So I rattled off some stuff about the charge density separating and forming a carbocation or partial positive on the secondary carbon and a partial negative on the primary. These charges would then recombine to form a double bond. Bell looked very happy with this and Reimer was looking at his iPhone.

Back to the reaction: It begins at second order in CP and at higher CP partial pressures becomes first order. Explain. Fairly ambiguous but from previous years I knew exactly what he wanted. I broke the reaction down

to $2\text{ CP} \rightarrow \text{CP}^* + \text{CP}$ and $\text{CP}^* \rightarrow \text{P}$. This led me to a discussion of collision theory and TST. The first reaction was better described by collision theory since there is no ΔH of reaction. They asked what it was dependent on (temperature, velocity, mass (not reduced mass because they had the same MW (this got me brownie points), etc). Bell asked if I knew where the distribution came from (Boltzmann velocity distribution). The second reaction was better suited for TST. I wrote out all the terms for the rate constant (including the entropy in the pre-exponential factor). Then I went back to the reaction and used PSSH on CP^* to find the rate law, which showed at high pressures, the reaction becomes first order in CP .

I think Bell asked another question here but I don't remember. I do recall Reimer asking the $\text{A} \rightarrow \text{B} \rightarrow \text{C}$ reaction in a batch and how would you find the optimal time to produce B. First he wanted me to draw the plot of concentration versus time (B has a maximum) but when I began to start the mole balances he stopped me and said that was all. I still had 10 minutes left but my grade came back well so I guess they were just sick of my voice by this point.

Clark / Iglesia

RL

This started off with them saying "oh you are in a catalysis lab, this should be easy for you!" great. they asked what classes/books I'd used before and when I said Fogler, Iglesia immediately jumped in and asked if I'd gotten to the end of the book. I said we'd jumped around, but yea I'd seen things in the last chapter. I could tell he was excited to talk about residence time distributions and he and Clark kind of look at each other with the "should we start with the hard question? yea lets do it!" So, we launch into a discussion of residence time distributions. If you have Iglesia, I recommend knowing these really well, because we spend 30 minutes talking about them. I started with the basics, talked about how do you determine residence time in a PFR (tracer study, inject small amount of tracer in the beginning, monitor concentration of it out at the end), then drew graphs of what the distribution would look like in the ideal and non-ideal cases (ideal is just a delta function, then I drew the non-ideal to be a broader distribution, mentioned that the areas of the two must both be equal to the amount of tracer injected). They asked how you calculate residence time, $\tau = \text{volume}/\text{volumetric flow rate}$. They asked about what phenomenon results in the non-ideal graph I drew, obviously diffusion. Then we started in with the math. I had reviewed the basics of the res time stuff (graphs, what non-idealities exist etc) but hadn't done the math of it. So I started out with deriving the basic PFR design equation, and at every step they asked what I was assuming (know your assumptions really well for these two!) I kept trying to insert the non-idealities too early into the design eqn, but they would ask me about it and we eventually figured out that you just have to account for a diffusion term in the rate expression, everything else stays the same. Then they asked for the math in how you could use the tracer study to predict the outlet concentration for your PFR with the desired second order reaction. Did another mass balance, fumbled a bit but eventually convinced myself that you have to have an accumulation term in your differential balance on the tracer. We discussed the tracer some more, talking about what properties are important, etc. They asked what dimensionless number would be relevant and I started trying to think of one, and they said lets figure it out instead of just guessing. Iglesia suggested finding the residence times for the tracer for diffusion and convection ($\tau_{\text{diff}} = L^2/D$, $\tau_{\text{conv}} = L/U$), divide them to get the mass transfer Peclet number $= \text{Re} \cdot \text{Sc}$. Then with the last few minutes Clark asked a gimme question about the Michaelis-Menton equation, I derived it for them assuming pseudo-steady state. Iglesia asked about the beginning of the experiment when there wouldn't be any enzyme-substrate complex yet. I said you couldn't use M-M cause thats only valid at pseudo-steady state when the concentration of E-S is non zero and approx constant. He said he wanted to use M-M but for the beginning, I wasn't really sure what he was getting at but said a few things, and luckily we only had a few mins left and Clark wanted me to finish the problem so we moved on. Apparently a bunch of other people got stuck for long periods of time with the PSSA with Iglesia though, so I would learn that beyond just the standard derivation everyone knows. Anyway,

I started the derivation, then he just asked me if I knew the final expression and to write that and explain each of the terms. Then Clark mentioned that the original M-M assumed equilibrium for the first reaction, not PSSA, how does that change things? (you don't have the $k_1' + k_2$ term in the K_m expression, luckily I'd actually made that mistake when studying so I knew that one). Iglesia asked what would have to be true for equilibrium to be valid, and obviously k_1' would have to be a lot faster than k_2 such that K_m could be approximated by k_1/k_1' . The entire exam Clark and Iglesia were both asking questions and responding to what I said, they didn't do the whole one question per professor thing. Overall, I felt good coming out of the exam with these two and correspondingly did well. They were really friendly and helpful, and I felt this was the most straightforward of my exams and actually learned some interesting things during it!

