1998 Prelims

Transport Denn/Graves

1. Describe the use of a hot-wire anemometer. Set up the basic equations. Could you determine anything about the heat transfer coefficient by doing drag experiments? (Got me into a discussion of Chilton-Colburn analogies, which,remember, are only applicable in the absence of skin friction) Do you know who Chilton and Colburn were? (Apparently, they were mere children in the 1920s)
2.You have a pipe with flow - sketch the boundary layer. What if you had a species diffusing into the fluid through the pipe wal?. Sketch Vx,Vy (Vy is due to bulk flow from diffusing species).
3. Take a semi-infinite Si slab. Oxygen from outside the slab diffuses into the slab and reacts with Si to form SiO2 at a reaction front that continuosly and slowly moves into the slab.Set up the diffusion equations and appropriate BCs. Solve them for the O2 profile.

Design Keasling/Lynn

1. Tell me all about your senior design project. Tell me why in god's name you chose to do it that way. Did they teach you anything useful at your school?
2. How would you control a surge tank (liquid level). Discuss various controllers and strategies.
3. Draw MTBE. Why is it an environmental problem? If it is coming from leaky gasoline tanks, why do we not find gas in our drinking water as well? (Polarity etc). How would you remove trace MTBE from drinking water? (Activated carbon) How would you regenerate this bed? (need water to extract the MTBE, as well as heat to desorb it from the carbon surface water + heat = steam)

Thermo/Kinetics Chakraborty/Clark

1. Set up the equations to describe a primitive fire starter made out of a piston and cylinder.
2. How does heat capacity of a pure substance behave at a phase transition? at the critical point?
3. How do you model reaction kinetics? (involved postulating a mechanism, testing it etc) Then got into a broad discussion of a free radical mechanism, PSSA, QE, low- and high-pressure-limit apparent rate orders.

Thermo/Kinetics from Iglesia/Reimer:

This was surprisingly my hardest prelim because It was my first and I was nervous. Although they were very friendly and cordial I got the feeling that a passing grade required that I nail most of the problems right away and not require much "guidance."
Reimer started off by asking me how to do a bubble/dew point calculation (I wrote down the full-blown equation relating fugacity of two phases and explained each of the terms. At one point I had a brain freeze and forgot the official name of gamma "the activity coefficient" and Reimer got a little annoyed). Then he asked for a Txy diagram for the water-HCl system (I drew a generic Txy diagram and he thought it was too ideal and asked me to redraw it more correctly for this system--apparently I didn't get the shape of the curve right). Next was

a question about a reaction at equilibrium and how to use LeChatier's principle to push it the way you want it. Iglesia asked me to derive a kinetic rate expression from a given reaction mechanism using MARI and QSS approximations (he got a little impatient when I started doing it analytically--kind of wanted me to do it more by visual inspection). Next a simple extent of conversion problem for a gas phase reaction with changing volume. Next I had to compare the temperature vs. distance curves for 2nd order and zero order reactions in an adiabatic PFR (they both increase exponentially, but zero order abruptly goes to zero slope somewhere in the reactor when the reactants run out, whereas the 2nd order goes smoothly to zero slope). Finally, Iglesia wanted me to explain the difference between equilibrium constants K, Kc, Kp and why we use each particular one.

Transport from Muller/Radke:

Muller first asked me their well-beloved lid-driven flow problem. (Basically, write down unidirectional Navier Stokes and solve for a velocity profile in the middle region of the box.) Then a small question then about the different terms in the N-S equation (what they mean, why we would want to neglect nonlinear terms). Next Radke asked about temperature profile in a rectangular solid electrophoresis gel with resistive heating (wanted 1-D energy balace with a constant source term. one BC from centerline symmetry and one convective dissipation BC). In neither of the above problems did I finish obtaining all the unknown constants from the BCs before they asked me to just sketch a qualitative form of the solution. They expected me to know the boundary conditions well, e.g., what the velocity or temp profile looks like at the edges. Then a few small questions on how to get that convective heat transfer coeff. including knowing what Re and Pr numbers are. This was my favorite (if there can be such a thing) prelim because I felt like it was straight-forward without nasty trick questions.

