National Science Foundation
Small Business Innovation Research Program

PROJECT SUMMARY

NSF PROPOSAL NO.

NAME OF FIRM	Protein Solutions, Inc.
ADDRESS	6009 Highland Drive Salt Lake City, UT 84121
PRINICPAL INVESTIGATOR (NAME AND TITLE)	Robert J. Scheer, Project Director
TITLE OF PROJECT	A Quantitative, Modular Exploration System for Chemistry
TOPIC TITLE: Education and Human Resources	TOPIC NUMBER AND SUBTOPIC LETTER: 25a

PROJECT SUMMARY

This Small Business Innovation Research Phase I project will study the technical feasibility and safety of a complete, quantitative chemistry explorations kit for use in high school and college chemistry classes. The kit goes beyond the phenomenological demonstrations of most chemistry kits. A large number of science and engineering courses taught in high schools, colleges and universities today do not involve laboratories, particularly "distance learning" courses offered via television or video. Although good instructors incorporate class demonstrations, hands-on home-work, and various teaching aids, including computer simulations, students in such courses often accept key concepts and experimental results without discovering them for themselves. Our kit will present the students and instructor with a compact, easy to use set of materials and textual explanations for discovery and incorporation of science concepts.

Research toward the development of a household safe, self-contained quantitative chemistry laboratory is proposed. Although packaged like a textbook, it will contain all of the supplies and information needed to directly discover, quantify and experience key concepts related to chemistry. It is expected that such a system will be widely adopted as a supplement to chemistry textbooks of all levels of instruction. from college telecourses to high school classrooms.

Potential Commercial Applications of the Research

A conservative estimate of the classes without a laboratory is 25%, indicating a need for approximately 45,000 high school level chemistry classroom kits. If each kit were to have enough materials for four students, then for twenty students to participate in their own research, 5 kits/class would be required (up to 225,000 kits per year.) Other markets include distance learning (telecourses), home teaching, and colleges and universities with inadequate laboratories.

CERTIFICATION PAGE

Certification for Principal Investigators and Co-Principal Investigators:

I certify to the best of my knowledge that:
(1) the statements herein (excluding scientific hypotheses and scientific opinions) are true and complete, and
(2) the text and graphics herein as well as any accompanying publications or other documents, unless otherwise indicated, are the original work of the signatories or individuals working under their supervision. I agree to accept responsibility for the scientific conduct of the project and to provide the required progress reports if an award is made as a result of this application.

I understand that the willful provision of false information or concealing a material fact in this proposal or any other communication submitted to NSF is a criminal offense (U.S. Code, Title 18, Section 1001).

Name (Typed)	Signature	Date
PI/PD Robert J. Scheer	[signature]	6/8/95
Co-PI/PD		
Co-PI/PD		
Co-PI/PD		

Certification for Authorized Company Representative
By signing and submitting this proposal, the individual applicant or the authorized official of the applicant institution is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding Federal debt status, debarment and suspension, drug-free workplace, and lobbying activities (see below), as set forth in Grant Proposal Guide (GPG), NSF 94-02. Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U.S. Code, Title 18, Section 1001).

Debt and Debarment Certification (If answer "yes" to either, please provide explanation.)
Is the organization delinquent on any Federal debt? Yes____ No X
Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department of agency? Yes____ No X

Certification Regarding Lobbying
This certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100, 000 and for an award of a Federal loan of a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements
The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress or any employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form LLL, "Disclosure Form to Report Lobbying," in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

AUTHORIZED COMPANY REPRESENTATIVE		SIGNATURE	DATE
NAME/TITLE (TYPED) Joseph D. Andrade/CSO		[signature]	6/8/95
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D. OPPORTUNITY AND SIGNIFICANCE

High school students in many science courses in the United States may receive little or no laboratory experience. The labless science course has become very common in chemical and physical science education. Although outstanding instructors attempt to overcome this deficiency with the use of classroom demonstrations, discovery-based homework assignments, class projects, and computer simulations, many instructors have neither the time nor the inclination to utilize these tools, particularly with the added responsibilities of instructing several classes a day over a broad range of subjects. Also, the rapid growth of "distance learning" – using television and video tapes to offer courses remotely over the national information infrastructure (internet) – is producing large numbers of "science" students with little hands-on, laboratory experience.

At a time when there are local, regional, and national initiatives to adopt hands-on approaches to learning science (1), it becomes increasingly important that science instructors involved in labless courses have at their disposal a complete and safe laboratory teaching tool. We call one such tool, which is appropriate for use in a regular classroom, laboratory or responsible home setting, the Labless Lab®.

The name "Labless Lab®" is meant to describe a prepared laboratory system for use in a previously labless class. It will consist of a single partitioned container, safety equipment (goggles, chemical resistant gloves, absorbent working surface and a safety checklist), and 10 to 20 lab explorations (instructions, supplies and devices). The kit will be safe, complete and ready to use (2). *To provide the rigorous and quantitative results found in more complex laboratory designs using only the simple and common materials to be found in this kit, novel experiments and experimental methods will have to be developed.*

The recent recommendations for change in chemistry education (3), determined by the American Chemical Society's Division on Chemical Education 1990 Task Force, include the addition of: novel problem solving, the methodology of science, experimentation in the lab, evaluation of students on their ability to interpret information and analyze data, and a reorganization of the course around the laboratory.

American businesses also perceive certain general defects in the education system and have initiated skills up-grade programs, spending nearly $40 billion a year educating and training employees (4,5).

Undergraduate college students, particularly those enrolled in large sections of the science core courses of physics, chemistry and biology, often find themselves performing experiments whose objectives are not coordinated with the classroom lecture. During my experience as a chemistry instructor at Salt Lake Community College I have encountered widespread dissatisfaction with the courses' laboratory component. Evaluations returned by the students contained comments such as,

> "The lab and the lecture were never in sync; the early labs were behind the lectures and the final labs were ahead of the lectures."

Even with classroom coordination, these experiments often do not instill a fundamental understanding of basic concepts. They often follow "cookbook" formats with right or wrong "fill in the blank" answers. Other comments included,

> "The labs were presented to us without any explanation of the concepts being covered. I felt like we were simply following a recipe without knowing why."

Other areas of importance include correspondence, distance learning, and TV/video delivered courses. Although some distance learning/TV-based education offerings work hard to incorporate a laboratory component, such as the University of Maine's unique course in biology (6), the very rapid growth in multi- and hyper- media and in computer, satellite, and TV based courses and even degrees, is leaving some question as to whether a "virtual education" is indeed desirable (7). Labs are either not available for these courses, or they must be scheduled during off-

(reactants) and were asked to determine the outcome or products. Students had to think, organize and persevere to complete the exercise, thus developing good science investigation techniques.

Dr. S.L. Seager, Professor of Chemistry at Weber State University in Ogden, UT, has developed a laboratory for first year chemistry students based on inquiry. His laboratory follows the path of exploration, invention/discovery, and application.

Dr. Art Ellis, University of Wisconsin–Madison has led a team of chemistry and materials science professors to develop a system of teaching freshman chemistry utilizing solid state materials (i.e. familiar objects) in an inquiry based format (5). The results of their efforts, *Teaching General Chemistry: A Materials Science Companion*, is utilized by several colleges and universities including Reed College, Portland, OR and Purdue University, West Lafayette, IN (19).

