

ANALYTICAL CHEMISTRY 256

ROLE - PLAYING LAB

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Northfield, MN 55057

Introduction to Role-Playing and Laboratory Computing
Defining the Kinds of Role-Playing Responsibilities
Round-Robin Certification of Laboratory Glassware
Production Quality Control Lead Analysis
Statistical/Chemical Evaluation of Lead Data
Semi-Automated Weak Acid Titration
Graphical Analysis of Weak Acid Titration
Designing a Mock Robot Experiment
Executing the Mock Robot Experiment
The Incredible Edible Easter Egg Grass Advertising Dilemma
The Downsizing Dilemma
The Broken Pill Coating Machine Assembly Line Shutdown Dilemma

The Individual v. Departmental Instrument Purchase Dilemma

Closure

ROLES:

Manager: Reaching a decision whether to buy four instruments
Chemist: Blending a test mixture of likely toxic hydrocarbons
Software: Interfacing the LC directly into the lab microcomputer
Hardware: Running the HPLC instrument connected to the lab robot.

OBJECTIVES:

When a research group is in pursuit of a hot idea, checking results along the way must be simple enough that the analytical instruments are part of the solution, not part of the problem. Here, **Manager** thinks s/he has found a new, inexpensive, isochratic liquid chromatograph that will be reliable under irregular and unscheduled use, handle aromatic hydrocarbon mixtures with good chromatographic properties, elute mixtures quickly, and still be simple enough to operate using commercial interfaced computers without the necessity for skilled programming. The primary objective is to form an evaluative "hit squad" to determine if this is true, and if so, whether four of the chromatographs should be purchased as individual research instruments, or if a centrally maintained and technician operated departmental instrument is a better choice.

MANAGEMENT INTERVIEW:

Manager has the above issues to discuss, verify, or refute. Computer records showing the chromatographic performance of the instrument must be available for inspection. The ease with which the testing was done is important. Quick startups, easy interfacing, drift free operation, rapid peak elution, and good chromatographic column properties (plate count, resolution, and selectivity) for the separation need to be *demonstrated*, along with **Manager's** estimate of instrumental suitability for the research task. The final conclusion is whether to buy or not, and then whether to put up with departmental politics on a centrally located and maintained instrument, or to attempt to operate and maintain within the group and retain complete control of the resource.

Introduction

This experiment is not "made up"! In the 17 years between 1965 and 1982 that I directed Ph.D. level research at the University of Wisconsin, Madison, my graduate students and I purchased well in excess of \$250,000 in "hard" instrumentation. All of this was at the state of the art level; in fact, some of the instruments were so new that we ended up trading our research notes to the vending company to be used as part of the instruction manual! This experiment is a direct mimic of what we did as a process of selection and purchase of a research instrument. The approach was a resounding success.

There is a different management emphasis active when a research instrument is purchased compared to when a production or quality control instrument is being considered. The quality control instrument has to be up to the task, but, it also must be highly reproducible, over a long period of time, and capable of being calibrated with standards. It must hold calibration on the same kinds of samples through long series of sample runs. The research instrument, however, must be "open", i.e., have a lot of versatility, and be adaptable to a variety of samples, many of unanticipated nature. The idea is not to have to fuss with it, and to be able to approach it for immediate action even if it has been unmaintained and idle for unpredictable periods of time.

The research instrument also has to be sensitive enough to adjust to unanticipated ranges of sample sizes and concentrations, yet predictable in its response when there may be dramatic changes in sample types, one after the other. The quality control instrument has a high duty cycle (time on/time off), while the research instrument has a totally unpredictable duty cycle; in fact, it may be off for weeks at a time and then suddenly turned on for a quick run "before lunch".

The quality control instrument has to be adaptable to automation. For example, it should be simple enough that it could be operated as part of a laboratory robot. The research instrument may in fact benefit from some degree of automation, but it should be more versatile in allowing full access for different sample sizes, mobile phases, and column types.

I think you can see that these are very different kinds of demands that the two kinds of instruments have to meet. And, mainly, that is why the research instrument is the more expensive of the two! The one demand that is the hardest to meet is the research instrument duty cycle. How can an instrument be expected to perform instantly when it gets little use or calibration or (often) maintenance for weeks at a time? How would you, as a research director ("**Manager**") run into this dilemma? And how would you handle it when you did run into it?

The Dilemma Anecdotally

Consider the following scenario, based on the **possible** purchase of an inexpensive liquid chromatograph to be used by your graduate students for exploratory research characterization of aromatic hydrocarbon reaction intermediates. You have started a series of synthetic problems that involve photodecomposition of polymer precursors. These compounds may be useful for synthesis of semi-flexible polymers you want to synthesize as (human) implantable membranes. The research is going to be to develop the polymers that will not be rejected by the body, and thus must be of very high purity when all synthesis is done, and at the same time can be synthesized in sensible quantities. You have four groups of 3 graduate students and one post-doc working on the project; all funded by independent industry. The urgency in the experiments is based on getting grant renewals from such "bottom line" sponsors.

Part of the project requires photo-assisted free radical chemistry. You want to make sure that the starting materials you will be using can withstand the UV synthesis steps without decomposing into low molecular weight aromatics that would be toxic (it has happened in some of your other work!).

While this is the kind of problem that is easily handled with a departmentally owned and operated GC/MS instrument, a new, inexpensive liquid chromatograph has been announced that appears to

have the sensitivity and adaptability you need to handle many of the "reaction intermediates" that you expect to be faced with in this kind of project.