Process Design from Cairns/Wallman:

Not many people know Wallman because he works out at Livermore Lab, but fortunately some things you can count on Cairns to ask. They pretty much wanted "the one right answer" so they just kept nudging me until I got it exactly right--but not too high pressure. I think they genuinely like the prelim to be a "teaching moment", not just an examination and would be disappointed if you knew everything they did.
Cairns asked me about my senior design project. After I drew the PFD, he was mostly interested in the reactions taking place (in my case they were electrochemical so he was especially interested) and in proper disposal/recycle of any nasties. Fortunately I knew where every waste stream went so this part was rather relaxing. I had heard that Cairns likes to ask about making silicon, phosphoric acid, aluminum, or any elemental metal that requires an electrochemical process--it turns out he asked me the "make lithium" question. I couldn't remember all the steps (I got to a point where I knew there was an electrochemical cell but I didn't know what solvent to use) but he helped me along after I got stuck.
Wallman asked me to propose a process to use hydrocarbons as an energy source w/o producing a lot of bad greenhouse CO2. Basically, it

required my knowing the steps of the 'partial oxidation of CH_4' reaction and later the 'water-gas shift' reaction (I'm glad I studied the section on syn gases from Shreve's). He helped me at the few times I got stuck.

Thermo/Kinetics
Petersen: explain Langmuir-Hinshelwood kinetics, when are they valid, when not (nonuniform surface).

Chakraborty: Assume you have a method to light a fire as follows: hollow stick, closed at one end (diathermal wall) placed next to ignitable fuel. Another stick (ie, piston) is rammed into the hollow stick. The fuel ignites. What is happening? (adiabatic compression of ideal gas).

Explain what happens to Cp at the critical point.

Process Design
Blanch - explain how you would design a cooling tower, what factors to consider (height, diameter, flowrate of air and water), show energy balance (using concept of wet bulb temperature).

Wallman - Say you have a wastewater pond. Model the pond: mass balance for water and for the pollutants
for the pond and for the sedimemt and outflow (it took me a very long time to figure out what type of system he was trying to describe). Sediment mass balance includes adsorption onto sediment particles. Remember to include rainfall and evaporation as parameters in the mass balance for water.

Transport
Muller - Model the heat transport in a electrophoresis gel. Assume the gel is suspended vertically (no table tops to worry about), heat generation is uniform in the gel, heat transport by conduction within the gel and by convection away from the gel. Know the general profiles that you would expect for the temperature.

Denn - Say you have a hose or pipe that is closed at one end and has several holes along the top. Water flows into the pipe and out the holes. Will the water rise to its highest height at the first hole or the last hole?

(answer: do a bernoulli equation balance on either side of a hole to get a relationship for the pressure profile down the pipe)

What are some correlations for h (heat transfer coefficient)? Why do they have this functional form? How are the constants derivied?

Goren

1). Sketch qualitatively the dimensionless velocity profile of fluid passing over a flat plate

2). Now sketch the dimensionless temperature profile in that fluid assuming that it is water (i.e Pr of 7) and that the plate is held at a constant surface temperature.

3). What is the origin of your relationship in the thickness of the two boundary layers (i.e. he wanted a quantitative discussion of the physical basis for the Chilton-Colburn analogies)?

Newman

1). Consider a bubble in a fluid with an imposed temperature gradient. HOw will the bubble move? What are the forces that determine the direction of the bubbles movement? He wanted to get to a quantitative description, but I was so lost by this question, we ran out of time.

DESIGN (Cairns and Prausnitz)

1). What was your senior design project?

2). What are the industrial uses of your product?

3). What is the origin of your starting materials? (I had acetic acid and acetone and they wanted me to walk them all the way back to oil).

4). How do you make zinc?

5). Why doesn't hydrogen form at the cathode instead of zinc metal? (Although hydrogen is the thermodynamically preferred product, the kinetics of zinc plating is faster.)

6) Name a strong acid

7). Name a weak acid

8). Name a salt that when added to water would give 1) a basic solution 2) an acidic solution.

9). How would you control the temperature of a tank filled with liquid? (You have an inlet flowrate and outlet flowrate and you can add heat through a boiler).

10). What are the different types of control strategies and why would you use one over the other?

11). How do you make nitrogen?

12). What do you use ultra pure oxygen for?

THERMO and KINETICS (Petersen and Reimer)

1). Name an indutrially relevant exothermic reversible reaction (I chose ammonia production)

2). Discuss the issues surrounding the design of a reactor to produce this compound?

3). What are some fo the ways you could increase the conversion of this reactor?

4). Write the design equation for a PFR.

5). Sketch conversion vs. T for this reactor (with the ammonia reaction)

6). What allows us to design a reactor for a particular residence time and then fill it with catalyst (thereby decreasing the residence time of the reactants) and still get the conversion we expect)? I still don't get the point of this question, sorry!

Reimer

7). Given the reaction Acetone --> Ketene + Methane, how would you determine the equilibrium constant at 1000 degrees celsius from data that you are likely to have in a regular handbook.

deltaG= -RT ln K

8). But I thought that deltaG for a reaction at equilibrium was 0...

He wanted me to put the superscript naught to indicate at STP.