MD

I was terrified going into this prelim, and it was definitely the worst out of the three, but not as bad as I had expected. It started off with Clark asking me what it means for a 2nd order reaction, so I said how it meant there were two molecules colliding, either the same or different, and that it resulted in a rate equation with exponents that summed to two. Clark asked me to write out the reactions and the rate equations. Easy enough. Then he asked me ways to calculate k . This is where I screwed myself over. I had been studying transition state theory because I had come across it while looking through previous prelims and didn't have any experience with it from undergrad. So out of my mouth along with "the arrhenius equation" and "calculating it experimentally" came "transition state theory". Whoops. Throughout the prelim I was able to figure out that Clark likes to jump on the most difficult concepts you mention and drill you as to whether or not you actually know every detail of the topic you decided to name. (he did this again later with diffusion limitations in packed bed reactors). Whatever you do, don't mention transition state theory. I have a feeling that if I hadn't mentioned it, they wouldn't have asked about it. Anyway, so now Clark wanted to know all about transition state theory and the equations and how it was related to the arrhenius equation. He wanted to relate it to the activation energy. I scrambled through the little I had memorized from the wikipedia page while studying, but knew it wasn't enough. Which it wasn't. They walked me through the derivation of the equation and how it related back to the energy of activation and the arrhenius equation. It was kind of a cool exercise to learn the derivation, but I knew it wasn't good that they were walking me through the whole thing. At the end Iglesia asked what pushes the transition state over the edge to being a product. Turns out it's the vibrational energy of the bond that will make it form the product. I had no idea. After we finally got the derivation they asked if I had seen that during my undergrad and I was honest and said 'no, we only talked about it qualitatively, never using any derivations'. Oh well. Next Iglesia asked me to derive the design equation for a PBR from a shell balance. This was simple enough, and I got through it just fine. But then he asked what assumptions I made in the derivation, and I said no radial gradients, no axial dispersion. He then wanted to know how I would include axial dispersion in the equation if it were present. You have to add dispersive flux times area to the flow term. I was kind of upset because I started writing out that flow was a flux times area (which I was then going to write the flux as dispersive and convective parts) and he cut me off and said that was transport. I am still confused at why he cut me off, because that would have led me to exactly the answer he was looking for. So then I was again confused at what he actually wanted if that wasn't it. I guess he just wanted me to be able to say it without writing out anything? I still don't know. Anyway, he then asked me how I would experimentally observe axial dispersion - through a pulse in the feed, and observing the dispersion as it comes out the other end. I had wasted a lot of time with the transition state theory part of the exam, so it ended abruptly. Moral of the story: just don't mention transition state theory, and if you think they're telling you you're wrong when you are pretty sure you're right: just finish what you're doing in case you are misinterpreting their "hints". Whatever. B-.

CA

I'm writing this several months after the fact and don't remember too much about it, other than Clark alternated between looking bored and "holier than thou" and Iglesia laughed under his breath at me the entire time. They definitely asked me to write the Theile-Modulus, which I did. To which Iglesia cracked, "We can see you've

memorized the Theile modulus, but where does it come from? I write it out but then he asks how it would be different for a second order reaction. I had a general idea from unit analysis but got confused by some of their questions.... basically we went in circles for a bit until Iglesia finally shouted at me to put $C(\infty)$ in the denominator. Not my best work, but for some reason they gave me a B anyway.

Honestly I think that one of the biggest keys to passing when you're borderline is to look confident. Even if you're getting things wrong, talk through your thought process and don't let on that you're freaking out. If you act like an competent engineer, they're far more likely to believe you actually are, especially when you're dealing with professors you haven't interacted with before.

Iglesia / Zhang

DO

This one was ugly. Zhang started with Michaelis-Menten, and although I knew the derivation well and could draw the plots the whole conversation was derailed when Iglesia asked about PSSA. He wanted a specific definition for PSSA and apparently I wasn't providing it. We went around in circles for what felt like half the time and I was getting flustered. We also talked about competitive enzyme inhibition and how that would modify Michaelis-Menten plots. Eventually we moved on and Iglesia asked about a PBR. I talked about PBR assumptions, he wanted to know how I would modify the mole balance to account for radial concentration gradients (annular shell). We talked about non-idealities and tracer experiments. He wanted to know how I would modify the design equation to account for dispersion. He wanted me to explain how I would quantitatively determine whether plug-flow was obeyed by looking at the Peclet number.

Overall, I felt like I was well-prepared for this exam and the questions they asked but it went poorly anyway. If you have these two just try to stay relaxed and think clearly despite the awkward silences.

AB

I had a non-Fogler background not that it mattered much in this prelim. Zhang first asked me about the Michaelis Menten(MM) equation and the reaction steps. She asked me why pseudo steady state assumption is valid. This was where I got stuck since both of them were not convinced with my explanation that E.S the intermediate does not stay for long hence $d(E.S)/dt \sim 0$. I guess they wanted a very specific answer. Iglesia suggested I compare the MM kinetics to an $A \rightleftharpoons B \rightleftharpoons C$ reaction. I was asked to draw the concentration profile of substrate S and intermediate E.S with time which I failed badly. Then she asked me about the rate vs substrate conc plot which is easy. But then she asked me about what would happen if there was a competitive inhibitor and how it would affect the rate plot. Apparently the max rate stays the same which I did not remember for this exam. I was asked to give a physical reasoning as to why it is so. Also Zhang asked me how the modified MM rate eqn would look like in presence of an inhibitor. After a lot of guessing and reasoning I came up with the right answer but this exam was not going well for me at this point. After that Iglesia took over and he asked me about a 2nd order rxn $A \rightarrow B$ in a PBR. He asked me to derive the working relation for the PBR through a mass balance. He then asked me to consider both diffusion and convection in the Z direction. He asked what the balance would be if there was diffusion in the r-direction. Then I was asked how diffusion would make the PBR deviate from ideal condition(talk about RTD). He asked me to plot the RTD for a dirac-delta input in the PBR(both ideal and non-ideal). Then he asked me what parameter would help in identifying the non-ideality to which I answered Peclet number. He wanted me to derive why it is the peclet number(it has to do with comparing the timescales for convection L/v and diffusion L^2/D). He seemed happy at this point and perhaps the reason why I got a B despite struggling in the 1st half of the exam.

Clark / Zhang

AML

I was the first student Zhang was giving a prelim to, so I think she wasn't quite sure how to go about it. Clark started off with simple questions about what it means to be first order/second order and what it means to be an elementary reaction. We then started talking about how to determine the rate constant, k , of a reaction. I talked about transition state theory and what goes into calculating k . He asked about the temperature dependence (both in the pre-exponential constant and in the exponent). We moved on to how to determine whether or not the order of a reaction determined by experiments is correct. I talked about falsified kinetics, and how diffusion limitations can skew your results. We went into the thiele modulus (he said he wouldn't ask me to derive it, but that "of course I could"... I think others had to), effective diffusion, and talked about effectiveness factor. He still needed to know how to determine if the experimental order is accurate or not, and I offered some experiments (such as using a catalyst with no pores- i.e. no internal diffusion) but it wasn't what he was looking for. In the end there was some other parameter (can't remember what it was) that I'd never heard of that would allow you to find the thiele modulus, and from there the effectiveness factor.