In fact, the instrument is so inexpensive that you suspect you could buy *one for each of the four research groups* you will have working on the project. Such is not without its advantages, since, if true, the turnover time from sampled identification to analytical result could be as short as a few minutes (the LC's would be at each group's benches). The GC/MS instrument is a departmental instrument, available only on a "9 to 5" basis, and requires such a degree of instrumental skill to operate that your graduate students cannot operate it themselves, but instead must submit their samples to a specially trained operator to run for them. This delays the return on results depending on who else is in line, as well as who else has done the proper departmental (divisional) politics. The new LC looks tempting!

The down side to owning four independent instruments concerns their calibration and routine maintenance. This has to be done by someone, and there are service charges of \$35/hour in both the electronics and machine shops for such work. The manufacturer service engineers are even more expensive, running in the \$100 - \$200/hour range. Unless the new HPLC's are essentially maintenance free, even if they are only used a few times a month, it could be better to use the departmental machine and let someone else worry about the maintenance, even if it means playing politics when necessary.

To explore this, you get a demonstrator instrument in from the manufacturer (*Perkin-Elmer TriDet LC*) to test. The idea is to put the demonstrator instrument into a situation that is as much like what you expect your graduate students to have and see how it performs. You form four people (one from each of your research groups) into a "hit squad" test group.

One person is to read the manual and run the instrument (**Hardware**). One person is to handle the data that the Perkin-Elmer TriDet LC produces (**Software**). One person is to make up a "cocktail" that can mimic a typical mess of photochemical juice and shoot this into the Perkin-Elmer TriDet LC on demand (**Chemist**). And, at the top of the pile, your post-doc (**Manager**) is going to have to come to you and tell you if you should buy four of the instruments!

The Group Structure

Note this group construct. The group is formed *only for a short time*. It has a specific purpose. It exists only to test and to select an instrument for possible purchase. The members of the group normally have other, independent, research tasks; they have come together only for an unscheduled problem solving task. And, each brings with them an adaptability, and a willingness to accept a task specific responsibility (a commitment), as opposed to bringing a set of special skills (Ph.D. candidates are expected to be able to read instruction manuals and have a general awareness of modern instrumental techniques!). And, when the problem is done, the group will disband, perhaps to later reform into another problem-solving group at a later time on another task. This kind of group requires diverse, independent skills. The key to its success is its diversity and commitment.

This kind of problem-solving group, for want of a better name, is called a "hit squad". The **Manager** is selected based on experience and problem solving ability, along with the authority needed to command the respect of creative, normally independent researchers. The ethics of community here stem from "enlightened self interest" (see Peck, The Different Drum for emphasis.).

The Goal of the Interactions

Who wins when a hit squad is formed for such a task as this? Obviously, the entire research effort wins if the instruments are purchased and if they actually will work on an unscheduled basis on diverse problems. Who loses? Obviously, the whole research effort loses if four instruments are purchased that have marginal adaptability and take lots of time and money to calibrate and keep

operating. The money would have been better spent on another detector or something equivalent for the departmental GC/MS! This is a classic example of community and "interdependence" in a problem solving group, and illustrates well how "non-zero sum" game theory applies to successful research efforts. I formed "hit squads" just like this as many as ten times in the tenure of a normal Ph.D. candidate. And, if the people involved "buy in", they really work! Such is what your role-playing experiment mimics.

Some Role-Playing Perspectives

I want to take some time at the start of this experiment to develop a few perspectives for you, since this experiment comes at the end of the course and involves a new kind of instrumentation. These perspectives are cast below in terms of the problems faced by each role. These are the most obvious ones. There may be others that come up during the execution of the experiment that I have overlooked.

As you read this material, consider the desirability of having a staff meeting before you come to the lab. You can discuss what the responsibilities are for each role, and **Manager** can have a chance to sound out each person on how they perceive their own role before the work actually starts.

Consider too that you can hire a consultant! While that may be just me, I have some experience here. And, I work for a reasonable fee (one apple per contracted task or problem successfully solved). And, I will agree to handle hazardous chemicals for you, if so requested, without a fee at all. Remember how very important it is to know the hazardous properties of what may, by the novice, be taken as "harmless" routine chemicals.

I urge you - prepare for this experiment!

Manager's Dilemma

Manager has a real challenge in this experiment. Here are the problems that s/he starts out with in order to design the experimental procedure in the lab.

1. The LC instrument seems too good on the face of things for the money. Other instruments having only a single detector cost as much or more. There has to be a hitch here somewhere, but it isn't clear where.
2. **Chemist** is going to have to make a cocktail that will test the reproducibility of the instrument. But, LC systems are notoriously slow; if more than 2 or 3 runs are going to be needed to get some precision data, the chemicals and the solvent are going to have to be chosen so that they give quick elution. **Manager** may also want **Chemist** to prepare special solutions to determine what compounds are eluting from the column. This all takes time and care.
3. The chemicals that have to be used, if for no other reason than to test for a "bottom line performance" are benzene derivatives. But benzene, itself, is high on the list of carcinogens, and it seems likely that its derivatives may also be quite toxic. In fact, in situations where chronic or repeated daily exposure is expected, it is possible that they can only be handled in the hood, and then only when properly gloved, gowned, or even equipped with a respirator! This is going to require special handling and lab air ventilation, not to mention waste disposal problems. **Chemist** will have to provide specific instructions on how to handle this, but it is going to be up to **Manager** to help develop this procedure. **Manager** may even go so far as to instruct **Chemist** not to use or handle certain of the benzene derivatives. While this may compromise some rigor in the testing, it is a fair decision on his/her part.