9). Well, then how would I get deltaG?

deltaG = deltaH - TdeltaS

10). Where do I get deltaH and deltaS?

deltaH comes from deltaH of formation at STP. To find deltaH at 1000 degrees use the heat capacity

deltaS comes from the third law (i.e. deltaS = 0 at T = 0) and use the heat capacity/temperature in order to convert it to 1000 degrees

Be sure to take into account the heats of vaporization and melting

11). What is K?

He wanted me to show that K was not just using partial pressures. He wanted activities.

12). What is an activity/fugacity?

13). How would you find the bubble point of a mixture?

14). Draw a T xy diagram What is the significance of each of the regions of the diagram?

15). In an HCl-H2O mixture, what might this diagram look like?

Process Design

Fully Describe your senior design project
- Know stream compositions, Temp, P
- name function & basic principal of unit ops units

What is MTBE
- Methyl-tert-buytl-ether a gasoline additive to make it burn cleaner.

How has it been mentioned in news?
- pollution in motor boats

How to treat water w/ contamination?
- activated carbon
- regenate w/ steam, @ HP & HT

Thermo Kinetics.

Draw a phase diagram for a pure substance?
How is water different?
Why?
Frozen water is not dence since it only bonds w/4 neighbors

1st Law, Open system
what is reversible work needed to pump water 80 m up?
- Bernoulli Eq.

Kinetics
what is ΔH of an exothermic & endothermic rxn
How would you determine the number of molecules in the intermediate state?

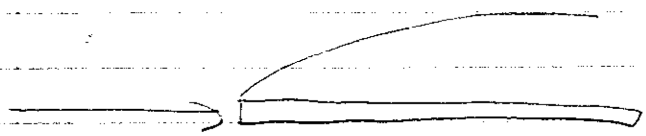
Transport.

Reynolds Analogy & Chilton-Colburn Analogy.

Transport of O_2 through Si w/ Rxn

Transport: Newnan + Goren
good cop bad cop

(1) Boundary Flow:



describe nondimensional velocity distribution, temp dist
=> derive Chilton Colburn Analogy from ~~and~~ Reynold's analogy (use Buckingham Pi Thm to explain nondimensionality)

(2) Bernoulli Eqn

asked general questions about, know assumptions needed from full energy balance

Thermo +kin: Petersen + Chakraborty
Chakraborty was checking his email while I was answering

(1) Thermo: (A) Primative fire starter (I don't think I ever quite understood what Chakraborty was getting at...)
Use first law to describe temp. rise (adiabatic), assume ideal gas, use maxwell relations, entropy,
A hollowed-out, small trunk with glass

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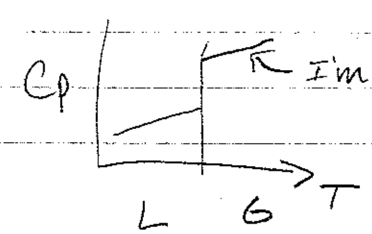
outside. A tight fitting stick (piston) is rapidly inserted into the hole, a fire ball pops out the end (but there is no hole at the end... like I said, I didnt really get it...)

③ How C_p changes with temp and over 1^{st} order phase transition (discontinuity at p.t. $\Rightarrow C_p \rightarrow \infty$)



I'm not sure of this slope

know reasoning behind this

Kin: An adiabatic, exothermic reactor. ~~to~~ know temperature profile along length, use energy balance (Yes! Memorize the whole thing)

Process Design: Prausnitz + Lynn ⇐ Two grumpy old men
Described project, then they ripped into me:
1) Why use this solvent? (I got schooled in organic chemistry)
2) They will hint at ways to do it better and will leave you guessing what they are talking about and how to make it better, which if you knew how to do it better, you probaly would have done it when

you designed the damn thing. They were harsh. Know organic chemistry of solvents.

3) Give two ways to separate O_2 from air
A) Cryogenicly: know why the pressure is increased/decreased, what happens to products, why remove H_2O + CO_2
O_2 is used to make steel!! (I said scuba and got yelled at!)

B) Pressure swing absorbtion
- know what molecular sieve looks like, what does it absorb? What if water gets in? Know the cycle/graph (I forgot what it is called) for when you need to regenerate the process. Know the temps at all points. Why is this advantageous over the cryo process.
- Do you want to absorb at 10 atm or 1atm and regenerate at 1 atm or 0.1 atm, respectively? (Answer: 10atm/1atm so you don't have to repressurize the N_2 + other products leaving)

- In all process know exactly why every step is taking (removal, T or P change, solvent added, etc then they asked about the control system for the fluid level in a tank. (Don't believe the hype! Since the revision Prausnitz and Lynn will ask about control. And they will be grumpy about it.)