The disadvantage of these laboratories has been the increased time commitment required of the lab instructors. Our safe, simple and complete Labless Lab® exploration system minimizes the need for instructors to use valuable time gathering equipment and chemicals and designing the laboratory experiments, thus providing the time for the instructor to work directly with the students.

To define the learning objectives of the Labless Lab® in Chemistry (summarized in Tables 1 and 2), we exhaustively reviewed both chemistry curricula and major chemistry textbooks (19). Each major learning objective or concept is divided up into several subtopics, typical of introductory chemistry texts. This idea is well represented by the "concept wheel" of Figure 1. The six major topics each make up one slice of the circle, and inside the circle are drawn example subtopic arcs. These arcs of influence are drawn inside the circle to indicate which major concepts are covered by which subtopics. For simplicity, only four subtopics are shown on the concept wheel, (all 15 will be covered by the explorations.) See Table 2 for a list of all subtopics.

Innovativeness and Originality Several publishers and manufacturers provide laboratory supplements to existing texts. These supplements usually consist of text which describes the experiments and lists the materials required for the lessons. Other supplements or kits which do contain materials required for the experiments are focused on only one or two concepts (i.e. acid/base chemistry, or ion exchange reactions); additional kits must be purchased to complete the series. These kits are relatively expensive and as a result are often used by the instructor only for demonstration purposes.

We propose to create a supplement which contains the supplies and explanation necessary to free students and instructors to explore the possible *reasons* for an outcome. These will arise out of new experiments and novel ways of preparing and presenting the experiments. Indeed, creating these novel ways is the primary research focus of this project. The Labless Lab® will free the instructor from gathering the required chemicals and equipment for each set of experiments since the students will each have their own complete set. This freedom will allow the instructor more time to interact with the students and the time to develop an inquiry-based laboratory/classroom. In this environment of student exploration, the laboratory or investigation could supplant the classroom. Our Labless Lab® in Chemistry will describe procedures and provide the means for the student to realize all of the major concepts of chemistry, with the versatility to encourage new explorations.

Expected Results Using simple procedures, "safe" household chemicals, and simple apparatus, we propose to develop, characterize, and produce novel explorations suitable for the direct observation of a range of phenomena related to chemistry. The explorations and fundamental concepts are considered in a matrix model, where the concept is "integrated" into several observations/experiments and each experiment "integrates" several concepts. See Tables 1 and 2. This supplement will be flexible enough to complement any one year introductory chemistry course regardless of the text used.

During the Phase I research period we will select the chemicals and materials and develop necessary devices to perform the explorations. Needed chemicals will include oxidants, ion exchange salts, acids, bases, gases, hydrate salts, metals, polymers, polar/nonpolar liquids, and electrolytes. All of these can be found among the average household kitchen/bathroom cleaning and personal care items and pose no particular new dangers. Emphasis will be placed on **safety and responsible use of these everyday items**, and should increase the safety conscious use of peak hours at a central location, defeating the purpose of a distance learning format. Nevertheless, most states, due to political and economic pressure, are rapidly increasing their distance and remote education activities. The Public Broadcasting System's adult learning service has issued a handbook on the subject (8), and the American Chemical Society is establishing an educational outreach program on the World Wide Web (9).

It is apparent that there is a need for small, inexpensive, completely self contained personal laboratories which are safe and can supplement existing textbooks (10). Many complex concepts can be safely observed, quantified and assimilated by experimentation with properly designed simple materials. Good elementary grade models are the *Explorabook : A science museum in a book* (11), *The Most Amazing Pop-up Science Book* (12) and *Earthsearch: A kid's geography museum in a book* (13) – available in nearly every bookstore in the nation.

If our goal is to produce a public with the knowledge to make informed public decisions, it is important that students are left with a positive and lasting science experience. This is accomplished by giving these new chemists a practical look at how chemistry works and affects their everyday lives. An emphasis on this type of discovery-based learning is taking hold, but its implementation has been slow due to several factors including: instructor time, safety issues, cost limitations, laboratory expenses, and resistance to change. The Labless Lab® in Chemistry addresses all four of these impediments to chemistry education.

This proposal is relevant to the program emphasis of the 1994 National Critical Technologies study (14), which states that the general public and scientific professionals in particular, must have awareness and appreciation, and preferably a strong working knowledge of the concepts, principles, and limitations of chemistry. Our Labless Lab® in Chemistry will incorporate activities and experiments related to improving math/computational skills, energy/Earth conservation, and communication skills. But the most important contribution this project will make in National Critical Technologies, is helping to produce individuals who have a real, rather than solely a virtual, background in chemistry.

E. BACKGROUND AND TECHNICAL APPROACH

Background The job of the chemistry educator is to "enable" the public to understand how chemistry affects our lives and how it can improve our lives. An innovative series of 26 half-hour segments entitled "The World of Chemistry" featuring nobel laureate Dr. Roald Hoffman and noted chemistry demonstrator, Dr. Donald Showalter, recently aired on many PBS stations and is available on video (15). During this series, Hoffman and Showalter create an environment where chemistry comes alive for each of us. They demonstrate how chemistry is part of our everyday lives. Shows like this help chemistry instructors *initiate student interest* in chemistry.

While demonstrations can be exciting, their set up can be time consuming. In addition, the lack of individual involvement often leaves the student without a *personal experience* or understanding. The step required to make chemistry "real," is left to the laboratory where each student is allowed to "try" chemistry. Unfortunately, without adequate laboratory space and equipment, or the time required to develop inquiry-based laboratories, this step ("personal exploration") is often bypassed in favor of videos or demonstrations. But it is this critical step, the *personal exploration*, that leads to the *retention* of chemistry knowledge (16-18).

Other than "microscaling" of experiments, chemistry teaching laboratories have not changed much over the past 40 to 50 years. The ability of a student to reproduce known values is still taken as evidence of "understanding" the scientific principles involved. We hope to shift the laboratory paradigm from that of well known but highly structured "recipe" laboratories, with "fill in the blank" lab reports, to one of *investigative* problem solving where the concepts can be appreciated and understood. This method, sometimes called "constructivist" or "inquiry based" learning, allows students great flexibility in answering their laboratory questions.

An example of just such a constructivist chemistry laboratory was presented at the 1994 Annual National Science Teacher's Association meeting in Anaheim, California by P. Clough and L. Clark, chemistry instructors in Wisconsin. The students were given a set of starting chemicals

Table 1. Activity matrix showing the 23 proposed explorations (numbered) along the horizontal axis and the subtopics of introductory chemistry along the vertical axis.