Zhang had the last 10 or so minutes. She wanted to know about graphical representations of kinetics. Somehow this was supposed to be enough info to get started. I wasn't sure what she wanted, so I asked for clarifications, ended up deriving some stuff here and there, drawing a lot of random plots... in the end she just wanted the levenspiel plot and to compare CSTR vs. PFR.

Clark was good about giving direction and it was almost like we were having a conversation about kinetics. Zhang just kind of left you hanging, but maybe she'll improve with more experience.

Stan Herrmann

This began with Zhang asking if I had heard of Michaelis Menten kinetics before and if I could derive the rate expression for her. I started off by writing the typical reaction mechanism and explained what was occurring. Then once I started to derive the mechanism Clark began to ask me to explain exactly what I was assuming for everything and why the assumption was valid. Halfway through the derivation they asked me to just jump to the end and write the final expression. Then Zhang wanted me to plot rate v. substrate concentration and explain why it was like that. Clark followed this by asking about the total enzyme concentration dependence, and then changed the system from homogeneous to heterogeneous. He explained that he performed an experiment with this heterogeneous setup and determined the rate, and then he added 4 times the amount of enzyme and did not see 4 times the rate (as the rate law would predict). He asked why this happened. I said the system is probably diffusion limited. This led into a discussion of the thiele modulus, how to calculate it and what it described. And then I talked about the effectiveness factor, what it meant and how it related to the thiele modulus. He also wanted numbers on the effectiveness factor v. thiele modulus plot.. This prelim really flew by and they were both very nice.

NS

Clark started about by asking me about my undergraduate institution and what book I used (Levenspiel). He seemed intrigued that I used that book for my kinetics course The first question was about the Michaelis-Menten enzyme reaction. Zhang asked me to write out the chemical reaction and the rate of consumption for all of the species in the reaction. They then asked what kind of assumptions I would make (steady-state, constant enzyme concentration, constant volume, batch reactor). I was then asked to write the MM equation

from memory if I knew it. I did. They asked what the variables in the equation represented and how I would find them if I graphed the equation. They asked how I would find the value for K_m from the graph. Clark then asked to draw the concentration of the substrate as a function of time. I initially put the substrate as going to a constant value. I knew this was wrong but it seemed like what he wanted to see, anyways after a few minutes of asking why this is the case and saying stuff like the Thiele Modulus and enzyme lifetime we reached the conclusion that the substrate concentration goes to 0 as time goes to infinity. He then asked me to draw the concentration profile of the enzyme substrate complex. We finish the problem, and Clark says that we'll talk about the Thiele Modulus since I mentioned it earlier. I talk about the properties of the Thiele Modulus and the effectiveness factor (Clark makes fun of me because my notations, from Levenspiel, are slightly different than what he's used to). He what do these two number represent in term of ratios. He then asked how we can derive the equations for a general n-order chemical reaction for both numbers; he said that I clearly memorized these equations. We get through the derivation and I say goodbye.

Transport

Radke / Muller

CC

A solid naphthalene plate is being pulled at constant velocity. At what length will the plate completely disappear? To solve this, you need to find the width (δ) as a function of z . Do a mass balance on a slice of the slab. At $z = 0$, width = δ initial. Draw concentration profiles in the slab and air. The concentration is discontinuous at the slab/air interface. The air right above the surface of the slab is saturated in naphthalene, so the concentration is a function of P_{sat} . Draw velocity profile in the air. How do you find the mass transfer coefficient? From the Sherwood number, but since the width is changing, the characteristic length is z (i.e. you have a local mass transfer coefficient). Now, the slab is at some initial temperature colder than the air. At what temperature will it disappear? Basically, do an energy balance. The heat convectively transferred from the air to the slab equals the heat of sublimation*amount of naphthalene sublimed. This question is a variation of those evaporation/wet bulb problems. They told me we ran out of time to do the energy balance, but when I came out, there was still a few minutes left. I should have tried to tell them really quickly how I'd do the energy balance, since I knew exactly what to do. Maybe that would have helped my grade.

I thought I did the best on this prelim, but I did the worst. Even though I got pretty far into solving the problem, I guess they didn't think I knew enough? I got tripped up by some of Radke's fundamental questions, like what type of differential equation is this? I actually had a pretty good time in this prelim, and maybe I'm a bit of a masochist, but I wouldn't mind doing it again (well, only if I got a better grade). Radke was his usual self, basically guiding me through the problem and asking me about everything. Muller didn't say too much throughout the prelim.

Macarons d'Amiens

Transport (Radke + Muller)

_____ There's a slab of naphthalene coming out of a slit, and it is coming out at a constant velocity U . What's the velocity profile in the (stagnant) air around the slab? What's the concentration profile like? (Constant in the slab because it's a solid, saturated in the air right next to the slab, then falls off to zero). I did a shell mass balance on a differential chunk of slab. Radke wanted the distance that the slab would disappear at. I never actually got there. I also did an energy balance. And used the $Nu \sim Re^{1/2} Pr^{1/3}$ (as well as the mass equivalent)... Radke kinda jumped around a lot, and kept asking me different questions. Muller didn't say much. Passed this one too though it felt pretty rough.