Upper Management definitely should be consulted on this before such a decision is made.

4. There are the usual kinds of problems with **Software**. But, here, the group has the double dilemma of whether to take the data into a laboratory microcomputer or just a strip chart recorder. If the data go into the lab microcomputer, then they are stored digitally, and can be dumped to a printer or telemetered to another computer. Spreadsheets such as Excel can be written to calculate retention volumes and peak areas. But, if they are taken only to a strip chart recorder, then all results (even areas) have to be taken from the piece of paper by hand. The only way that **Manager** can tell how hard it is going to be to use the laboratory microcomputer is to make a trial run.
5. A LabVIEW VI is available from the Instrumental Analysis class. This writes directly to files that can then be read into Excel. The vendor has taken time to connect the instrument to the VI as part of showing the ease of data collection to the group. **Hardware** will want to look at this system to assess its feasibility during routine, and sporadic use.
6. Some truly inventive way is needed to determine if the instrument will produce the same result when the unit is just started from a cold start at unpredictable times during the day compared to what it will produce if carefully calibrated and allowed to remain on 24 hours a day. There isn't time enough to do this for a few weeks; some tests will be needed that emulate the unscheduled startup that will be routine lab practice. Be clever here!
7. Although he would not want to have it generally known, it has been a few years since **Manager** actually did any liquid chromatography, especially with reversed phase columns. Some of the basics have become a little rusty! A quick refresher course on some of the column parameters that **Software** will have to calculate to index the instrument performance will be needed. But, from where? Is the library a good source? What about the manuals that come with the instrument? What about our textbook?

Hardware's Challenge

While **Manager** has many dilemmas, it is **Hardware** that has to show the real technique in the experiment. The problem is that no matter what kind of policies **Manager** comes up with to test the precision of the instrument, they will all be absolutely meaningless if the "injection loop" is filled incorrectly (getting air into it), or if the test sample prepared is allowed to evaporate. These are **Hardware's** responsibilities.



Other responsibilities that **Hardware** has are to set the attenuation properly on the signals feeding the recorder, and, if **Manager** chooses to do so, to work with **Software** on the simultaneous operation of the microcomputer and the recorder (see next section on this).

During the experiment, **Hardware** also will be faced with the tricky problem of handling the syringe used to fill the microliter sampling loop. The port into which the syringe is inserted is on the rear (!) of the injector valve. This requires some hand twisting to get the needle into the port, and, with the solvents used here, some real dexterity to keep an air bubble from getting into the syringe when inserting it. And, given the highly toxic nature of the chemicals being injected, there can be no "squirts" on the floor or bench.

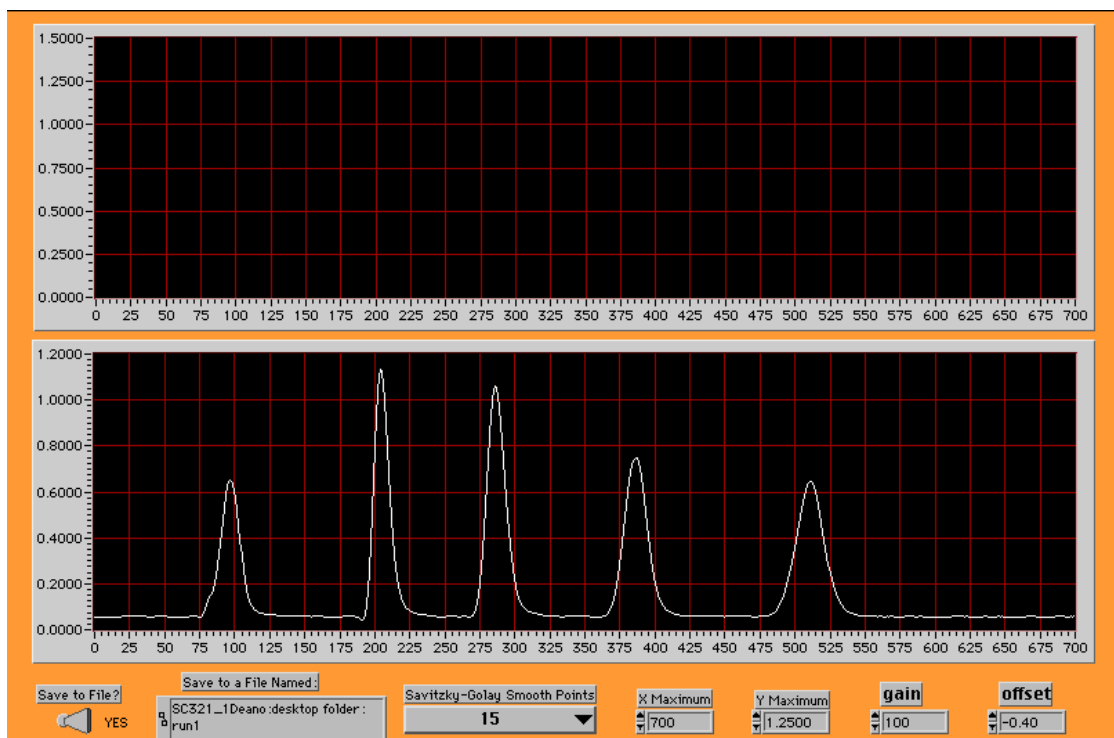
Software's Labor

In this experiment **Software** has to really work hard. If **Manager** chooses to use a direct link between the LC and the lab computer, then **Software** has to receive a tutorial from **Upper Management** on how to do the button pushing and file management for that device. Then, as data are taken into the Excel spreadsheet, **Software** will have to arrange and rearrange the columns and display to allow multiples of peaks and chromatograms to be displayed for **Manager**.