Labless Lab in Chemistry: Activity Matrix

Exploration/ Fundamental Concept	Density	Phase Changes	Gases	Metals	Crystals	Chemical Reactions	Exothermic/Endothermic	Equilibrium	Oxidation/Reduction	Aqueous Solution Chemistry	Gas Formation	Precipitation	Acid/Base Chemistry	Intermolecular Forces	Chemical Bonding
(25) LCT Calorimetry						X				X				X	X
(24) Construction of a Battery						X			X					X	X
(23) Dehydration of Hydrate Salts						X		X						X	X
(20) Conductivity Tester															
(19) Crystallization of Salts					X							X		X	X
(18) Crystallography		X			X									X	X
(17) Stoiciometry/Continuous Variations						X					X	X		X	X
(16) Ionic and Polar Bonding								X				X		X	X
(15) Electrochemcial Metal Series					X	X		X	X	X				X	X
(14) Gases and Pressure	X		X								X			X	X
(13) Chromatography															
(12) Hot Packs: Heating System		X				X		X				X		X	X
(11) Polar and Hydrogen Bonding	X					X						X		X	X
(10) Polymers															
(9) Kinetics						X								X	X
(8) Colligative Properties		X												X	X
(7) Titration of Acids/Bases						X		X	X	X			X	X	X
(6) Acid/Base Indicators						X			X	X			X	X	X
(5) Ice Calorimetry		X						X						X	
(4) Advanced Measurement	X		X	X	X			X	X				X	X	X
(3) Simple Measurement	X	X				X	X			X	X	X		X	X
(2) Introduction to Measurement	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
(1) Lab Safety	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 2. Introductory Physical/Chemical Science Concepts and their corresponding Exploration Numbers (19)

Major Theme and Subtopics	Exploration Numbers
Safe/Accurate Laboratory Practices (Experiment # 1):	
States of Matter:	
Density	2, 3, 4
Phase Changes	5, 8, 12, 18, 19
Gases	14
Metals	15, 18, 19
Crystals	12, 16, 18, 19
Atomic Structure:	
Electromagnetics	15
Metals	15, 18, 19
Crystals	12,16, 18, 19
Oxidation/ Reduction	6, 7, 15, 24
Acid/Base Chemistry	6, 7
Chemical Bonding:	
Metals	15, 18, 19
Crystals	12, 16, 18, 19
Chemical Reactions	6, 7, 9, 11, 12, 15, 17, 23, 24
Oxidation/Reduction	6, 7, 15, 24
Aqueous Solution Chemistry	6, 7, 8, 9, 11, 12, 16, 19, 25
Gas Formations	7, 9, 14
Precipitation	11, 12, 16, 17, 19
Acid/Base Chemistry	6, 7
Intermolecular Forces:	
Phase Changes	5, 8, 12, 18, 19
Gases	14
Metals	15, 18, 19
Crystals	12,16, 18, 19
Chemical Reactions	6, 7, 9, 11, 12, 15, 17, 23, 24
Aqueous Solution Chemistry	6, 7, 15, 24
Precipitation	11, 12, 16, 17, 19
Thermodynamics:	
Chemical Reactions	6, 7, 9, 11, 12, 15, 17, 23, 24
Exothermic/Endothermic	5, 7, 12, 15, 16, 23
Equilibrium	7, 10, 12, 15, 17, 25
Aqueous Solution Chemistry	6, 7, 15, 25
Gas Formation	14, 17, 25
Precipitation	11, 12, 16, 17, 19
Acid/Base Chemistry	6, 7, 17
Kinetics:	
Chemical Reactions	6, 7, 9, 11, 12, 15, 17, 23, 24
Exothermic/Endothermic	5, 7, 12, 15, 16, 23
Equilibrium	7, 10, 12, 15, 17, 25
Aqueous Solution Chemistry	6, 7, 15, 25
Gas Formation	14, 17, 25
Precipitation	11, 12, 16, 17, 19

The general objective of the Phase I research is to convert the major concepts, principles, and themes of basic chemistry at both the high school and university levels (now in a written format) to a hands-on format. By carefully reviewing modern chemistry textbooks, current reports, and leading discussions with educators, those concepts, principles, and themes have become one dimension of the matrix given in Table 1. The second dimension of the matrix in Table 1 includes experiments, activities, and projects enabling the student to *experience and discover* the major concepts, principles, and themes (19,20). Refinements will be made as suggested by upcoming conferences, reviewer comments and task force reports.

Phase II research will include the study of more complex chemistry questions as well as the development of a software component (for molecular modeling, safe visualization of dangerous procedures. During Phase II we will address the question of how to quantify the student's senses so they will be able to answer the questions, "How bright is the light? What is the temperature of that material? What is the mass of that object?" Other Phase II extensions will include rewrites of the explorations to establish quantifiable results and the addition of further explorations as suggested by review committees. We will convert the typical phenomenological results of these explorations to quantifiable results, "real numbers". During Phase II and on into Phase III we will scale up the production of the materials and equipment in a cost-effective manner and provide the further materials needed for a comprehensive Labless Lab® in Chemistry. The Labless Lab® in Chemistry will be produced, packaged along with appropriate written materials and given wide commercial distribution during Phase III.

G. PHASE I RESEARCH PLAN:

Design and Development of Explorations

To alter these explorations from producing phenomenological to a quantifiable results will require extensive development. During the Phase I research period we will examine the following explorations to determine if they can produce easily measured quantifiable results.

1. *Safe Chemical Laboratory Practices*. Important issues to be addressed include personal, neighbor and environmental safety. We will compile proven safety systems from university (Dr. Tom Richmond), high school (Mr. Laurence Burton), industry (Dr. Michael Kralik) and college lab instructors. Our set of explorations will begin with the review and practice of these safety issues as shown in the appendix. We will incorporate safety reminders throughout each exploration.

2. *Introduction to Measurement*. The explorations described here require the measurement of mass, volume, temperature and pH. Measurement accuracy, significant figures and repeatability will be discussed and emphasized through examples and exercises in this exploration and reinforced through out each exploration.

3. *Simple Measurement*. We will design a simple mass measurement device using a pencil, ruler, paper clips, BB's and double-sided tape. Other measurement devices to be included are a TLC (thermochromic liquid crystal) thermometer for temperature measurement, pipettes for volume and density measurement, and pH paper for pH measurement. Exercises in this exploration will include practice measuring mass, temperature, volume and pH. It is recognized that these devices do not offer the accuracy of standard lab equipment, but they will offer the students a chance to record numerical data and perform meaningful calculations.

4. *Advanced Measurement*. We will design explorations centered around determining density, energy/enthalpy changes, solubility, and ionic content. For example, the student will build a simple device for measuring liquid density (hydrometer) from pipettes and wood screws. The accuracy of such a device is expected to be within 1% for specific gravity's between 0.95 and 1.05. The density of solid materials can be determined using the mass measurement device and the volumetric measurement device. Densities near that of water are measured using various water solutions such as NaCl/water and alcohol/water solutions of different ratios.

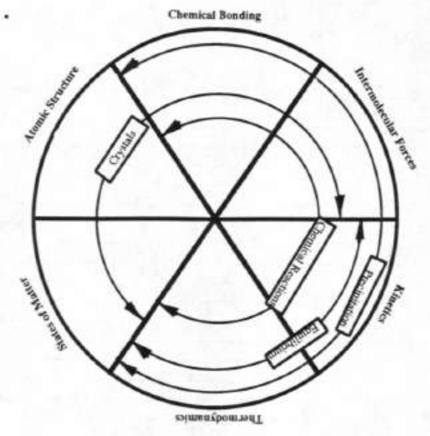


Figure 1. The "Concept Wheel" demonstrates the interrelatedness of each subtopic (written inside the circle) to each major concept (written outside the circle).

these materials in the course of everyday activities. Suitably accurate lab equipment/devices will be constructed from common kitchen and office supplies. The lab will be supplied with simple and inexpensive devices for determining mass, density, temperature, volume, etc.