Radke / Blanch

Stan Herrmann

This was my final prelim and it started out very nice with a discussion about the University of Delaware where I did my undergrad (apparently Blanch did some work there and wanted to know about some of the profs). Then Radke came to the board and explained that I would be doing a modified version of the problem that no one answered correctly on our final for his transport class. I knew what problem he was talking about before he even asked it and I knew that I didn't know how to do it on the final. The problem was that a tape of a pure substance was being pulled from a dispenser at a constant velocity. Once this tape was exposed to the air it began to sublime. The task was to calculate at what distance would the tape completely disappear. This involved a shell balance around a section of the tape. Eventually I need to calculate the mass transfer

coefficient from the local Sh and explain how the Re and Sc number allow you to calculate the Sh (be sure you know why Re is to the $\frac{1}{2}$ power and Sc to the $\frac{1}{3}$ power). It's also good to know the Sc is very large for gases. After showing how to calculate the distance, Radke said that now the dispenser holding the tape was colder than the air around the tape. He wanted to know how to calculate the temperature of the last bit of tape before it sublimed. Since I didn't have much time left, this part was mainly a discussion rather than actual equations. It began with a discussion of a P-T diagram and plotting where the two temperatures were. This led to a discussion of the thermal boundary layer, whether convective or conductive heat transfer dominated in each region, the local Nu, the Pr and what everything meant. At the very end they had me draw all three BL's on one plot just because they thought it would cool to see all the forms on one plot. Overall, both Radke and Blanch were very enthusiastic and helpful. Initially I thought I was screwed, but if you just know how to do a shell balance, the flux terms, and the common dimensionless numbers you'll be fine.

BC

This prelim made me very happy that Thermo and Kinetics had gone so well. Thankfully it was last!

Radke started off by wondering aloud why it had been so many years since I had taken my Transport courses (Heat and Momentum in Spring 2007 and Mass in Spring 2008). He also didn't seem happy that I had taken Fluid Mechanics in mechanical engineering and that we had used Geankoplis in Mass instead of BSL. Sorry! They then looked at my grade in Grad Transport this semester (B), and I tried to make a joke that it wasn't exactly my best work. Instead of laughing, they agreed.

Blanch described the problem: A pure HCl waste gas needs to be disposed of safely; design a system to do this. I draw my best idea of what an absorber should look like: a tank full of water with spargers, an impeller, and liquid inlets and outlets. When I draw in a rupture disk that bleeds to a secondary tank of similar design, they seem particularly happy that I included this (and this may have been what saved me on this prelim!).

Their happiness did not last long.

Blanch asks how I will determine the tank geometry, and I say it must be tall enough so that the HCl gas is completely absorbed into the water before it reaches the top of the tank. They ask me to draw a single bubble, describe what's going on as the bubble rises, and draw the concentration gradient of HCl in the two phases of the bubble and the surrounding water. I initially draw a continuous concentration profile, but catch myself and make it discontinuous across the interface.

Radke asks me: how can I determine how much HCl can go into solution? I try to reason that I can do this with Henry's Law, but he does not seem at all happy about this answer. At his negative reaction to my answers, I start to lose my confidence.

Blanch asks me to explain what is physically occurring as the HCl dissolves into the water, so I draw the process: $\text{HCl(g)} + \text{H}_2\text{O} \rightleftharpoons \text{HCl(aq)} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{Cl}^-(\text{aq})$. He asks me again about how much HCl can go into solution, and then again about how I drew my concentration profile. I try to draw several profiles and say that it depends on the Damkohler number (or something like that), but they cut me off.

At this point I should have realized that in the physical process, HCl(g) to HCl(aq), equilibrium (and hence the magnitude of the driving force across the interface) was dictated by Henry's Law, while equilibrium of the chemical process, HCl hydrolysis, was dictated by the equilibrium coefficient for that reaction. But I didn't.

Blanch then told me that the dissociation step was extremely rapid, and asked me to redraw the profile. I make the gradient very very steep, and he asks me to draw it steeper, so that it is like the reaction is almost infinitely

fast compared to diffusion. They then ask me how I will figure out how long it takes a bubble of a given size to disappear as it rises, and I start reasoning that this is not how you would do it in practice because the bubbles would be going all over the tank, breaking up in the impeller and recombining, and the pressures inside the bubbles would be changing as they changed in size due to surface tension... and they cut me off again, and said that I should neglect all of that and only consider a single bubble of pure HCl gas rising unperturbed in a column of water. I started describing how I should probably figure out a mass transfer coefficient ($k_L a$) and use that to calculate the rate at which the HCl gas was dissolving into the water, as this would be the rate-limiting step if the reaction was essentially infinitely fast.

They then confused the heck out of me by asking how I would analyze the problem with thin film theory, or penetration theory, or any one of a number of things that I either hadn't learned, had forgotten, or didn't understand what they meant by them.

Finally they let me have my mass transfer coefficient, and asked how I would figure out how tall to make the water column. I began reasoning through the rate of mass transfer and the rise velocity of the bubble, leading to a force balance on the bubble to determine this velocity. I then got sidetracked talking about bubble pressure as a function of bubble depth and bubble diameter, and then all of the sudden I realized that I did not remember the expression for drag force in my force balance. Apparently this is one of two things that we were supposed to memorize for Grad Transport(?), and Radke was quite unhappy that I didn't know it. He was even unhappier when I could not name the one other thing we were supposed to memorize (the Hagen-Poiseuille flowrate equation). Eventually he gave me the expression, and I pointed how I would solve for whatever it was I wanted and finish off the problem. Radke then told me that I should have gone about the problem a completely different way, with a shell balance over a thin disk of rising bubbles, so that I never had to introduce time into the problem at all.

After this, time was up and they kicked me out. As I left the room, Blanch joked that my punishment was to retake Grad Transport every semester until I graduated.

I have absolutely no freaking idea how I got a B in this prelim.

Alexander / Graves

RL

This prelim was super random and not what I was expecting after having Radke for a semester/practice. I didn't write a single differential equation or boundary condition or anything. It was my first prelim so I was pretty nervous, and not having it be what I expected didn't help. Graves says that we have an ideal gas flowing through a tube and there is a heated section of the tube. Assume the gas heats quickly such that it has a step change in temperature. What happens to the pressure and the velocity? Now this is sounding an awful lot like thermo which I already suck at to begin with, so not looking so great. I start rambling on about a bunch of things some of which they agree with and some of which they do the whole "are you sure?" thing which is a pretty good indication that you should not be sure. Graves eventually asks me to consider the ideal gas law, what is the key variable when you change the temperature? I suggest pressure which he says we will get to later, then volume which he says doesn't really make sense in a flowing tube system, and he eventually has to tell me to consider gas density n/V , which I think sounds an awful lot like volume but I don't say anything. Anyway, for a step increase in temperature, you get a corresponding step decrease in gas density. Then we start talking about the velocity and pressure profiles, he asks something about the relation between the two. I write the Hagen-Poiseuille law which I mostly remember (which gets a "it's nice to have a young memory" comment, where I'm thinking that Radke told us to memorize that). I talk about increase in pressure drop with velocity and Graves says "huh, I hadn't thought about that before, guess I led you in the wrong direction." I'm