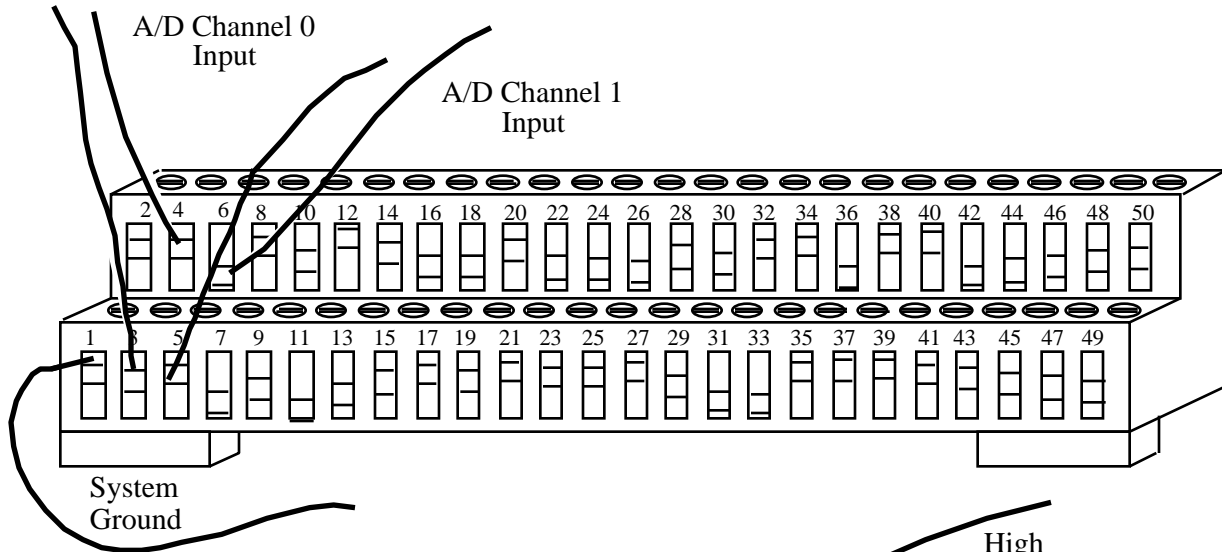
There will be some pivotal management decisions that have to be made on how to interpret the data. One way is to use the math functions of the spreadsheet. While practical, there are some tricks to this, and **Manager** and **Software** are going to have to have a meeting of the minds about how much time can be devoted to this kind of learning, compared to, say, using a ruler and calipers on a piece of strip chart recorder paper.

Interpretation of the data when it is imported into a spreadsheet is a task that **Software** and **Manager** will probably want to work on together. Many have found it useful to subtract baselines and calculate peak areas once in the spreadsheet environment. And, what most folks find really exciting, once the sheet is set up, other columns of data can be imported and graphed to determine if there are changes in retention times and peak heights.

Just to help, the following is an example of a LabVIEW VI that **Software** may want to use, or modify, to get the lab data into an Excel spreadsheet. **Manager** may advise on its current state and any new modifications. This VI provides the top window for the raw signal from one detector and the bottom window for displaying the data after performing a smoothing algorithm.



Although the sales representative has cabled the instrument to the computer, **Hardware** may wish to examine the connections between the HPLC outputs and the terminal block that are used to interface the analog to digital converter in the Mac to the HPLC. Diagrams of these connections are shown below for a single channel of the detector.



System Ground

High

Low

Adc Input GrouND	1	2	Adc Input GrouND
Adc In CHannel 0	3	4	Adc In CHannel 8
Adc In CHannel 1	5	6	Adc In CHannel 9
Adc In CHannel 2	7	8	Adc In CHannel 10
Adc In CHannel 3	9	10	Adc In CHannel 11
Adc In CHannel 4	11	12	Adc In CHannel 12
Adc In CHannel 5	13	14	Adc In CHannel 13
Adc In CHannel 6	15	16	Adc In CHannel 14
Adc In CHannel 7	17	18	Adc In CHannel 15
Adc In SENSE Line	19	20	DAC channel 0 OUT
DAC channel 1 OUT	21	22	EXTernal REFERENCE
dAc Output GrouND	23	24	DIGital i/o GrouND
port A DigIO bit 0	25	26	port B DigIO bit 0
port A DigIO bit 1	27	28	port B DigIO bit 1
port A DigIO bit 2	29	30	port B DigIO bit 2
port A DigIO bit 3	31	32	port B DigIO bit 3
DIGital i/o GrouND	33	34	+5 V dc @ 500 mAmp
+5 V dc @ 500 mAmp	35	36	SCANned CLoCK out
EXTernal STROBE out	37	38	EXTernal TRIGger in
EXTernal GATE in	39	40	EXTernal CONVerT in
pulses SOURCE in 1	41	42	count GATE on in 1
gate counted OUT 2	43	44	pulses SOURCE in 2
count GATE on in 2	45	46	gate counted OUT 2
pulses SOURCE in 5	47	48	count GATE on in 5
gate counted OUT 5	49	50	Freq. division OUT

Low

High

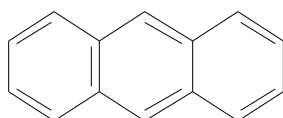
Chemist's Challenge

Chemist has a real opportunity in this experiment! The opportunity is to save group an immense amount of money! Perkin-Elmer will sell us sealed glass vials of "test standard mixtures" that they use to determine the reproducibility of this instrument. These are ideal samples, since they are in sealed ampoules, have been made up from high purity compounds, and can be used directly (without filtering or other handling steps). This would seem to preclude the need for **Chemist** to do anything in the experiment other than keep a degassed supply of filtered mobile phase coming to the LC.