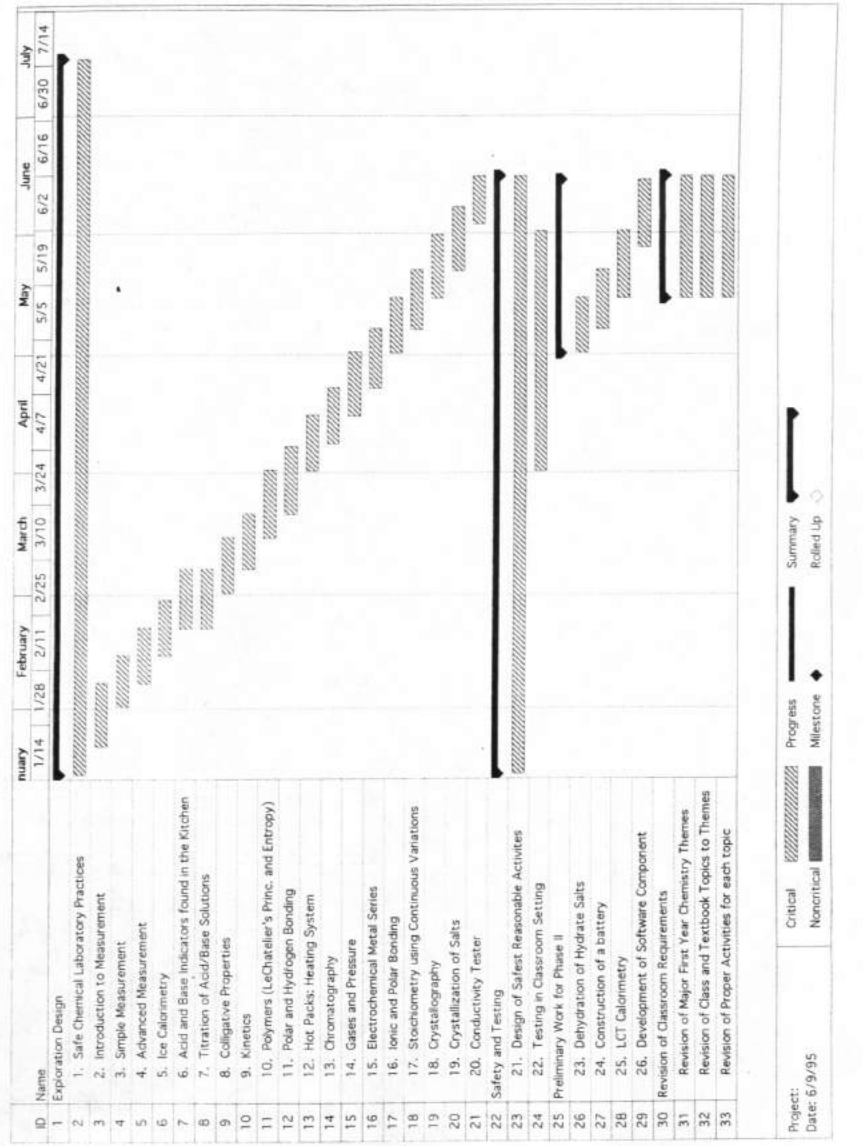
At the conclusion of Phase I we will have established the feasibility of a Labless Lab® in Chemistry. The materials, equipment, and procedures developed during the early part of Phase I will be tested during the spring of 1996 in an introductory chemistry course at Salt Lake Community College, offered and taught by Dr. Rob Scheer*. Other evaluators will include Mr. Laurence Burton, a chemistry instructor at East High School in Salt Lake City, Dr. Tom Richmond a chemistry professor at the University of Utah who instructs both chemistry majors and nonscience majors, and several chemistry instructors from our junior high teacher network. Thus we will have the benefit of rigorous field testing of the concepts and prototype of this Phase I project prior to the completion of the project report and submission of the Phase II application.

F. PHASE I RESEARCH OBJECTIVES

We are proposing the development of a completely self contained chemistry laboratory which, although packaged like a textbook, will contain within it all of the supplies, devices, and information needed to directly discover and experience key chemistry concepts. It will include a set of hands-on, discovery-based experiments (3) which the students can perform for themselves, enabling them to experience, utilize, understand, and apply the major concepts, themes, and topics of "first year" chemistry. Common consumer products will be employed as the supplies and devices. Experiments which are designed for inquiry, discovery and quantification of complex concepts will be designed. The experiments and observations will utilize both the students' senses and simple measurement devices for detection and quantification of data. The Gantt chart in Figure 2 outlines our proposed schedule.

* See attached letter concerning PI eligibility.

Figure 2. Gantt chart outlining project milestones. Numbered explorations correspond to numbers in Section G of this proposal (Phase I Research Plan.)



5. *Ice calorimetry and "Coffee Cup" calorimetry*. Using the heat of fusion and the heat capacity of water, one can measure the amount of energy given off from an exothermic reaction by determining the mass/temperature of ice/water before and after the event. Using a 150ml sample of water and a TLC thermometer, the heat change can be measured to within 1.5 kilojoules.

6. *Acid and Base Indicators found in the Kitchen*. Many vegetable extracts indicate pH change with a change in color. Red and green cabbage and other leafy vegetables exhibit this phenomenon. The reasons for color change will be discussed and the student will calibrate their indicator color to a known pH value. This lab will include discussion and exploration of what pH and pOH mean and the discovery of other possible indicators.

7. *Titration of Acid/Base solutions*. Using included weak acid/base solutions of known concentration, students will determine the molar concentration of unknown samples.

8. *Colligative Properties*. The task here is to design an exploration to teach the concepts of how solute concentration affects vapor pressure, osmotic pressure, boiling point and freezing point. Extensions of this exploration can include ionic charge and chemical composition. For example, how and why the same number of moles of NaCl in solution produces a different effect than $CaCl_2$.

9. *Kinetics*. Design of explorations to teach the effect of temperature, surface area and concentration on the rate of reaction. Extension to determination of reaction constants will be studied during the second phase of this research project. An example is given here:

> "Fill two clear tubes about one-half full of 0.60M acetic acid. Leave one of these tubes at room temperature and put the other into a warm water bath, a Styrofoam cup of warm water. Allow three minutes for the tube and its contents to warm up and then add 1 drop of acid/base indicator solution to each tube and mix by inverting twice (cover with Parafilm.) Keep the warm tube in the water bath for three minutes of observation."

10. *Polymers (LeChatelier's Principle and Entropy)*. We will design an exploration centered around the use of elastic polymers as "entropy springs." Again, quantification will be an important area of development.

11. *Polar and Hydrogen Bonding*. Design of an exploration which follows the principle of "like dissolves like". Using various oils, alcohol, water, dyes, surfactants and food coloring, students will explore hydrogen and polar bonding in liquids.

12. *Hot Packs: Heating System*. Outdoor equipment suppliers have designed a *reusable* "hot pack" which uses the latent heat of fusion in a supersaturated solution to generate a temperature increase. In addition to its use as a demonstration of the heat of fusion and supersaturation, this device can be used as a safe heat source for several explorations.

A copy of exploration 12 is included in the Appendix as an example.

13. *Chromatography*. Chromatography is a common laboratory method used to separate various chemical species based on their abilities to travel through a given medium. An excellent classroom demonstration of this was developed in India (21). By using simple transport systems, i.e. sand or filter paper the student can quickly and easily see which molecules will move faster than others based on the separation of colors from drink mixes, water-soluble color markers, etc. When asked to devise their own method for separation of a given substance, the students will have to understand what causes the components of a liquid solution to separate.