pretty sure I probably just said something dumb, but he seemed to think that I had brought up a good point (can't even remember exactly what I said anymore). In any case, he decides to move on after that, and I still don't have much of an idea of what the problem was or what he wanted from me. Next it's Alexander's turn, and he asks about the walls surrounding a furnace. He says we have 3 different materials, brick, insulation and cement or some such thing and a constant heat flux, what does the temperature look like through the materials. This is a problem straight out of your basic heat transport book and is pretty easy, but I hadn't reviewed the material since I was expecting something a lot harder. I drew the temperature profiles (linear in each region, different slopes depending on the properties of the material) and he asked about what made the differences. I talked about thermal conductivities of different materials, how molecules interact with each other, basically the physical significance of the k . Then he said, ok we only know the temperature at the two outside ends, not the intermediate ones between each material, how can we find those. I go on to talk about the different resistances, how you can sum them to get an overall heat transfer coefficient where the driving force is the overall temperature difference etc. He asks how could we determine what widths we should make all the materials and I say you can do it any way you want, in theory if you had a wide enough block of any material you could get to the desired temp on the other side, and that you would use economic considerations to determine the size of each one. Then he proceeded to spend the next 10 minutes trying to get me to say what I thought I had already said, asking what the resistance would be, mentioned how you could relate the process to Ohm's law summing resistances in series etc. I wrote down the resistance (though I had them upside down which he pointed out oops) summed them then could use the overall driving force. Thought I had already said all that, but just went where he was directing and he seemed happy. Graves then asked about what if you didn't know the temperatures at the two outside walls but rather in the center of the furnace and in the outside air, then what. Said you would just add another term in the resistance sum accounting for the heat transfer to the air $h \cdot \Delta T$ and extended the graph into the bulk on both sides. He asked about how I would find the heat transfer coefficient (Nusselt number, correlation with Reynolds and Prandtl) then asked if I knew any of those correlations. I mentioned I thought there was one like $Nu = 0.6 Re^{1/2} Pr^{1/3}$, he asked what that was for, couldn't really remember, he said flat plate. Then Graves moved on to ask if I'd seen the film falling down an incline plane, if we could talk about that. Said yes, he started asking different random questions about it, including draw the velocity profile, what BCs you make (no slip at wall, liquid-gas interface has no shear). He asked why we could use that BC for liq-gas interface, I said cause the viscosity of the gas is way less than the liquid, equated the two stresses coming to $\mu_{\text{gas}}/\mu_{\text{liq}}$ which is basically zero so say shear is zero. Then he asked about the pressure drop, I was pretty sure there wasn't one but was having trouble coming up with a coherent explanation, so he asked what the pressure was at two points on the surface and at the wall (in both cases it's P_{atm} at surface, $P_{\text{atm}} + \rho gh$ at wall), since they are equal at two different distances down the slope then no pressure gradient. Overall, it wasn't anything like what I had studied (which was mainly combined heat and mass, PDEs etc), but they gave me a good grade so I must have said some reasonable things to outweigh everything else. Basically, you need to know the basics really solidly, not just the more advanced stuff.

DO

After the usual chat about where I did my undergrad we jumped right into it. Graves pitched flow down an inclined plane except he wanted to know how far down the plane the water would travel before all of it evaporated. He had me start with the velocity profile, I wrote Navier-Stokes and started cancelling out terms. He asked me to justify why there was no pressure gradient and why the velocity doesn't change in the direction down the plane (continuity). He called my explanation about the pressure gradient hand-wavy and wanted a more rigorous explanation using hydrostatic pressure. I then drew the velocity and shear stress profiles. Next he asked me to describe how I would approach solving the evaporating film problem in words. I talked about convective mass transfer, he wanted to know which mass transfer coefficient I was using and what the concentrations were. He asked what the temperature of the falling film would be at the surface, I fumbled with this for a bit before eventually realizing it was the wet bulb temperature. He asked me if I knew how to do a wet bulb calculation, I explained the general concept but again he didn't make me write any formulas.

Alexander, who had said nothing during the Graves problem, then asked me to draw a furnace with three regions of steel, insulation, and refractory material. He told me we knew the temperatures at the far left and right edges but wanted the temperatures at the interfaces between the regions. We were running low on time but I talked about how the heat flux must be constant and could set up this problem analogous to a circuit using the overall heat transfer coefficient U . He also wanted the temperature profiles (linear with different slopes).

This was my first prelim, and a nice committee. It was important to justify assumptions. I passed, but felt like I should have done better based on the questions I had.

CA

I had essentially the same questions as the other two. Started with a composite wall of a furnace... Alexander asked for a circuit diagram of the resistances. Then set up the equation for heat transfer and drew some temperature profiles, talked about the Nusselt number and what h referred to. Then he gave me some numbers and asked me to solve for the R values. I got the point where we had three equations and three unknowns and asked them if they wanted me to continue since the problem was solved. Graves starts to say we're done but then Alexander jumps in: "I'm still not convinced we have all the information we need to solve these equations." I count out the equations and unknowns for him and say that I think we're done. Alexander is still not convinced (Graves is just shaking his head and trying to keep a straight face) so I start doing the math and within about 3 minutes Alexander is like yes, I see, ok we can move on.

Thankfully this didn't leave much time for the second question, which was the flow of ketchup down an inclined plane. I didn't get very far/do very well (although I should have nailed this one, since it gets asked all the time), but they gave me a B anyway.