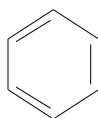
But, there are no free lunches in this life! These sealed ampoules hold only a single (one!) mL of mixture. And, each fill of the sampling loop takes 0.1 mL, if there are no spills, etc. The best we can hope for is between five and nine injections in each one of these ampoules. So, what's the problem? They cost \$25 each! That makes each test cost an average of \$3.00.

That's pretty expensive testing. But, we know what these contain, and can get to reference chromatograms to see what the retention times are. Surely, given the reservoir of organic chemicals that we stock, **Chemist** can prepare a larger amount of an equivalent test mixture?

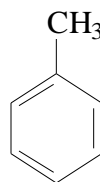
What is the problem that **Chemist** has to deal with? Later we shall see that one of the components of the test mixture is benzene! And, benzene, under certain handling conditions, has been classed as carcinogenic! **Chemist** will have to find out these toxicity limits, when it misbehaves, how to handle it, and then proceed to set up for blending the juices needed with real safety protocol. The benzene derivatives that are in the cocktail (except anthracene) are shown below. These too may be teratogenic, mutagenic, or carcinogenic.



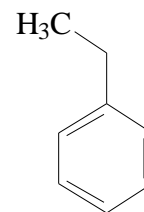
anthracene



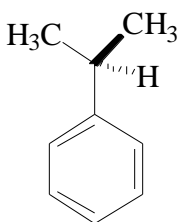
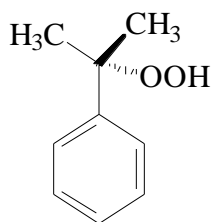
benzene



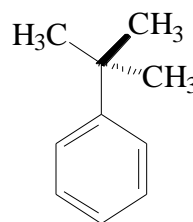
toluene



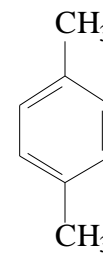
ethylbenzene

cumene
(iso-propylbenzene)

cumene hydroperoxide



tert-butylbenzene



para-xylene

One ponders. Which is better? Buy the commercial mixture, or blend locally. There are some real opportunities here. Again, it will be up to **Manager** to make the decision, but, once made, it will be up to **Chemist** to make it happen. **Manager** may, however, after reading what **Chemist** finds out about handling benzene, decide not to run it at all. Consult with **Upper Management** on this.

What Upper Management Wants

There are some goals that **Manager** needs to know are **Upper Management's** expectations. Here are the most important ones.

1. I am primarily concerned with how easy the instrument is to use for the hydrocarbons we expect to happen if starting materials photofragment.
2. I cannot help but be concerned with how reproducible the instrument is, even though we are not doing quality control! I would hate to develop an intuitive sense of research direction based on peak areas or retention volumes only to later discover that these are not reliably achieved unless the instrument is very carefully standardized or calibrated or some other series of fussy steps. In a word, I want it easy and reliable.
3. I would like to be able to use the instrument without any setup time at all (that may be unrealistic), and, if there has to be some, I would like it to be little more than priming the pump. I don't want to have to spend time waiting for the pump to come up to some special "speed equilibrium" or some other thing. I may have to compromise here, but it would be nice to just leave the detector on all of the time and simply snap on the pump when I want my people to analyze a few samples.
4. I hate instruments that drift! Baseline noise due to the pump fluctuations is one thing, but slowly drifting baselines are a real pain. I want to make sure that this system has some sensible degree of baseline stability. And, I don't want to have to run the pump for an hour every time I want to use it to get a stable baseline!
5. After a time, the people who are first trained on these four instruments will get their Ph.D.'s and move on. I don't want to be left with the job of training every new graduate student that comes into the group in how to use the LC! Ideally, each new person should be able to learn how to run the instrument by just reading the manual!
6. Most importantly, I want a brief, clear, succinct report from **Manager speaking to these issues**, giving me some properly named computer spreadsheets or clearly labeled strip charts to look at to get an idea of what the data look like, and, finally, telling me if I should spend the \$25,000 to buy four of these units. I do not want to have to plow through a bunch of records on my own that don't have dates or labels that tell me what is on or in them!

The Consultants' Work

It really isn't fair to expect all of the Role-Players in this experiment to set up the whole lab without something to go on other than a statement of the problem! This stuff can get pretty tricky. So, to give you something to read before the fact, Professors Walters and Pearson, acting out the roles of **Hardware and Software** (Walters) and **Chemist and Manager** (Pearson), spent a day in the lab doing some research on the experiment. Their work is not the final word (indeed!), but by showing you what they discovered, you may get some help in deciding how to set up your own work. What follows then is a "recording" of their lab work.

Manager/Chemist needed manuals for the instrument, but not the whole thing! Selective portions of the manual were copied by **Secretary** and organized for each role to read. They are in the local company library, in **Hardware's** book, for you to use, if you want to, as well.

Chemist spent a lot of time working on the test mixture problem. What was not known were the relative proportions of material Perkin-Elmer had put in their test mixture. Finally, using a solvent of pure HPLC grade methanol it was discovered that, using a "dispo" pipette, adding about 3 - 4 drops of the test components available in the stockroom to 20 - 25 mL of either pure HPLC grade methanol or to the same amount of actual 75/25% methanol/water mobile phase produced a good blend.

