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A Problem Solving Approach to the Introduction of Chemistry

Curriculum Unit 80.07.12
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This four to six week unit is to be used to introduce chemistry to college bound high school students. Their reading ability is generally on a high school level and their math background varies from algebra I to pre calculus.

Chemistry is usually the first subject these students encounter which requires the application of the various math skills they have been exposed to over the years. They usually tend to compartmentalize their learning experiences, and to leave their math neatly filed away for math class, or semiforgotten. They have probably avoided as much as possible any problem solving and have not needed to apply their problem solving or math skills to any specific area in any organized way.

The most universally accepted definition of the word “science. is “a systematic, organized method of solving problems in some defined area”. Because of this, the introduction to chemistry would seem to be an ideal opportunity to combine a physical science, the review of math skills, and a methodical approach to problem solving. It is hoped that by thus allowing him to see a practical application for these skills in becoming familiar with the physical properties of matter, the student will improve his math proficiency. The student should begin to acquire a “feel. for attacking problems that increasingly meets with success.

This combination should help the student build confidence in himself and his capabilities, developing an attitude that will help him succeed not only in chemistry, but also in other problem solving subjects. There is probably nothing so conducive to success in this life as the ability to confront problems headon, analyze them, and produce viable solutions.

OBJECTIVES

1. To define chemistry for the student and to familiarize him with the vocabulary used in describing the physical properties of matter.
2. To introduce the student to a step by step method of Problem solving.
3. To familiarize the student with the metric system and decimals.

4. To present a set of sample problems using our problem solving method in the areas of the derived quantities of density and heat.
5. To demonstrate the calculation of percentage of error.

VOCABULARY

calorie	energy	gas
heat energy	hypothesis	inertia
kinetic energy	law	length
liquid	matter	mass
potential energy	solid	specific heat
temperature	theory	time
unit	volume	weight

work

Chemistry is the study of matter, its composition, its structure and the reactions that change matter from one form to another. There are two broad areas in chemistry: first, descriptive chemistry. This is the collection of data and discovery of information. Secondly, there is the using of this information to form laws and theories which explain our observations, and the using of these laws and theories to predict the future behavior of matter.

Mathematics, or the abstract treatment of quantities, is of paramount importance to chemistry. We must constantly answer such questions as how much will we need? How long will the reaction take? We must measure matter, express our measurements in numbers, and be able to manipulate these numbers to form conclusions, or solve problems. However, this should not frighten the student because high school chemistry usually involves only simple arithmetic, simple algebra and proportions. Most of the difficulty students encounter is not In the math, but in setting up the problem.

Since our activities in science involve the solving of problems, the sooner we devise a problem solving method that works, the sooner the students will be comfortable as chemists.

G. Polya has written several books on this subject, and I found his book, How to Solve It especially helpful in developing our chemistry problem solving plan. This plan can be applied to any problem in any area and should meet with a high degree of success. There are four steps involved.

Step 1 Understand the problem. We must read it carefully to discover what it asks us to find. This is the unknown. We must discover what facts are given to us. These are the data.

Step 2	Formulate a plan. We develop a suitable plan for solving our problem, using the data we have been given. We ask ourselves such questions as Is this a familiar problem? Do I have sufficient information to answer it?
Step 3	Carry out our plan. (1) Carefully list our data. (2) Write down any formula we are going to use. (3) Substitute our data into the formula. (4) Make careful calculations, being sure to include units. By carefully writing down each step of our solution, we avoid careless errors and we will be able to check our work.
Step 4	*Check our work* . Recheck each step, being sure we have used correct formula, substituted correct numbers in using the formula, that our computations are correct and that we have included correct units.

The importance of including units and handling them correctly should be stressed.. It means nothing to say we have 5. We must say we have 5 dogs, or 5 apples, or 5 grams of water. The following things should be remembered when dealing with units.

1. Unlike units must be changed to common units before calculations can be made.
2. Units are manipulated in the same manner as numbers. That is, they must be squared or canceled during calculations.
3. The sign “/” is read as “per” and means “for every” as in 60 miles/gallon.

Examples: addition and subtraction

4 liters + 7 liters = 11 liters

10 grams 5 grams = 5 grams

Multiplication and division

3 cm ^{2} x 2 cm = 6 cm ^{3}

3 hours x 50 miles/hour = 150 miles

(figure available in print form)

Now, let us illustrate our method with a very simple problem.