Graves / Chu

NS

They begin my saying that they are sick of the problems that they have been given throughout the morning and say that they want to do another problem. I was thinking oh no, and they gave me the formation of SiO_2 from O_2 and Si . I had been hoping that I wasn't going to get this problem but unfortunately I did. I didn't spend much time really looking at how to set up this problem and what the boundary conditions were. Graves describes the situation and I draw it on the board. We go over the how to step up the governing equations and what assumptions we can make. One important one is that the rate of film growth is much slower than the rate of diffusion or something like that. I can't remember what he said but either that assumption was a commonly made mistake or that was the right one. Anyways I struggle through the problem but somewhere while solving I made a math mistake or so Graves thought I did. I get an equation but it depends on the SiO_2/Si interface that we don't know. Anyways Graves nor Chu couldn't figure out why my math gave me something different, but I redid it according to them and got the same thing. This took a while to get over for Graves. Chu decides to move on and ask about the characteristic time for flow through a pipe to reach steady state. It depends on the radius and kinematic viscosity. I didn't do as well as I hoped but oh well.

MS

After awkward small talk, Chu had me go the slateboard and said I had a pipe with fluid that initially had no applied pressure. At $t=0$ a pressure is applied to the inlet. He wanted me to describe the flow in the pipe as a function of distance down the pipe both at $t=0$ and $t=\infty$ (steady state). I did that one first because it's just HP flow, easy. I wrote out the Navier-Stokes and continuity equations and began canceling terms. They asked for assumptions/explanations for each term, which took some time. When I went back to the $t=0$ portion, I got a little tripped up and their subtle hints were not helpful. I began again with the NS equation, canceling terms.

Some how they directed me into explaining dilational viscosity and the dimensions of the stress tensor. I got back to the problem, and just explained verbally what I would do since I had coupled equations.

Then Graves asked about measuring heat properties of a fluid the way a mechanical engineer does since I made the mistake of saying I used a MechE heat transfer book in undergrad. After peeling through the layers of vagueness and convolution that existed in his wording, I realized he just wanted the correlation for the Nusselt number in terms of the Reynolds and Prandtl numbers. Then it was over. I was nervous coming out of this one because in my first one I flew through 4 questions and in this one I essentially had 1.5. I passed though; so don't let the number of questions worry you.

Tullman-Ercek / Muller

AML

Muller asks about a flat plane of water in which the reaction $A+BC$ is occurring. The left side ($x = 0$) is maintained at $C_a=C_{a0}$ with no B or C and the right side ($x = L$) is maintained at $C_b=C_{b0}$ with no A or C. The reaction is catalyzed heterogeneously at some plane $x=x_r$. They asked me how to approach the problem. I had trouble with where to incorporate the reaction term (depends on homogenous vs. heterogeneous).

Tullman-Ercek asked about a cylindrical viscometer (inner cylinder stationary, outer cylinder rotates) and how to determine the viscosity of a fluid using it. I talked about how you can approximate it using a flat plane, and how $\text{Force} = A \cdot \tau$ and $\tau = -u(dv/dx)$. She kept asking me what I would need to measure to determine the viscosity. I thought I'd said everything, and couldn't come up with it. Turns out she made me to explicitly say the force, which I'd already said. She then says that she drops a dot of colored dye, and rotates the outer cylinder 4 times one way, stops, and rotates it 4 times the opposite way. What happens to the dye? Depends on the viscosity, since more viscous fluids will remain in a dot, less viscous will streak. Depends on diffusion.. etc.

AH

My last exam, so I was a bit tired, but both profs were nice and helpful. Problems were exactly the same as described above by AML, so I'll just add a few points.

I described that you would obtain linear concentration profiles for A from $x = 0$ to x_r and for B from $x = L$ to x_r . On the far side of x_r , the concentrations of each would be zero. Then they asked for the concentration profiles of C. These were also linear, with a discontinuity at x_r . Muller asked me if the discontinuity would be a problem and I got really confused. After some minutes of talking in circles, I said, no, it's not a problem because x_r is where C is generated. She confirmed that was the correct answer.

First Tullman-Ercek asked me how we could measure viscosity experimentally. I went with the cone and plate viscometer, which we covered extensively in Radke's class. She set up a Couette viscometer situation. I wrote an expression relating the torque experienced by the stationary cylinder to the force exerted by the fluid on the cylinder. $\tau = \text{surface area} \cdot \text{shear stress at } R_1 \times R_1$. I had to be reminded about crossing the force with the lever arm (it's been awhile since I took physics). The shear stress could be found by differentiating the velocity profile and evaluating at R_1 . I mentioned that everything would be known in that equation (R_1 , L , velocity) except τ , which is measured. Using these you can solve for viscosity. Next she gave a hypothetical, asking if I'd seen a demo where a drop of dye is added. The outer cylinder is moved slowly for a set number of rotations, then it is slowly rotated back the other way for the same number of turns. I said that you would basically see the dot reform (with some diffusion, since there is a concentration gradient of dye). I said you might also see some spread from when you stop the rotation and go backwards, because it will take time for all the fluid to feel the change in force. She asked which sort of fluid would see more spread here - low or high viscosity? I managed to confuse myself and went with low, but she had me write the Reynold's number and realize that high viscosity fluids are more likely to have a perfect dot re-form, while fluids with a high Reynold's

number would not.

Take care with Muller to be accurate with what you write. At one point I accidentally wrote a partial derivative and she immediately jumped on it. The problems were not complicated, but she asked more detailed questions to really make sure you understand. Tullman-Ercek was nice, but didn't interject much besides when setting up her questions.

Verdict: Passed

Tullman-Ercek / Blanch

MD

This was my first prelim, and I was really nervous going in that Tullman-Ercek and Blanch would frame their questions around bio-related themes (the issue being that I know nothing about biology). However, this ended up being a completely unfounded worry. The lesson here is that you shouldn't waste energy fretting over the research background of your professors. Prelims are stressful enough without coming up with extra things to worry about.