14. *Gases and Pressure*. We will design a simple device, probably involving soda bottles, straws and needle-less syringes, to teach the concepts of the ideal gas law, atmospheric pressure,

An example is the general safety warning on the outside cover and in every document:

> **WARNING:** THIS SET CONTAINS CHEMICALS THAT MAY BE HARMFUL IF MISUSED. READ CAUTIONS ON INDIVIDUAL CONTAINERS CAREFULLY. NOT TO BE USED BY CHILDREN EXCEPT UNDER ADULT SUPERVISION.

For the final product warning, labels specific to each chemical and activity will be included on each bottle and with the literature. Copies of MSDS sheets, although not required for "consumer" amounts, will be in the hands of the school superintendent, the school safety officer, the school principal, the janitor and the instructor.

Other specific safety precautions and warnings will be incorporated under advice from Michael Kralik (consultant), Mojdeh Khalighi (Utah department of State Risk Management) and Louie Pain or representative from the CPSC.

22. *Testing in Classroom Setting*. During the spring quarter of 1996, Rob Scheer will assist in teaching an introductory level chemistry class at Salt Lake Community College. Those activities which have been developed up to that point will be implemented, where appropriate, for the given lesson. Other trials during the Phase I will include use of the kit in two local high schools (pending approval) and a junior high chemistry class. These contacts will be made through our relationship with the University of Utah's Center for Integrated Science Education (CISE).

We have developed a review panel of 25 junior and senior high school science instructors who have assisted us with evaluating our current science kits. During Phase II of this grant we will send prototype Labless Labs® in Chemistry to these instructors for evaluation. These professionally supervised student trials during both Phases I and II will aid us in determining ease of use, safety and learning effectiveness of the chemistry kit.

Preliminary Work for Phase II

The development of the following are seen as long term projects requiring more effort than available during the Phase I research period.

23. *Dehydration of Hydrate Salts*. This is a classical experiment to determine the hydration coefficient of a salt, and an excellent method for investigating stoichiometry. See example. This will require refinement of chemistry and technique for use with relatively cool heat sources and crude mass balances.

24. *Construction of a Battery*. The concept of reduction/oxidation, ion exchange reactions, conductivity, and electric potential can be discovered by building a simple electro-voltaic cell. Models for implementation of this procedure have already been established. These typically involve the metals and ions of Cu/Pb/Fe/Ni/Sn/Ag/Zn/Mg. A cell with wide applicability to these related concepts will be developed using "safe" metals and ions.

25. *LCT Calorimetry*. To test for an energy change during mixing, a procedure of reading temperature change from a LCT thermometer is used. The method is described here.

> "To test for the energy change, if any, when a solid dissolves in water, place a very few small crystal of the solid on the green band of the thermometer. Put one drop of water on the crystals; observe and record the color changes, if any, that occur under and around the water, as it interacts with the crystals. Put a drop of water at another spot on the green band to be sure that the water itself causes no color changes on the thermometer."

Tests must be performed to determine if the temperature rise of a safe exothermic reaction is large enough to be indicated on liquid crystal thermometers. Otherwise, different reaction systems or unique thermometers will have to be developed.

hydrostatic pressure and vacuum. Using relatively simple devices the students can determine the gas constant, *R*. Students will also measure and atmospheric pressure and its changes with the weather pattern by constructing a simple barometer.

15. *Electrochemical Metal Series*. A series of metal ion solutions is compared according to their ability to coat or remove metal ions from other metals in the series. Variation of metal geometry, (i.e. powder or bar, or strips, or beads) and competition between different metals will be explored. Concepts learned include electronegativity, charge, voltage and solubility.

16. *Ionic and Polar bonding*. An exploration of ionic/polar bonding will be designed using several kitchen ingredients. This may be extended into the phase II research period.

17. *Stoichiometry using the Method of Continuous Variations*. By varying the ratios of two reactants and observing the ratio needed for optimum reaction, the correct stoichiometric ratio is determined by the student. Various reactions will be examined.

> "In the continuous variation method, the total amount (moles) of the two reactants is held constant in a series of reactions, but the ratio of the two reactants is varied. With the total amount of the reactants held constant, the maximum effect will be observed when the reactants are mixed in their stoichiometric ratio. You will explore different ratios until you find the one that produces the largest effect (Energy change (ΔT), precipitation or color change); this is the stoichiometric ratio."

18 *Crystallography*. The task here is to design an experiment comparing the crystal structure of several solid state minerals and polymers. Comparison will lead to discussion of why they differ and to crystal shape, size, density and symmetry.

19. *Crystallization of Salts*. By evaporating a concentrated salt solution the student can witness the formation of typical crystal structures for various soluble salts. Examples are a saturated sodium chloride solution, which produces a cubic crystal structure upon evaporation of the water and a saturated copper (I) chloride solution which forms a hexagonal close packed structure. Variations of recrystallization techniques (temperature and evaporation rates) can be tried to determine their effect on crystal size and shape (demonstrations of kinetics and diffusion).

20. *Conductivity Tester*. A prototype of a simple and inexpensive visual conductivity meter designed to indicate "good", "poor" or "non-" conductivity of either a solid or a liquid is being designed and tested in a classroom setting for the Labless Lab® in Polymers. This should be included with the Labless Lab® in Chemistry for determination of ionic content in a liquid solution and measuring the conductivity of a metal or other solid.

Concurrent Thematic Objectives

Along with the development of the above explorations will be the continued effort to ensure safety and relevance. These will be accomplished by weekly reviews from both Mike Kralik, Laurence Burton and Utah State Risk Management officer, Mojdeh Khalighi.

21. *Design Safest Reasonable Activities*. This is a review process. Each activity will be examined for safety by experienced laboratory directors, safety officials and long-time chemistry instructors. During Phase II of this grant, we will assure complete and final compliance with safety guidelines in accordance with the Consumer Product Safety Commission (CPSC) *Code of Federal Regulations*. Our CPSC representative is Mr. Louie Pain.

26. *Development of Software Component*. We will establish connections with software publishers through our involvement with the Journal of Chemical Education: Software editor, Dr. John Moore, one of our Labless Lab® in Polymers consultants. Our goal in Phase II is to incorporate a software component into this lab. Software development during Phase II will primarily be done through subcontracting.

In general, Phase I and II research will center around turning these explorations into experiments which will produce quantifiable results similar to those found in most conventional chemistry laboratories. It is recognized that without the enhanced sensor equipment found in the well-equipped chemistry laboratory, the results here will not be as *accurate* as those found in a chemistry laboratory. For those students who would not otherwise have any lab experience this reduction in measurement *accuracy* is not as important as the act of making a measurement in the first place.

H. COMMERCIAL POTENTIAL

There are over 10 million students in high school grades 10-12, with a student/teacher ratio of 20 to 1 (22). Each student will participate in an average of one year of chemistry, thus accounting for approximately 180,000 high school chemistry classes being taught each year. Many of these classes have inadequate or absent laboratory facilities due either to lack of time or funds. Motivated and prepared instructors can prepare class demonstrations and show instructional videos, such as "The World of Chemistry"(15), to enhance classroom learning, but these do not provide the thorough understanding gained through the experience of doing chemistry. A conservative estimate of the classes without a laboratory is 25%, indicating a *need* for approximately 45,000 high school level chemistry classroom kits. If each kit were to have enough materials for four students, then for twenty students to participate in their own research, 5 kits/class would be required (up to 225,000 kits per year.) Other markets include distance learning (telecourses), home teaching, and colleges/universities with inadequate laboratories.

Protein Solutions, Inc. now has three products in the science education market: Night Life®: Science in the Dark, a bioluminescent science kit for upper elementary and junior high students, Galaxsea®, an adult science novelty consisting of packaged bioluminescent plankton and Teacher's Kit™, a set of four science explorations involving bioluminescent phytoplankton designed for individual and classroom use. These kits are distributed through several major national catalog distributors which target science and nature stores in museum/science center gift shops.

An informal assessment indicates that the market for chemistry textbooks alone is in the range of $10 million/year for colleges and universities. If one includes the high school market this total rises to $30-40 million/year. A recent marketing survey of the college textbook market (23) indicated that there are ten major publishers who reported revenues in 1991 of $1.6 billion/year.

A typical high school/university chemistry text can be purchased for $20-50/unit. PSI's Labless Lab® in Chemistry must be priced similarly in order to be competitive.

We are targeting our existing Labless Lab® activity, the Labless Lab® in Polymer Science, to retail in roughly the $50-75/unit range, which is the upper end of the range for textbooks in the subject. Since many colleges and universities already charge laboratory fees in the range of $25 to an excess of $200 per term for laboratory intensive courses, the price is reasonable.

PSI already has considerable experience in the Labless Lab® concept. Our Labless Lab® in Polymers is a successful extension of research begun with the aid of an NSF, Phase I SBIR (January, 1994). We will introduce a prototype of the polymer kit for evaluation at the October National Science Teacher's Association (NSTA) conference in Salt Lake City. We hope to begin a full marketing effort of the Labless Lab® in Polymers during the March, 1996 NSTA conference in St. Louis. There the focus is on sets of materials and experiments to facilitate the direct experiencing and understanding of many unique concepts and characteristics of macromolecules and polymeric materials. We are working with the University of Utah's Center Integrated Science

Education on the development of a Labless Lab® in Science through Art being designed for a general education telecourse on science for non-science majors.

I. PRINCIPLE INVESTIGATOR

Dr. Robert Scheer, Principle Investigator, received his Ph.D. in Materials Science and Engineering in 1993. He served as the principle investigator of PSI's Labless Lab® in Polymer Materials, a completed SBIR Phase I from the National Science Foundation. This project is making rapid progress and will result in a Phase II submission about September 15, 1994. Dr. Scheer has had considerable experience in the teaching of college level chemistry, and is a part-time adjunct chemistry instructor at Salt Lake Community College. A letter from his Department Chair attesting to the fact that he is a part-time, non-permanent employee, and thus cannot submit research grants through Salt Lake Community College is included here in accord with NSF's PI instructions regarding eligibility (pp. 3-4 of the 1995 SBIR Solicitation). Dr. Scheer's abbreviated CV is included as the next page.

Dr. Joe Andrade is founder and Chief Scientific Officer of PSI, although he is not listed as a senior personnel participant, he does spend about 25% of his full time activities with Protein Solutions, Inc. and will be working closely with Dr. Scheer on this project. Dr. Andrade is Professor of Materials Science and of Bioengineering at the University of Utah and has taught at the University undergraduate and graduate levels for the past 25 years. He also had some experience teaching high school chemistry and biology many years ago, directs the University's Center for Integrated Science Education and is heavily involved with jr. high and high school teachers locally. He is also involved in the development and conduction of inservice courses for local teachers and in the revision of the state core science curriculum.

J. CONSULTANTS AND SUBCONTRACTS

Dr. Michael Kralik is a Ph.D. graduate of the University of Utah's Department of Chemistry. Since graduation he has consulted with several educational firms concerning the safety and packaging compliance of their science related education products. He has developed ongoing relationships with regulatory agencies including the Consumer Products Safety Commission. Mike has a firm understanding of the requirements of marketing science kits involving chemicals and materials, and his contribution to the proper safety and packaging of our kit materials will be vital.

Mr. Laurence Burton is a veteran science (chemistry, biology) instructor at East High School in Salt Lake City, Utah. He regularly teaches 4 to 5 classes of 30 students each day in the areas of both animal biology and chemistry. Laurence has developed some of East High's laboratories and often uses personally designed experiments and demonstrations in his classes. His experience in the classroom will allow him to judge from a practical standpoint the benefits and drawbacks of our submitted explorations.

K. EQUIPMENT, INSTRUMENTATION, COMPUTERS, AND FACILITIES

PSI's laboratories and office are located in the University Research Park at 391 Chipeta Way. The labs are adjacent to the University of Utah's Center for Integrated Science Education (CISE) with whom PSI has a synergistic relationship. Cooperation between CISE and PSI has produced workshops and science exhibits. PSI's facilities include about 150 square feet of office space and 600 square feet of laboratory and production space. Research and development equipment includes spectrophotometers, ovens, measuring electronics, Macintosh and IBM computers with appropriate sensor and monitoring interfaces, optical microscopes, and other general routine laboratory equipment.

PSI is a member of the Center for Biopolymers at Interfaces at the University of Utah, a University/Industry/State consortium. As a member, PSI has priority access to equipment, laboratories, and technical personnel in the Center, including specialized analytical facilities,

INSTRUCTIONS FOR USE OF SUMMARY PROPOSAL BUDGET (NSF FORM 1030A) (10/94)

1. General

a. Each grant proposal, including requests for supplemental or incremental funding, must contain a Summary Proposal Budget in this format unless a pertinent program guideline specifically provides otherwise.

b. Copies of NSF Form 1030A and instructions should be reproduced locally as NSF will not supply the form.

c. A separate form should be completed for each year of support requested. An additional form showing the cumulative budget for the full term requested should be completed for proposals requesting more than one year's support. Identify each year's request (e.g., "First year____," or "Cumulative Budget," etc.) in the margin at the top right of the form.

d. Completion of this summary does not eliminate the need to fully document and justify the amounts requested in each category. Such documentation should be provided on additional page(s) immediately following the budget in the proposal and should be identified by line item. The documentation page(s) should be titled "Budget Explanation Page."

e. Revised budgets must be signed and dated by the authorized organizational representative and principal investigator and submitted in at least the original and two copies.

2. Budget Line Items

A full discussion of the budget and the allowability of selected items of cost is contained in the NSF SBIR Solicitation and guidelines. Following is a brief outline of budget documentation requirements by line item. (*NOTE: All documentation or justification required on the line items below should be provided on the Budget Explanation Page.*)

A., B., and C. Salaries, Wages, and Fringe Benefits. On the Budget Explanation Page, list individually all senior personnel who were grouped under A.5, the requested person-months to be funded, and rates of pay.

D. Permanent Equipment. Items exceeding $5,000 and 2 years' useful life are defined as permanent equipment. Fully justify.

E. Travel. Address the type and extent of travel (including consultant travel) and its relation to the project. Itemize by destination and cost and justify travel outside the United States and its possessions, Puerto Rico, and Canada. Include dates of foreign visits or meetings. Fare allowances are limited to round-trip, jet-economy rates.

F. Participant Support Costs. Normally participant support may only be requested for grants supporting conferences, workshops, or symposia.

G. Other Direct Costs.

1. *Materials and Supplies.* Indicate types required and estimate costs.
2. *Publication Costs/Page Charges.* Estimate cost of preparing and publishing project results.
3. *Consultant Services.* Indicate name, daily compensation (limited to $443/day), and estimated days of service, and justify.
4. *Computer Services.* Include justification based on established computer service rates at the proposing company. Purchase of equipment is included under D.
5. *Subcontracts.* Include a completed budget and justify details.
6. *Other.* Itemize and justify. Include computer equipment leasing.

I. Indirect Costs. Specify current rate(s) and base(s). Use current rate(s) negotiated with the cognizant Federal negotiating agency.

APPLICANTS MUST NOT ALTER OR REARRANGE THE COST CATEGORIES AS THEY APPEAR ON THIS FORM WHICH IS DESIGNED FOR COMPATIBILITY WITH DATA CAPTURE BY NSF'S MANAGEMENT INFORMATION SYSTEM. MISUSE OF THIS FORM MAY RESULT IN RETURN OF PROPOSAL TO APPLICANT.

specialized material testing facilities, and materials production and fabrication equipment. A letter to this effect is included.

L. CURRENT AND PENDING SUPPORT OF PRINCIPAL INVESTIGATOR AND SENIOR PERSONNEL

Robert J. Scheer:

1. Current Support:

NSF Phase I STTR, Direct Reading, Quantitative Biosensors for ATP Dependent Processes (ends 8/15/95) Dr. Scheer's involvement during the year long project was approximately 4 months.

2. Pending Support:

NSF Phase II STTR related to the current Phase I support; Dr. Scheer's role here will be approximately 9 months. (tentative dates from 4/96–4/98)

NSF Phase I SBIR "Enhancing Optical Biosensors by Interface Orientation of Engineered Luciferase." Dr. Scheer's role here will be approximately 1 month. (tentative dates from 1/96–7/96)

M. EQUIVALENT PROPOSALS TO OTHER FEDERAL AGENCIES

None.

N. BUDGET

See Appendix D, NSF form 1030A.

Senior Personnel: Dr. Robert J. Scheer, Principle Investigator.

Travel: National Science Teachers Association Conference, St. Louis, MO, March, 1996.

Materials and Supplies: Purchase of chemicals ($1800), safety supplies ($1500) and disposable labware ($1500) for testing and evaluation.

Publication, Documentation, Dissemination: Evaluation of kits by the four classes listed in Research Objectives, section G. Publication in proceedings of NSTA conference.

Consultant Services: Dr. Michael Kralik and Mr. Laurence Burton each 2 days @ $320/day. See attached letters.

Other: Safety testing of chemical components at Nelson Laboratory in Salt Lake City, $1500. Co-development of our Labless Lab® with a CDROM course aid being evaluated at the University of Utah's Department of Chemistry, $1500.

O. PRIOR PHASE II AWARDS

Protein Solutions, Inc. has not received more than 15 Phase II awards in the past 5 fiscal years.

18. DuPont Communications Team. Fun with Science. Dupont Ponchartrain Works: Kinston, NC. (1994)

19. (All of the following chemistry textbooks and lab manuals were evaluated for their content and topics)

Amend, et al. *General, Organic, and Biological Chemistry*. Saunders. 1993.
Bell, J.A. *Chemical Explorations*. D.C. Heath. 1993.
Brady, J.E.; Holum, J.R. *Chemistry: The Study of Matter and its Changes*. Wiley. 1993.
Chemistry in Context: Applying Chemistry to Society. American Chemical Society. 1990.
Ellis, A.B., et al. *Teaching General Chemistry: A Mat'ls Science Companion*. ACS. 1993.
General Chemistry (117-119) Laboratory Manual. University of Utah. 1993.
Korchin, F.G. *Science and the Marketplace*. Tiger Publications. 1992.
Kotz, J.C. et al. *The Chemical World: Concepts and Applications*. Saunders. 1994.
Kotz, J.C.; Purcell, K.F. *Chemistry and Chemical Reactivity*. Saunders. 1991.
Masterson, W.L.; Hurley, C.N. *Chemistry: Principles and Reactions*. Saunders. 1989.
Milio, F.R. et al. *Experiments in General Chemistry*. Saunders. 1991.
Shakhashari, B.Z. *Chem. Demos: A Handbook for Teachers of Chem.*, v. 1-4. U. of Wisc. 1992.
Smoot, R.C. et al. *Chemistry*. Macmillan. 1993.
Snyder, C.H. *The Extraordinary Chemistry of Ordinary Things*. Wiley. 1992.
Summerlin, L.R.; Ealy, J.L. *Chemical Demos: A Sourcebook for Teachers* . ACS. 1988.

20. Selvaratnam, M. "Coherent, Concise, and Principle-based Organization of Chemical Knowledge." *J. Chem. Educ.* 70 (1993) 824.

21. Lalitha, N. "Chromatographic Separation of Plant Pigments Using Sand as the Adsorbant," *J. Chem. Educ.* 71 (1994) 432.

22. Schwartz, B.B. *The American Physical Society News*. May 1994.

23. *Educational Marketeer*. August 10, 1992.

SALT LAKE COMMUNITY COLLEGE

4600 South Redwood Road / P.O. Box 30808 / Salt Lake City, Utah 84130-0808
Telephone (801) 957-4111 FAX (801) 957-4444

Grants Official
National Science Foundation
SBIR/STTR Programs

June 7, 1995

Dear Official,

Dr. Rob Scheer is an adjunct instructor in the Physical Science department. In such a capacity, he is not eligible to apply for Research Grants through Salt Lake Community College.

If you have any questions please let me know.

Sincerely,

Davis V. Ballard
Division Chair
Math/Physical Sciences Division

June 9, 1995

Dr. Rob Scheer, Project Director
Protein Solutions, Inc. (PSI)
350 West 800 North, Suite 218
Salt Lake City, UT 84103

Dear Rob:

I am pleased to confirm that CBI's facilities are available to you and your co-workers at member rates.

I am pleased to learn of your SBIR submission to the National Science Foundation, The Labless Lab: Chemistry. CBI is pleased to acknowledge that you will have access to labs and facilities related to chemical and materials characterization.

Faculty affiliated with CBI and its technical staff have the experience and skills which will greatly aid you and your co-workers in the conduct of this innovative research.

Sincerely,

Karin D. Caldwell
Professor, Department of Bioengineering
CBI Director

Center for Biopolymers at Interfaces
108 Biomedical Polymers Research Building
Salt Lake City, Utah 84112
(801) 581-3867

THE WILD GOOSE CO.

375 Whitney Ave. • Salt Lake City, Utah 84115

Protein Solutions, Inc.
Science Education Innovator
Rob Scheer, Ph.D.
Research Instructor, University of Utah
350 W. 800 N., Suite 218
Salt Lake City, Utah 84103

June 9, 1995

Dear Rob;

I would be more than willing to consult with your firm to ensure compliance with chemical safety and product labeling. My standard fee is $40.00 per hour and I am immediately available to assist you. If I can be of any further help, please let me know.

Sincerely,

Michael Kralik, Ph.D.

Laurence S. Burton
Science Teacher
1455 E. 6050 South
Salt Lake City, UT 84121

June 8, 1995

Rob Scheer, Ph.D.
Protein Solutions, Inc.
350 W. 800 North, Suite 218
Salt Lake City, UT 84103

Dear Rob:

I would be glad to participate as a consultant for the "Labless Lab in Chemistry" project at the rate of forty dollars per hour. I will be able to provide suggestions or feedback on the contents of the "labless Lab", help to determine whether the curriculum is appropriate for the level of the student, and, address safety issues related to the use of "Labless Lab" in the classroom. With the approval of the administration at my school and school district, I would also be willing to test the use of "Labless Lab in Chemistry" with my chemistry students. Thank you for offering me for this opportunity and I am looking forward to working with you on this project.