By inserting the "dispo" pipette directly into a small bottle of benzene, no human contact with the stuff was possible, and the dropper could be thrown away afterwards. The 30 mL bottle that later held the test mix of benzene and mobile phase could be capped with a "septum", preventing contact with hands, air, etc., and allowing the LC syringe to be inserted directly into the mix for filling. There also was no waste, except the test juice itself, which could be stored indefinitely for use by others. **Chemist** was pleased with himself!

Chemist did run into a problem though with finding the right chemicals. The Perkin Elmer test mixture was run by **Hardware** and is shown on the next page. **Chemist** found benzene, toluene, and ethylbenzene in the departmental stockroom, but the isopropyl benzene available ("cumene") was a mess. It gave lots of peaks, none at the right retention times, and **Chemist** concluded that it had decomposed on storage to produce some kinds of peroxides. Not neat! There also was no t-butylbenzene, and the s-butylbenzene found had also decomposed into some kinds of peroxides. Anthracene was found, but it was a solid and a horrible mess to handle and dissolve in mobile phase. It also gave a huge peak when even a little was dissolved. **Chemist** said we had better things to do than to fool around trying to find out how much to dissolve to get a peak that was on scale. I wonder.

Hardware spent a lot of time reading the manual! The syringe found was too slippery. Every time it was filled the plunger kept slipping back in the barrel and drawing air into the tip. **Hardware** complained a lot, but there were no other syringes available and the stockroom person was on vacation.

Hardware did not like the small bottles that **Chemist** had chosen to hold the juice. He was constantly fooling around trying to hold the bottle and load the syringe, and he was always afraid that the bottle would tip over spilling benzene all over the table! finally **Hardware** and **Chemist** had to work together, with **Chemist** holding the bottle and **Hardware** filling the syringe. Both felt that there had to be a better way !

After a lot of fooling around, **Chemist** and **Hardware** decided to make just a mix of the first three components in mobile phase. **Manager** was not happy, but they were running out of time. To keep **Manager** happy **Hardware** used the Perkin-Elmer commercial standards that he had and spend \$100 in chemicals just to get the consulting done.

Software was having fun with the lab microcomputer. A data set was acquired into it using the LabVIEW VI. The data were not perfect; they had some baseline noise and a weak signal. This

made **Manager** unhappy, mainly because the signal/noise ratio was so bad, but it made **Software** happy because he got to do a few tricks with the internal software in a spreadsheet!

He first chose to do a little "running averaging" to smooth the data set to get rid of the random noise (leaving just the pump fluctuations so **Manager** could see what a single piston pump did for the runs!). Then he used a formula to subtract 1 from each of the 500 points in the data set, and to multiply the results by 2. The results were, to say the least, impressive. **Software** had the data into a form where anyone could look at them on their own computer using their own personal copy of Excel.

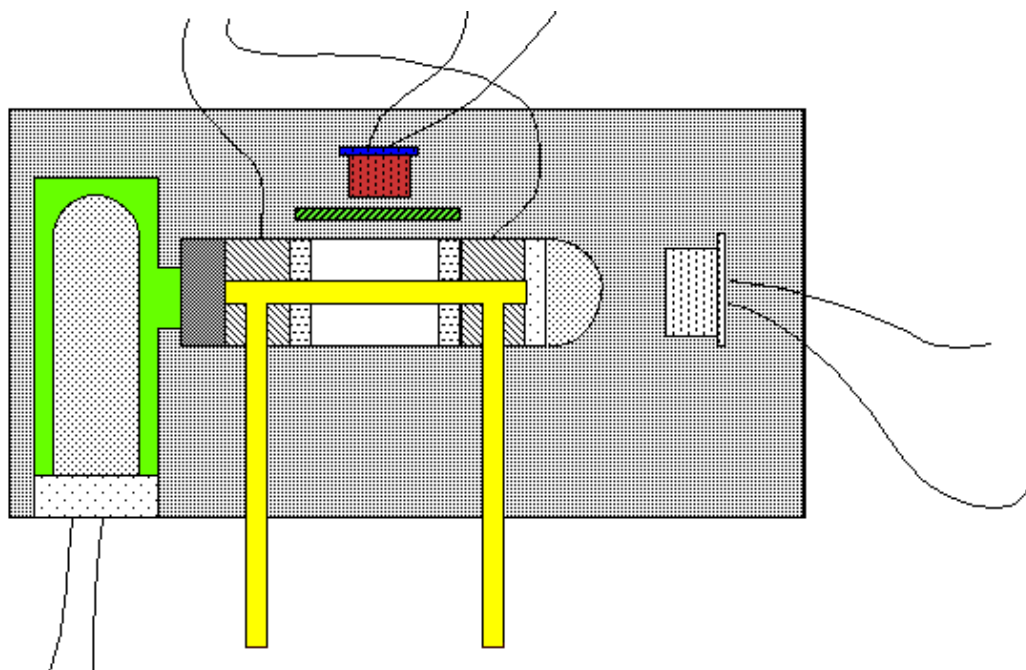
Later on **Software**, really getting into the signal processing, modified the VI such that it applied a smoothing algorithm to the data and saved both the raw data and smoothed data together in a file.

Manager played around with Excel for a bit to get the areas of the peaks. A couple of pictures of his work follow. No reports were actually written because the Role-Players were tired and had other things to do! But both had a pretty good time in the lab together and **Manager** particularly enjoyed getting out of the office.