Tullman-Ercek and Blanch were both extremely personable and friendly during the entire exam. They were in Blanch's office sitting on his couch facing the whiteboard, which made for a much more relaxing environment than in my other tests where the professors were sitting around a table. Blanch started out by asking me where I went to school, but didn't ask anything about textbooks or classes. My first question was from Tullman-Ercek, who asked me if I knew how to measure viscosity. I started out explaining how a falling ball viscometer worked, but she stopped me and said "yes, that's one way, but the problem i have involves a rotating viscometer. do you know how that works?". I switched over to explaining how the rotating viscometer works by measuring the torque on an inner cylinder as an outer cylinder rotates around the fluid sandwiched between them. Blanch then asked me how we could measure the torque on the inner cylinder. I fumbled for a bit and he prodded me toward the answer he was thinking of, by asking how we could measure it with a string and a rock. The answer didn't come to me right away, so I thought out loud for a while about what I knew about the system and about what I wanted to learn. This seemed to be a good strategy, because there wasn't any awkward silence and I received helpful hints when I said something that was on the path to the answer they were looking for. Eventually I figured out that you could tie one end of the string around a rock, the other end to the inner cylinder, and feed the string around a pulley so that the string would wrap around the inner cylinder as it began to move from the torque, being resisted by gravity acting on the rock. You would then know the torque when you had a heavy enough rock to resist the rotation of the cylinder. From there Tullman-Ercek described a scenario of placing a dye tracer in the fluid in the rotational viscometer and spinning it. Would it be possible to undo the mixing if the rotational viscometer were run in reverse? I had heard of this before, and knew the answer was 'yes'. She then wanted to know what sort of properties of the fluid/ operating conditions I would choose so that the process was most reversible. (high viscosity to reduce molecular diffusion, laminar flow to reduce mixing from turbulence). She then told me about how I could look up cool videos of people doing the experiment on youtube. :)

Blanch asked the next question, which involved cooling towers. He began by asking if I knew how a cooling tower worked. I knew the basic construction (hot water is poured down in sheets through the air, which cools it on the way down), but I was uncertain as to the exact mechanism how it cooled. Blanch said he wanted to know how to calculate the temperature of the water at the bottom of the cooling tower if he knew the temperature at the top. Sometimes my method of verbally thinking through problems was ineffective (as in this instance), in which I began by saying that there are two methods of cooling - evaporation of the water and heat conduction. My intent was to then explain how the evaporation of water would account for a much greater energy loss than conduction, but I was cut off as soon as I listed to the two methods and told that conduction would be negligible compared to evaporation. It's really frustrating to be told what you were about to explain,

but I chose the path of just dropping it and moving on as opposed to saying something like “yeah, I was about to say that”. Try not to let anything get you agitated during the test. Anyway, eventually Blanch had me draw a diagram of what the water-gas interface concentration profiles looked like (high flat line within the water, decaying line in the gas). He asked what the driving force would be - humidity. Tullman-Ercek then asked what the formula for relative humidity was, which I completely blanked out on, but she said it was just a side-note and to continue. Eventually we got back to how the water cools, and how the sensible heat loss in the water is due to the latent heat required for evaporation.

The last question was from Tullman-Ercek. She asked me to draw the velocity and shear profile for a fluid flowing down a vertical pipe. (parabolic velocity, triangular shear profiles on each side of the pipe - assuming cylindrical coordinates coming from the center of the pipe). She then asked how the profiles would change if the viscosity of the fluid was changed. I knew the velocity profile would become shallower, but I had to think through how the shear profile would change. I knew velocity was proportional to the inverse of the viscosity, and shear is viscosity times gradient of the velocity, so I said the viscosity would cancel and it would be independent of viscosity. Turns out this was the right answer, but they either didn't understand my argument, or were just looking for a specific derivation, because they then took me on this long and roundabout journey in which they were trying to get me to say that the driving force was the pressure difference, but for whatever reason I just wasn't catching on to what they were trying to lead me to say, so it was a very drawn-out process trying to get there (I was also distracted by the fact that I thought I had already answered their question, so I thought maybe my answer had somehow been wrong and I was supposed to be looking for a reason why it would be wrong). Anyway, eventually all they wanted me to say was that the flow was driven by a pressure gradient, which had nothing to do with viscosity, so that's why the profile was the same? I am still confused as to the motivation behind the exercise they put me through. At the end they said I still had a little time, but they were done with their questions so I was free to leave early.

CS

I was pretty confident about transport - but this had nothing to do with what I've been preparing myself for! Tullman-Ercek asked the first question and she told me that she was going to ask a new question and that it was a very complicated question and that she just wanted me to only set it up. There's a capillary in which blood flows through and it's surrounded by tissues (cells?). The oxygen in the blood is transferred to the tissues, and how would I get the oxygen concentration profile inside the tissues and the capillary? This question really threw me off; first I assumed that the capillary was a straight cylinder with no end effects and drew the coordinates and velocity profile inside it. Then I thought about the oxygen and for some reason I started thinking about the red blood cells and how oxygen is carried by them??? So I blabbered on about assuming that the oxygen is simply dissolved in the blood and that it would be well-mixed across the radius, but Tullman-Ercek did not like that. She kept asking me would it really? And I kept arguing back that yes it would, or at least I can assume that, when I knew I should have just accepted that she wanted me to say that the concentration actually does depend on both r and z . I kept arguing back until Blanch finally told me that “she wants you to”. Then I wrote a shell balance on the concentration of oxygen inside the capillary. And Tullman-Ercek told me that there's another shell balance, which I just couldn't see, but after some hints, I realized that diffusion is also going on inside the tissues, so that oxygen would move in the z direction inside the tissues, so I wrote another shell balance for the diffusion inside the cells. And I wrote out the boundary conditions, which turned out to be not so simple and I struggled a bit. Tullman-Ercek never told me if I got it right or not.

By then, I was ready for another question; a real transport question. Blanch told me about lactic acid and how it is produced and used for some things. I listened carefully and patiently waited for the transport part of the problem to come. But the question was: how do I get lactate? From lactic acid? I still don't know for sure if this was actually a preface to a real transport question, but for the next 20 minutes I struggled through different chemical reactions until after a bunch of hints and chemistry lessons from Blanch I finally found out that first adding CaOH_2 and then H_2SO_4 , it can be achieved.