Problem: Find the area of a room 400 meters long and 100 meters wide.

Step 1	Understand the Problem What is our unknown? Look for such clue words as “find”, “how much” and “how many”. In this case we are asked to find the area, and the data given includes length and width.
Step 2	*Plan* We know that area of a rectangle can be computed by multiplying the length times the width, using the formula A = L x W.
Step 3	*Carry out plan* or *make calculations*

Data length= 400 meterswidth = 100 meters

Formula A =L x W

substitution of our data into formula

A 400 m x 100 m = 40000 m ^{2}

Step 4 *Check our work* Did we use correct formula? Yes,

Did we substitute correct data? Yes.

Are our calculations correct? Yes.

Did we handle units correctly? Yes.

Our Problem is complete.

Since all scientific measurements and calculations are made in the metric system, some time should be taken at this point to review the metric system. Students should not be asked to change measurements from the English to the metric system. They should, for all intents and purposes, forget about the English system in science, except for using it for a rough approximation of the relative size of the metric units. It has been my experience that the following facts should be included in the review of the metric system.

meter the unit for measuring length in the metric system. One meter is just slightly longer than one yard. (39.37 inches)

liter the metric unit for volume. One liter and 1 quart are about the same size. (1 quart = .95 liters)

gram the metric unit used to measure mass. One kilogram is equivalent to about 2 pounds. (2 pounds .91 kilograms)

The following list of prefixes can be used with any of the above three units to indicate how many of the units we are dealing with.

milli	1/100	centi	1/100	deci	1/10
deka	10	hecto	100	kilo	1000

Students find the system easier to work with if they understand what the units are based upon, and how they are related to each other. The metric system is a decimal system. Each unit is a multiple or a dividend of 10. There are 10 millimeters in each centimeter, and 10 centimeters in each decimeter, and 10 decimeters in a meter etc. It follows that there would be 10 x 10 millimeters in a decimeter, or 100.

The meter is the length of a certain number of wavelengths of the orange red line in the spectrum of krypton 86. Water is then used as the medium for transferring length to mass. One cubic centimeter of water is assigned a mass of one gram. (This is at 4°C, the densest point of water.) This gram of water is then said to have a volume of one milliliter. Because water is used in the transition from one dimension to the other, we can say that one cubic centimeter of water, one gram of water, and one milliliter of water all refer to the same quantity.

Before assigning problems in metrics to the students, it is necessary to review with them the operations of multiplying and dividing by 10’s and multiples of 10. To multiply by 10 or multiples of 10, you move the decimal one place to the right for each zero in the number you are multiplying by. To divide by units of 10, you move the decimal one place to the left for each zero in the divisor.

To add or subtract decimals, the decimals must be lined up directly underneath each other, because this aligns the units correctly. To multiply with decimals, you multiply as usual, then count the total number of digits that appear after the decimal point in the numbers to be multiplied, and place the decimal that many places from the left in the answer.

Students should be given several objects to measure in the metric system. They should familiarize themselves with using this system by finding areas and volumes of such things as their desk top, milk cartons, books, etc. Some sample metric problems and their solutions are below. Students should probably be reminded of the formulas used for computing areas and volumes of common objects.

area of a rectangle length x width area

area of a rectangle length x width area of a circle ^{1} x radius ^{2}

volume of a rectangular box = length x width x height

volume of a cylinder = ^{1} x radius x height.

Example 1 How many centimeters are contained in 14 meters?

Step 1	Unknown the number of centimeters in 14 meters Data we have 14 meters.
Step 2	We know that the prefix centi means 1/100, and that there are therefore 100 centimeters in each meter. Since we are converting from a relatively large unit meters to a relatively small unit centimeters we know that we will have more of the smaller units and therefore we must multiply. *In going from a larger unit to a smaller unit. we multiply the number of large units given by the number of small units in each large unit.*
Step 3	unknown centimeters in 14 meters
	data 1 meter= 100 centimeters
	14 meters = 14 m x 100 cm/m = 1400 cm
Step 4	Check work.

Example 2 How many grams are in 76.3 milligrams.