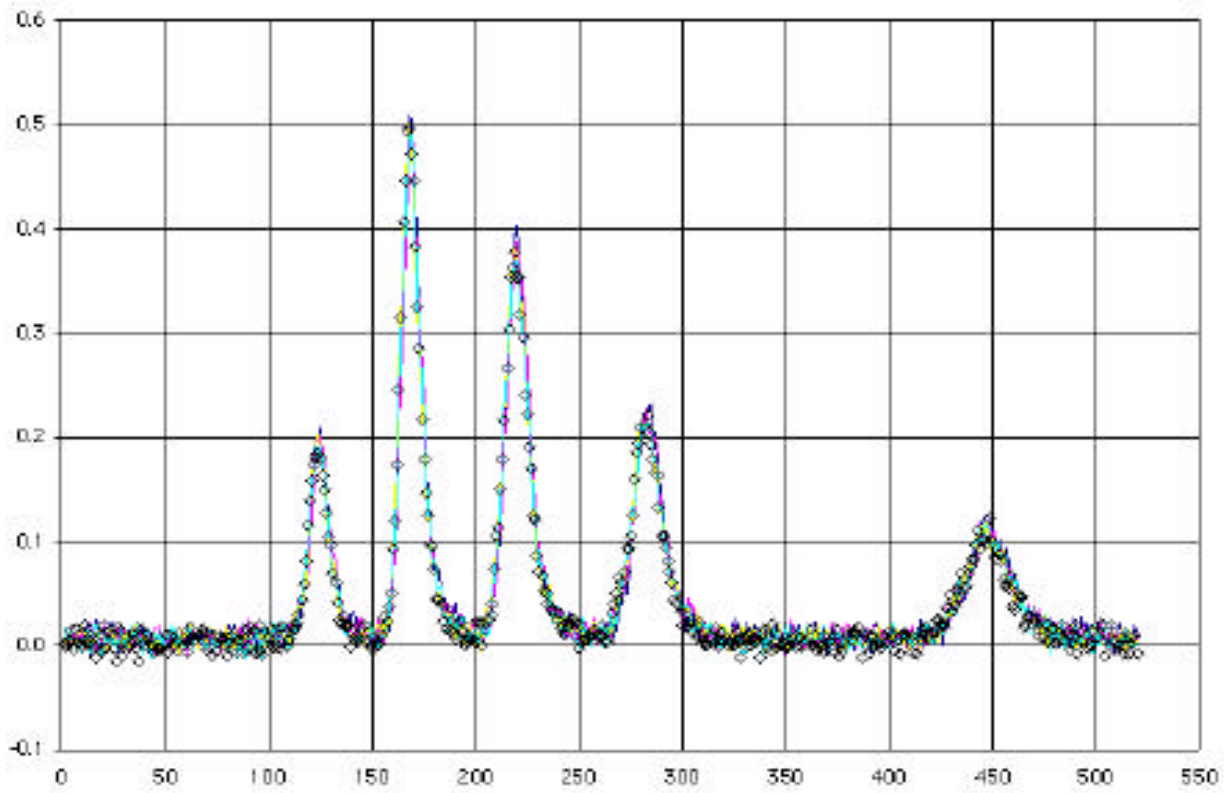
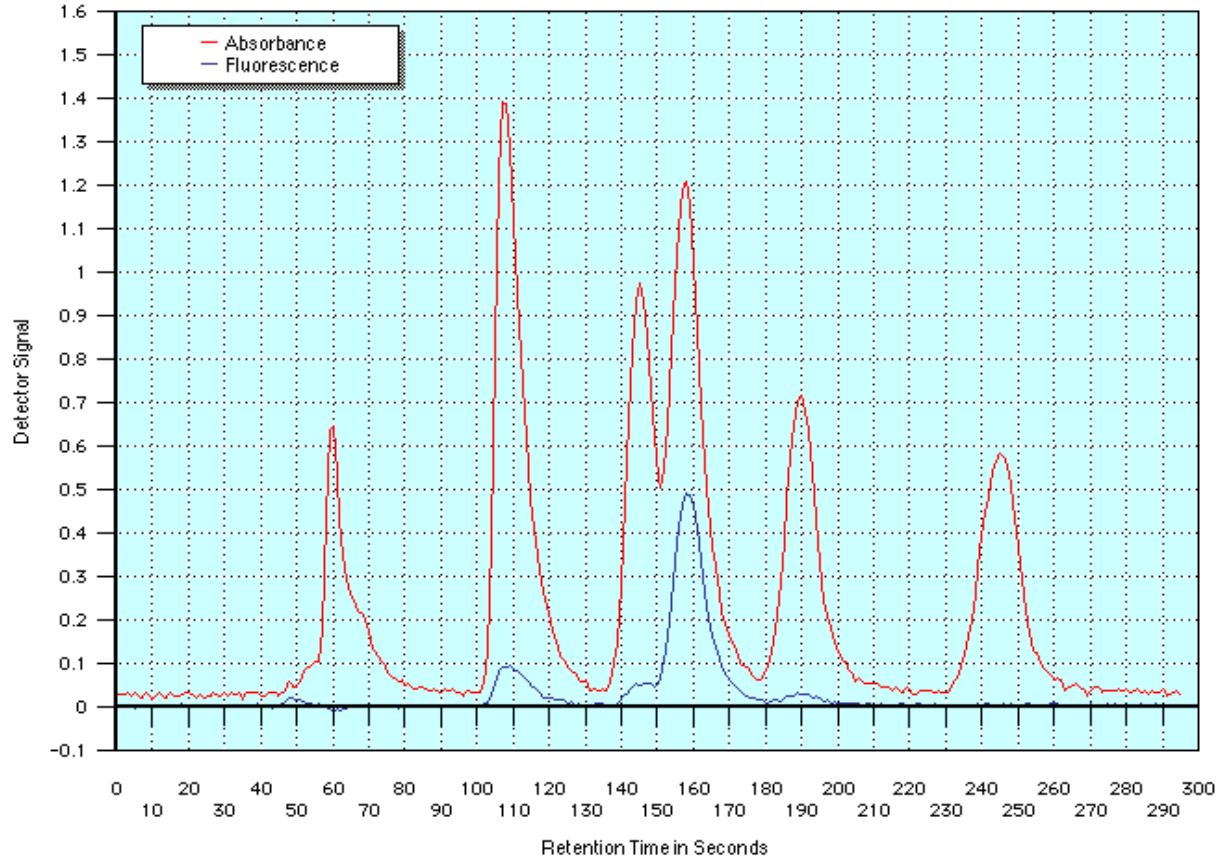
What Next