AB

Started off with my background and where I am from. The Blanch asked me about a problem where you have 2 immiscible liquids between 2 flat plates with the bottom one being pulled at constant velocity V and the top plate stationary. I was asked what the velocity profile would look like. He then asked why is it parabolic (from NS eqns). Also asked why dp/dx is a constant in NS eqn for this case (because $f(x)=g(y)=\text{const}$). Then Tullman Ercek asked me about how to measure diffusion coefficients. She asked me about the dumbbell shaped instrument where 1 chamber is empty and the other has gas and at $t=0$ the gas is allowed to flow. She asked when can the value of D be considered independent of the trajectory of molecules (mean free path \ll diameter of connecting pipe). Asked about order of magn of D . Then Prof Blanch asked me about how we can heat a bucket of water to make tea by dropping a heated sphere into it. Usual heat balance but here the temp of sphere and the bulk water both are changing so 2 heat balance eqns required. He asked about some of the assumptions I had made while writing the heat balance eqns like lumped capacitance, temp of water being same everywhere etc. Also he asked how shaking could be used to accelerate heating (influence on h). Then Prof Ercek talked about measuring viscosity where you have 2 concentric cylinders with the fluid whose viscosity is to be measured is within the cylinders. The inner one is rotated while the outer one is stationary. She asked me which force I would measure. Then she asked if I put a tracer how the tracer would spread out as we rotated. Then if we rotated back to the original position what would happen to the tracer (it will come back). She asked if the analysis was valid for non-newtonian liquids. Also the influence of reynolds number on the tracer experiments (whether tracers would come back to exactly where they were). They let me go after this.

Preparation Advice

Gateau Paris-Brest

General advice: Overall, prelims is a pretty stressful experience. I've never felt so stressed and I stressed out a lot in undergrad, so that's saying something. It definitely affected my sleep schedule (and afterwards too since I'm writing this at 4am), but it was a good experience. It'll amaze you how much you can re-learn or, in some cases, learn in a week and a half. I think your attitude towards prelims definitely is key. You need to go into them with a confident mindset. Just think about prelims as an opportunity to show professors how much you know. If you think about it in the right way, prelims are one of the few times you can show off and flaunt your knowledge without anyone thinking you're trying to show off.

Spend lots of time practicing talking while thinking and writing at the same time. I found it hard, but I think that professors get less antsy if you keep talking and explaining. They also sometimes latch onto the correct things you say, and prod you along.

AH

I took about 10 days of serious studying, but I set some limits for myself. I found a good study space (my desk in lab), brought all my books and flashcards and things there (and lots of snacks), then went and studied there from like 9 AM - 6 PM. In the evenings, I went home, had dinner, relaxed, and went to sleep early (lots of sleep is so crucial, you guys). This was instrumental in helping me not burn out. The Monday before the exams, I started participating in mock sessions from older graduate students and other first years. If your lab doesn't set these up for you, I suggest asking the older students in your lab or others you know from class/social times to take an hour to help you. It's tremendously helpful to practice being put on the spot in a friendly environment first. I also made some quiz sheets to help me memorize dimensionless numbers and various equations. I printed out a stack and took one a day for practice.

BC

Prelims were Thursday and Friday, and I started studying seriously on Tuesday evening. I worked alone, at my desk in my apartment, for about 36 hours straight right before (and during) the exams.

I had TA'ed multiple times and had done a huge amount of tutoring as an undergrad, so a lot of this stuff was decently fresh despite having taken the classes 5+ years ago. I did a mock prelim with some senior grad students on Wednesday night, and this was extremely helpful to remotivate me and refocus my efforts in the last few hours. Working past prelim problems was way, way more efficient than reading textbooks or notes.

Did I memorize dimensionless numbers? No, because who really cares. I think people fixate on this (and other silliness, like memorizing the minute details of every thermodynamic cycle [Brayton, Otto?] that no one's ever heard of) because they are easy and obvious ways to waste a lot of time without thinking particularly hard. Senior grad students often quiz on this garbage during practice prelims because simple, mindless trivial pursuit questions are a lot easier to come up with than solid, difficult, realistic 'heart of the matter' conceptual questions.

Not knowing some single chemical engineering fact will never derail a prelim for you, so invest that time instead on ensuring that you can assemble meaningful technical arguments using the core superstructural elements available to the chemical engineer. Transport, Thermodynamics, Kinetics - sure there are lots of

details, but this is the really, really big stuff. Why memorize a single specialized design equation when you can start from the very most general mass balance and reason from there? Put away the crown molding and get out the I-beams, and save yourself a lot of time and sanity.

Does cramming at the very end help? Absolutely, if you haven't put much time into studying. This is especially true if it makes the difference between knowing *something* about transition state theory (or the like) and knowing absolutely nothing.

Will this strategy work for most people? Absolutely not. Proceed at your own risk.

CA

I studied for maybe 10 days to a week before prelims. I think this was about my max... any longer and I might've gone a little stir-crazy. I definitely wasn't studying 24/7 either... I took breaks to go running, make dinner, go to Berkeley Bowl, etc., and I think that helped a lot. Anyway, I think that was a fine amount of studying.

One of the harder parts for me was finding people to study with. I absorb much more when I can talk about problems with someone else, and it helps me stay focused, but a lot of people disappeared into holes for those two weeks. I spent most of the first week in various coffeeshops going through old prelim questions with a stack of textbooks next to me so that at least there was stuff going on around me. I recommend Berkeley Espresso- the WiFi is decent, tea is cheap and they play soothing classical music. About 3-4 days before prelims, I started studying with other people who lived nearby or at the GSL. In this phase, whiteboards are clutch. On second thought, leaving the group studying until later was probably best because people were a little strung out by then and someone might have gotten hurt.

Honestly, I wasn't too stressed going into prelims. Not because I thought I'd do good - the extra three years between undergrad classes and grad school certainly didn't help, and my grades fall semester were not stellar. But I figured I'd just try my best, and worst case scenario I would definitely know everything by the next year. Just try to keep things in perspective, and you will save yourself a lot of unnecessary stress.

I recommend just going in with a smile and when you don't know the answer, try to learn something. Not everyone returns your smile (cough*Iglesia*cough) but I think looking calm helps. I ended up getting straight Bs, which was good enough for me. (: