1997 Prelim Questions

TRANSPORT

Blanch /Goren:

Goren: You have a hemispherical rain gutter that is slightly inclined from both ends to a downcomer of unspecified length. The gutter specifications are given, including slope. If the gutter were filled to overflowing, what would limit the rate at which water could be removed through the downcomer? Derive equations for the flow. Quantitatively, what would the flow through the downcomer be?

You have a pipe with fluid flowing turbulently through it. Let's say you have a given velocity profile. Draw the temperature profile.

What is the Prandtl number? What is the value of the Prandtl number for water? (You admit you haven't memorized the Prandtl number for water...the answer is 7. Goren laughs heartily and says, "You don't know the Prandtl number for water?! Water is the most important fluid in the world!")

What is the universal velocity profile?

What is the form for heat flux by radiation? On a hot day, would you want to wear white or black? At night, would you wear white or black? What if you were in the desert?

Blanch: Explain wet-bulb temperature.

Muller/Radke

There is a naphthalene pipe coated on the outside with metal. The initial condition is given: the concentration of naphthalene in the pipe is at saturation. Air flows through the pipe with a naphthalene concentration of zero.

a) Describe how pipe thickness varies with time.
b) Determine mass transfer coefficient. What are the Pr, Re, Nu number?
c) How long does it take for the air to be saturated with naphthalene?

Denn/Graves

Denn: Qualitatively derive the steady-state temperature profile in the entrance region of a pipe for a very viscous fluid in laminar flow.

Graves: Derive the steady-state fully-developed temperature profile of water in a circular pipe with steam condensing on the outside.

Denn/Radke

They gave one question:

In a rectangular electrophoresis gel with no flow and constant resistive heating, find the temperature profile.
They first asked to sketch the profiles in a qualitative way and explain what's happening.
Then they wanted the solution for the profile. This entailed shell balances, knowing what resistive heating is, finding the BCs (one of which is the Danckwertz BC), solving a nonhomogeneous ODE, etc.
They then wanted me to play with the physical parameters to generate a dimensionless group governing the energy transport. It turned out to be the Grashof Number.

Blanch/Graves

Blanch:

There is a diver at the bottom of a swimming pool blowing bubbles of pure oxygen through a straw. Before it detaches from the straw, write a force balance to estimate the size of the bubble when it leaves the straw. What is the velocity of the bubble as it rises? Describe the flux of oxygen out of the bubble into the water. In the equation that relates the Sherwood number to the Reynolds number and Prandtl number for this situation, what is the significance of each of the terms? Why do you not have to consider flux within the bubble? Is this a case of equimolar counterdiffusion?

Given a tank of water with a pipe coming out the bottom, find the time to empty the tank of water. Know how to use and set up Bernoulli's equation. Be sure you know how to account for frictional losses in the pipe. i.e. orifice meter, pitot tube, venturi meter.

Explain how a cooling tower operates. Write the governing equations.

Graves:

Derive the equation that describes pressure-driven, fully developed flow in a horizontal pipe. How do you know that the pressure gradient is a constant? Describe non steady state Couette flow. Flow of Newtonian fluid between two parallel plates.

Find the temp conduction profile of a thick tube. Know how to derive and solve a shell balance. Know Fourier's law. Know the units of all symbols used.

Graves/Denn

Graves: Cylinder containing pure solvent a, flow over the cylinder is component b which is insoluble in a. Write down the governing equation and solve using appropriate boundary conditions.

Denn: How does a pitot tube work? How does the pressure in the boundary layer around pitot tube vary?

Blanch/Radke

They really didn't split their questions up, but Blanch started the problem, so it might have been his. You have a scuba diver with a slow leak in his O_2 line. What is the radius of the bubble right before it detaches from the tube? (Find from force balance with buoyancy and surface tension)
2. When the bubble is released from the tube, how does it transfer O_2 to the surrounding water? ($N_a = K_c (C_{interface} - C_{water})$)
3. Sketch the concentration profile. (not continuous)
4. How do we find K_c? (Heat and mass transfer analogies)
5. What group best characterizes the mass transfer situation? (Sh)
6. What does Sh depend on? (Sc, Re)
7. What is this relationship? ($Sh = 2 + Constant*Re^X * Sc^Y$)
8. When is Sh=2? (when velocity = 0)
9. How do we find v? (Assume creeping flow and use Stokes Law)
10. (Luckily, I ran out of time for this one since Blanch and Radke had spent most of their time cracking jokes like "Wow, you knew that one" or "Don't forget the Radke and Blanch numbers. Which one goes to infinity and which one goes to 0?")
How does the bubble radius vary as we transfer O_2 to the ocean? How will this affect the terminal velocity?