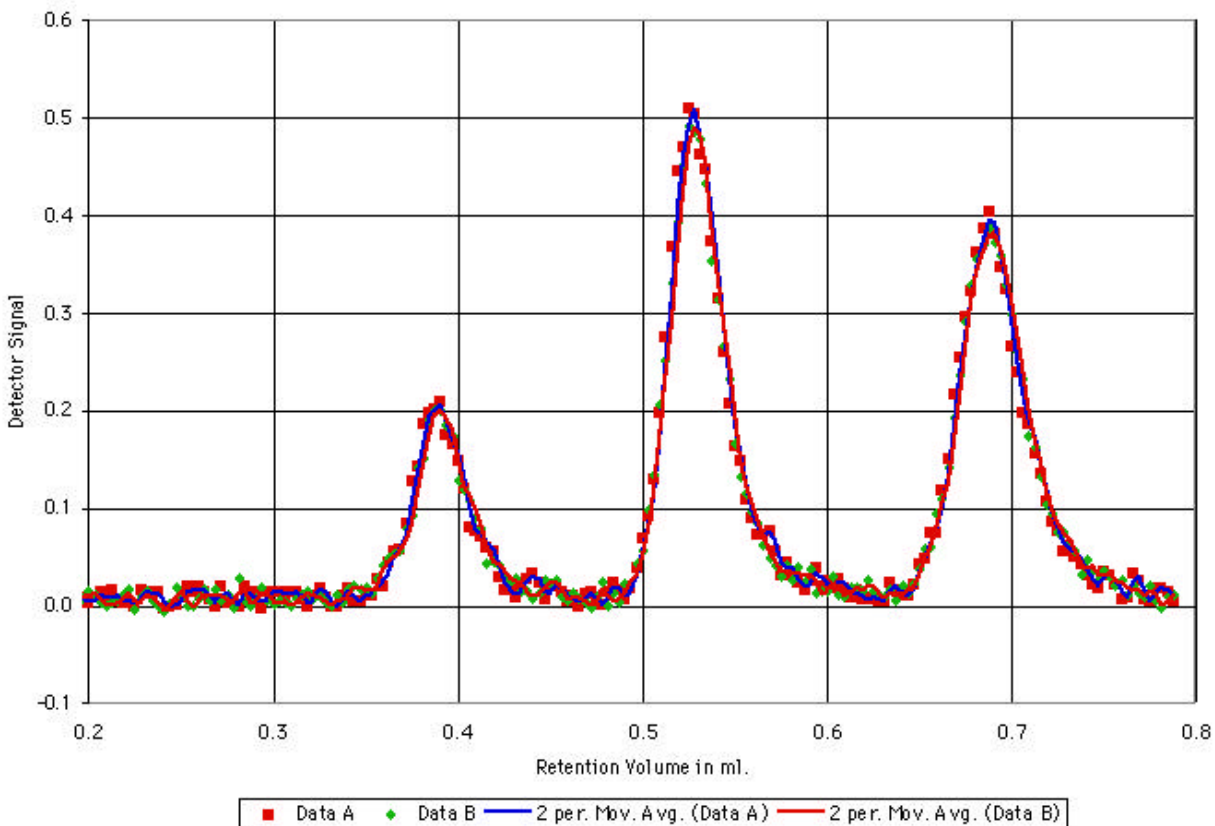
As you plan this experiment, keep in mind that consulting help is available. The computer links are exciting, and, if **Manager** decides to use that approach, both **Hardware** and **Software** will probably want to have some tutorial help there. **Chemist** may want to hire out the benzene manipulations if this is what **Manager** decides needs to be in the juice.

Watch the lab time. The peaks come out of the LC rapidly, so there is little problem with getting the data out of the instrument. But, there is a time problem in getting the juices ready, and **Software** may especially need some help in all of the data processing. I see no reason why **Manager** cannot complete his/her report before leaving the lab for the afternoon, especially if it is being written as the lab progresses.



An example of a well formatted graph showing the output of two of the above Tri-Det's three detectors follows below. Manager can use this as an example of what constitutes a professionally acceptable spreadsheet output to bring to the Management Interview.





For your reference, the raw data from the strip chart recorder, taken by a previous class, is shown on the next page, along with what they concluded were the correct peak assignments. The value of a simultaneous chart recording is obvious.