Sincerely,

Robert J. Scheer

350 West 800 North, Suite 218
Salt Lake City, UT 84103
(801)596-2675
e-mail <rob.scheer@m.cc.utah.edu>

EDUCATION

Ph.D. in Materials Science and Engineering, December 1993, University of Utah, Salt Lake City, UT. Dissertation emphasis: Mechanical, interfacial, and surface study of composite materials.

B.S. in Mechanical Engineering, May 1989, Duke University, Durham, NC. Emphasis: Fracture mechanics and failure analysis of polymeric materials.

UNIVERSITY HONORS

National Science Foundation Fellow, University of Utah Graduate Research Fellow, Dean's List Duke University, Academic All American, Duke University Magna Cum Laude

EXPERIENCE

Project Director
Protein Solutions, Inc. Salt Lake City, UT. 1994 - present. Directed research for the design and implementation of novel science education materials.

Instructor
Salt Lake Community College, Salt Lake City, UT. 1993 - present. Planned, instructed, and graded for undergraduate physical science and engineering classes.

Research Assistant
University of Utah, Salt Lake City, UT. 1989 - 1993. Tested mechanical properties of polymers and composites, studied surfaces and interfaces, tested adhesive bonds on the microscopic scale, and developed stress analyses related to materials testing and bimaterial interfaces.

Engineering Technician
Sandia National Laboratory, Albuquerque, NM. Summers, 1988-1989. Designed engineering experiments for failure analysis of ceramic materials, and extensively researched current experimental techniques for determining material fracture toughness.

AFFILIATIONS

American Society for Mechanical Engineers
ASM International
The Minerals, Metals, and Materials Society
American Physical Society
The American Chemical Society, Division of Chem. Ed.
National Science Teachers Association
Utah Science Teachers Association
American Society for Engineering Educators

PUBLICATIONS

Andrade, J.D. and R.J. Scheer. "Applying 'Intelligent' Materials for Materials Education: The Labless Lab™." *Proc., 2nd Annual Conference on Intelligent Materials*, Tech. Publ. Co.: PA, 1994.

Scheer, R.J. and J.D. Andrade. "Applying Intelligent Materials to Materials Education." *Journal of Intelligent Materials*, in press 1995.

Scheer, R.J. "A Labless Lab® Approach to Materials Education using Intelligent Materials." Proceedings, American Society for Engineering Educators, 1995 Annual Conven. in press 1995.

Exploration #12: Measuring "The Heat Solution™" using Coffee Cup Calorimetry

The Heat Solution™ hand warmer device utilizes a chemical "activity" to generate a temperature increase.

You are to determine the nature of this chemical "activity".

Materials supplied:

Heat Solution™ packet
1 20 oz. styrofoam cup with lid
1 12 oz. styrofoam cup with lid
thermometer
goggles
mass balance (the one you've made)
tongs/tweezers
100 ml volumetric measuring cup
Thermodynamic Chart (listed below)

Other required materials:

Vessel with boiling water
Timepiece

Procedure:

1) Don your safety goggles.
2) Heat your vessel of water to boiling.
3) Place the Heat Solution™ packet in boiling water using tongs.
4) After ten minutes, remove the vessel from the heat source and gently remove the packet from the hot water using the tongs.
5) Allow the packet to cool for at least 30 minutes or until it reaches room temperature (cool to touch).
6) Carefully dry the packet and measure and record its mass.
7) If the packet should accidentally activate (turn white and feel solid), repeat steps 2 through 5.
8) Add 150 ml of cool water to the 12 oz. styrofoam cup.
9) Place the 12 oz. cup in the empty 20 oz. cup
10) Gently submerge the packet in the 150 ml of water.
11) Measure and record the time and temperature of the water in the cup.
12) Measure and record the temperature every five minutes until it does not change between readings.
13) Activate the packet by "clicking" the metal disk.
14) Quickly cover both of the cups with their plastic lids.
15) Measure and record the temperature every two minutes until it reaches a maximum (3 readings in a row).
16) Remove the packet, dry it, and measure and record its mass.

You now have all of the data required to answer the following questions:

I. Is the chemical "activity" exothermic or endothermic?
II. Is the "activity" reversible?
III. What is the specific heat (joules/g) of the "activity"? (Do the following four items.)
1) Calculate the difference between the temperature of the water just before activation and the plateau temperature. This is ΔT.
2) Add the mass of the water (148 grams) to the mass of the packet. This is the total mass.
3) Multiply the total mass by the change in temperature (ΔT) by the specific heat of water. (4.184 J/g•°C). This is the total heat generated.
4) Divide the total heat generated by the mass of the packet. This is the specific heat generated.

IV. Use the information you know about the specific heat and the temperature to determine which one of the following chemicals and activity are involved in the temperature increase?

THERMODYNAMIC CHART

Chemical Name/Specific Heat	Heat of Solution	Heat of Fusion	Melting Point
Sodium chloride	67 J/g	517 J/g	800°C
Sodium acetate	208 J/g	≈364 J/g	324°C
Sodium hydroxide	1072 J/g	209 J/g	322°C
Potassium acetate	151 J/g	≈275 J/g	292°C
Calcium chloride	185 J/g	230 J/g	782°C
Potassium bromide	181 J/g	176 J/g	742°C

SAFETY EXPLANATION SHEET

WARNING: THIS SET CONTAINS CHEMICALS THAT MAY BE HARMFUL IF MISUSED. READ CAUTIONS ON INDIVIDUAL CONTAINERS CAREFULLY. NOT TO BE USED BY CHILDREN EXCEPT UNDER ADULT SUPERVISION.

Important safety issues.

1. Always perform explorations with the aid of an adult partner or supervisor. Never work alone.
1. You are required to wear splash goggles in all chemical laboratories.
2. Learn the following emergency procedures:
   Call 911 in case of emergency.
   If you feel dizzy or sick, stop what you are doing and leave the room.
3. Wear appropriate clothing (no shorts, short skirts, or short sleeve shirts or tank tops) and shoes (no open toed sandals); confine long hair.
4. Do not eat, drink or smoke in your lab area.
5. When mixing or heating chemicals, point the container away from individuals.
6. Clean up all spills immediately by covering the spill with the appropriate clean-up materials listed below:
   Paper Towel, Chemisorb, resealable plastic bags
7. Dispose of chemicals as properly described in each exploration.
8. Only those experiments included in this instruction manual should be used.
9. Chemicals should be mixed only in the proportions and by the methods prescribed in the instructions.

Please sign the following agreement:

I have read carefully and understand all of the safety rules contained on this sheet and in the laboratory manual or laboratory handouts required for this course. I recognized that it is my responsibility to obey them faithfully.

I realized that all chemicals are potentially dangerous; therefore I will exercise care in handling them. If I am unsure of the potential hazards of any chemical, I will discuss this with my instructor prior to using the chemical in question.

I understand that I am required to wear approved chemical splash goggles <u>AT ALL TIMES</u> while I am in the laboratory. I also understand the dangers involved in wearing all types of contact lenses in the chemical lab. If I elect to wear contact lenses in the laboratory, I will assume all responsibility for damages caused by wearing them in the lab.

I further understand that I am permitted to work on these explorations only when accompanied by a lab partner or supervisor.

____

Name　　　　　　　　Signature　　　　　　　　Date

____

____

____
School Address

____
School Phone Number

____
Instructor Name