THERMO AND KINETICS

Iglesia/Reimer

Reimer:

Estimate the temp rise in a primitive fire starter composed of a piston in a cylinder.
Estimate the change in temp when mixing H_2SO_4 with water.

Iglesia:

A mechanism analysis of Langmuir-Hinshelwood kinetics problem requiring PSSH, QE, and MARI.
A reactor design problem for a PFR with multiple flow points, estimate the ideal spacing between the reactant entrance points.

Maboudian/Clark:

Maboudian:

What is the Carnot cycle? What does the first law tell us about the Carnot cycle? Derive the thermal efficiency. Show the Carnot cycle on a S-V, P-V,etc., whichever diagram with which you feel comfortable. Give additional details about what the areas enclosed were and what they represented, e.g., the area enclosed by on the P-V curve represents work, etc.

What is the Rankine cycle? What does the first law tell us about the Rankine cycle?

What happens if you put a van der Waals gas into the cycle? Specifically, what happens to the efficiency? (answer= nothing!!)

Clark:

How do you determine reaction rate constants? Why are they Arrhenius? What are the three main types of reactors? Derive their design equations. What does the residence-time distribution look like for each reactor(ideal and nonideal cases)?

MSS stuff: When can you have MSS, why do they occur, which are stable, write down the governing equations off the top of my head (arrrgh! Yeah, right Clark!)
How to measure stuff like specific rate constant, specifically for CSTR.

Reaction within particles. Diffusion with reaction. Thiele modulus. Effectiveness factor. Arrhenius form for rate constant. Kinetic vs. transport limited regimes and their effects on apparent activation energy and reaction order. Non-ideal reactor models, e.g., a PFR with axial diffusion.

Petersen/Chakraborty

Chakraborty:

What is the change in entropy for an ideal gas expanded from V_1 to V_2 at const T?
What causes a gas to condense as you lower the temp? (I think he was just looking for something like Delta G has to be >0)

What is a liquid? What is a gas? Explain the difference.

Petersen:

How do you make H_2SO_4? Is the rxn endo or exothermic? How do you make SO_2 for the process? Where do you get sulfur from? (At this point, I thought he was confused and thought this was a process exam) Write the equations to describe the reversible step of the reaction. (He was just looking for the PFR design equation and he tells you to assume 1st order rxn).
What's k, what is in it, how is it a fxn of T?
Draw Xeq vs T for the rxn.
Is X a unique function of T? (No idea what that was supposed to mean. He mumbled something about how X vs T lines from your energy balance may be curved if the rxn isn't adiabatic).

Is the formation of ammonia from N_2 and H_2 exothermic or endothermic? Why?

Determine the reactor volume needed to produce ammonia.

Iglesia/Reimer

What are the three laws of thermodynamics? How would you design a thermo class to teach to college sophomores? What would you do to help students with different learning styles to understand ideality?(Reimer)

If I have an arrangement of papers on a desk and I dump it on the floor, does the entropy increase?(Reimer)

Pyrolysis of methane occurs, forming CH_3* in the elementary step. Write the mechanism.(Iglesia)

Define bubble point and dew point.

Chakraborty /Clark

Chakraborty:

Why do substances give up entropy to exist in the liquid phase as you lower the temperature?

Clark:

What defining parameters make PFRs and CSTRs reactors different? Show the residence time distribution for PFRs and CSTRs.

Reimer/Clark

Reimer:

Describe how you would organize an undergraduate Thermo course. Give an outline. He then took apart my outline and asked for details.
Examples:
Show how to teach conservation of energy to an undergraduate using quantitative examples (Joule's experiment works well here). For equilibrium thermodynamics, describe the equilibrium conditions and give examples for solid, liquid, and vapor phases with equilibrium equations. If you wanted to illustrate the first, second and third laws of thermo experimentally to your class, how would you do this?

Clark:

Describe the basic types of reactors. Which reactor has the highest conversion for a given volume? When would you want to use a CSTR over a PFR? Think of an example which does not involve multiple reactions. Describe the residence time distribution in a PFR and CSTR. Derive the equation for the RTD in a CSTR. What type of experiment would you do to show the RTD? What are the assumptions entailed in CSTR and PFR design equations (and the equations, too, of course). Describe different models to describe nonideal PFRs. How can the degree of axial dispersion in a nonideal PFR be measured. (This spawned a hellish entry into the land of distributions: E and F curves for step and pulse inputs, etc.)

What is the significance of the chemical potential when it comes to mass transport?

Reimer/Petersen

Reimer:

The native African people use the following device to start a fire (you can't rub two sticks together to start a fire due the humidity): take a tree trunk and drill a hole through it, find a rod that is approximately the same diameter as the hole. Place a dry piece of grass at the bottom, push the rod into the hole and down pops a fire grass ball. How would one go about modeling it and what principle is used?

Petersen:

How does the kinetic rate and thermodynamic equilibrium vary with temperature for both endothermic and exothermic reaction? For exothermic reaction, plot temperature vs. conversion How does one go about maximizing the conversion? Derive the PFR and CSTR design equation. Tell me how you would teach a course in kinetics. Give a course syllabus. Then he asked many questions concerning RTD. What info do you get from them? How does a change in volume change the rate expressions, design equations. Know different definitions of conversion and why you would use one or the other.

DESIGN

Keasling / Lynn

What are the 3 main types of controllers? How do they work?

What was your senior design project?

Cairns/Wallman

How do you make zinc?

What happens to the pressure if you increase the cooling rate of a condenser? Show this with equations.

Vorhis/Keasling

Describe your senior design project. Describe how a membrane separation unit works.

Describe and give an example of feed-forward and feed-backward control. what are the advantages and disadvantages of each?

Describe the 3 main types of controllers. What are their advantages and disadvantages?

Vorhis:

Make H_2 on a lab scale.
Make H_2 on a industrial scale.

Prausnitz/Cairns

Prausnitz:

What was your senior design project?
Why did you use oxygen for a catalytic reaction instead of air?
How do you make oxygen? How do you make hydrogen? What is hydrogen used in?
Why do distillation towers operate at elevated temperatures?
How do you purify air?

Cairns:

How do you make lithium? Where is Li found in nature?
After you smelt $LiCO_3$, how do you separate it? Is $LiCO_3$ basic or acidic?
How do you make zinc?
What is syngas?
Why do wastewater treatment plants use pure oxygen and not air?

Lynn/Cairns

Lynn:

So, what was your senior design project, little boy?
I didn't have one but they made me recall a process I knew and I put it on the board.
Typical things asked about the process (I can't recall who asked what nor do I want to):

What temperatures and pressures to operate at.
Size the reactor.
Find the amount of steel needed to construct reactor. (Hahahahahaha)
What streams should be recycled and why.
Construct separation scheme to get pure product.

How is Nitrogen obtained commercially? Give two other alternate methods for obtaining Nitrogen.
How does a multistage evaporator work?

Cairns:

Write out the reactions at the cathode and anode of your electrochemical cell. If the current efficiency is only in your electrochemical cell, where does the other 5% go? If this other governing reaction is more thermodynamically favored , why in practice does it not occur noticeably in the process?

Vorhis/Wallman

Design of a flash drum...w/ controls (tank level stuff); what you have to do before you put it in (pressure and HX, etc); governing equations (don't forget enthalpies) and sort of degrees of freedom stuff (how many equations/variables do you need/have?)

How do you get rid of sulfur containing compounds (and not just the claus process, which is what I knew---other ways like making salts)?

Keasling/Lynn

Lynn:

Lynn mainly asked questions about my senior project (styrene plant). He wanted a full plant diagram (including as much of heat exchangers, operating T's and P's, and reactor yields). These questions were obviously specific to a styrene plant, but they might have enough general principles to be of use or allow people to gauge his questions.

1. Which separation is the most difficult? (Here, he was wrong about which of two species were more volatile, so, after arguing, I had to play along and redraw my plant based on component separations that were coming out of the wrong ends of the columns).
2. Why use steam in the reactors? (equilibrium rxn, use inert H_2O to favor the desired rxn by lowering partial pressures)
3. How would the reactor length be affected if we ran it with high P steam or at vacuum pressures without steam? (For some reason, both would increase the length)

Keasling:

1. Design a controller for a heated tank.
2. What type of controller would you use? (± of P, PI, and PID)
3. Is feedback or feedforward control better? (Depends - either T fluctuations with feedback or need a really good model for feedforward).

Wallman/Vorhis

Wallman:

Find the operating conditions of a feed going into a heater then passes through a valve that enters a flash. How do you find the composition of the product streams coming out of the flash unit? How would you control the liquid height in the flash? how would you control the pressure in the flash? Know when and how to use a mass balance, component balance, enthalpy balance.

Vorhis:

Given pure H_2S what can you do with it? Do you want to dispose of it? Can you use it for something more economical? What can you do to it so that you can just dump it outside? Can you make solid S or liquid S?

Can you make mercaptans to odorize natural gas (why?...for safety). Naturally occurring sulfur compounds include CuS, CaS, Na_2SO_4 (where is this from? From the ocean..it's a salt).