Step 1	Unknown grams in 76.3 milligrams
Step 2	The prefix milli means 1/1000. Since we are changing from a smaller unit to a larger unit, we will have fewer of the larger units, and must therefore divide. a larger unit we *must divide the numbe* r Of small units in each large unit.
Step 3	Unknown - grams in 76.3 milligrams
	data 1 gram contains 1000 milligrams

(figure available in print form)

Step 4	Check work. Be sure you have the number of smaller units per large unit correct, that your multiplication and division are correct, and that units have been handled correctly.

Enough problems of this type should be completed by the students so that will be familiar enough with the metric system to use it in handling density problems.

Properties of Matter

Properties of matter fall into two categories A Chemical properties those properties that describe how a material reacts with other materials in reactions that change its identity. We will deal with chemical properties in a later unit. B Physical properties those readily observable properties which can be noted without changing the material, such as color, state (solid, liquid or gas) hardness, texture, odor, solubility, density and specific heat.

As we make our observations about size and quantity, always using the metric system, we have two types of measurements (1) fundamental quantities those which can be directly measured such as length, mass, temperature and time, and (2) derived quantities those which must be arrived at by using combinations of the fundamental measurements. Area, volume, density and heat are derived quantities.

By this time, the students will be familiar with the concepts of area and volume. In this unit we will concentrate on the concepts of density and heat content, important measurements in chemistry, which will be unfamiliar to the student..

Density is a measure of the relative heaviness of a substance. In order to compare “heaviness”, it is necessary to compare the masses of equal volumes of that material. The volume unit usually used is cm3 and the mass used is grams. Density is then expressed in grams per cubic centimeter g/cm3. Density is an identifying characteristic of any substance. One cubic centimeter of silver will always have a mass of 10.5 grams. One cubic centimeter of lead will always have a mass of 11.35 grams. Thus we can say the density of lead is 11,35 g/cm3’ and the density of silver is 10.5 g/cm3. These densities, along with the densities of all other elements and many other materials can be found in a table of physical properties in any chemistry text or handbook of physics and chemistry.

If we know the mass and volume of any object, we can compute its density. Density = mass/volume (D M/V). Once again, water becomes the standard. We know that 1 cm of water has a mass of 1 gram. It follows that the density of water will then be 1 gram/1 cm ^{3} = 1 g/cm ^{3} . Density expressed in grams per cubic centimeter is also called specific gravity.

The following 5 examples of density problems have been completed using our problem solving method.

Example 1 Find the density of sulfuric acid if 15 cm ^{3} has a mass of 27.6 g.

Step 1	Unknown density of sulfuric acid data V = 15 cm ^{3} M = 27.6 g
Step 2	To find density, we must divide the mass by the volume. We have the necessary data for this.
Step 3	Mass = 27.6 g Volume = 15 cm ^{3}
	D = M/V = 27.6g / 15 cm ^{3} = 1.84 g/cm ^{3}
Step 4	In our formula correct? Did we substitute correct numbers? Is our arithmetic correct? Have we handled units correctly? If we can answer yes to all these questions, then our problem is complete.

Example 2 Find the density of a block of metal which is 16 mm long, 12 mm wide and 5 cm high. The mass of this block is 108960 mg.

Step 1	unknown density of block	
	data mass = 108960 mg	length = 16mm
	width = 12 mm	height 5 cm
Step 2	We know that to find our density we want the mass in grams and the volume in cubic centimeters.	

We have been given the mass, but the unit is milligrams.

We will need to convert these to grams . There are 1000 mg in each gram, so we must divide the number of mg by 1000.

We have not been given the volume. We do, however have the necessary data to compute the volume.

If we look at the units given, we will note that some are mm and some are cm. We will need to convert all these measurements to cm and compute the volume using the formula A = L, x W x H

The final step will be to compute density using D=M/V.

Step 3

(figure available in print form)

Step 4 Check all calculations as in example 1.

Example 3 Find the mass in grams of a bar of silver 6 cm long, 10 cm wide and 4 cm high. Silver has a density of 10.5 g/cm ^{3}

Step 1	unknown the mass of silver bar
	data D = 10.5 g/cm ^{3} L = 6 cm W = 10 cm H= 4 cm
Step 2	Density tells us how much each cm ^{3} of a substance weighs. Therefore, since we know the density, we have only to find out how many cm ^{3} we have (volume) and to multiply the volume by the density. M=D x V We have not been given the volume, but we have the necessary measurements to compute it.
Step3	Volume = L x W x H = 6 cm x 10 cm x 4 cm = 240 cm ^{3}
	Mass= D x V = (10.5 g/cm ^{3}) (240 cm3) = 2520 g.
Step 4	Check all calculations.

In all density problems, only three quantities are needed, mass, volume and density. I feel it is very important to spend some time with the students in discovering how these quantities are interrelated, in the hope that they will be able to see other similar relationships in other types of problems as the course progresses. This should prove much more valuable than simply providing formulas for them to use.

In problems 1 and 2 we were given mass and volume and asked to find density. We find we can use the formula D= M/V in all problems of this type. In problem 3 we were given the density and volume, and asked to find the mass. We find the formula M= V x D will solve problems of this type. The only way a problem involving density could be presented would be to give us the density and the mass, and ask us to find the volume. Let us demonstrate a problem of this type.

Example 4 Find the volume of a container necessary to hold 200 g of mercury. The density of mercury is 13.55 g/cm ^{3} .

Step 1	unknown volume of mercury
	data m = 200 g D =13.55 g/cm ^{3}
Step 2	Density tells us that each cm3 weighs 13.55 g.
	We have 200 g. We need to find out how many 13.55 g units are contained in our 200 g. V = M/D
Step 3	D = 13.55 g/cm3

(figure available in print form)

We now have reasoned out three formulas which we can use to solve any conceivable density problem, once we understand our problem. D = M/V V = M/D M = D x V

The learners should now be led to see that once we have derived any one of the formulas used to solve density problems, it is then only a matter of simple manipulation to get the other two. If D= M/V than M = D x V and V = M/D. This type of relationship will be encountered many times throughout the duration of the chemistry course.

Our young problem solver should now be ready to use his knowledge of density to solve a problem of slightly more complexity, involving an equation with one unknown quantity. Simple equations with one unknown should be reviewed here as they too will be used again and again during the year.

Example 5 We have 500 cubic centimeters of a liquid which has a mass of 2000 grams. How much water must be added to this liquid if we want to obtain a mixture with a density of 2 grams per cubic centimeter.

Step 1	unknown volume of water to be added
	data V of liquid = 500 cm3 Mass of liquid = 2000 g
Step 2	The density of water is 1 gram per cubic centimeter. This tells us that for every cubic cm of water we add, the mass will increase by one gram. We know that our final density will be 2 g/cm3. If we call our unknown quantity of water "x", then our new mass will be 2000 + x grams and our new volume will be 500 + x cm ^{3} . D = M/V, therefore we can say

(figure available in print form)

Step 3	v of liquid = 500 cm ^{3} M of liquid = 2000 g
	Density of mixture = 2 g/cm ^{3} Density water = 1 g/cm ^{3}
	Let quantity of water to be added x

(figure available in print form)

Our new mass will now be 2000 + 1000 = 3000 g

Our new volume will now be 500 + 1000 = 1500 cm ^{3}

Step 4 In this case, we can check our answer by computing the density of our new quantities.

(figure available in print form)

It would appear from this that our problem has been solved correctly.

We needed to add 1000 grams of water (1 liter) to the liquid to bring the density to 2 g/cm ^{3}

The following list of problems of increasing difficulty are suggested as types for the student to solve. More than one of each type should be assigned. As much attention should be paid to the students method of solving the problem as to his answer.

Suggested problems (answers in parentheses)

1. Find the density of ice if 10 cubic centimeters weighs nine grams. (.9 g/cm ^{3})

2, 72 cubic centimeters of alcohol weighs 57.6 grams. Find its density. (O.8 g/cm ^{3})

3. What is the mass of a 8 centimeter cube which has a density of 0.67 g/cm ^{3} ? (343.03 g)
4. Find the mass of a cylinder of aluminum that has a radius of 3 centimeters and is 10 centimeters high. The density of aluminum is 2.7 g/cm ^{3} . (763.02 g)

5. Find the volume of 130 grams of nickel. The specific gravity of nickel is 8.9. (14.61 cm^3)
6. A 22.4 liter container full of sea water has a mass of 25.96 kilograms. The empty container weighs 3 kilograms. Find the density of sea water. (1.024 g/cm^3)
7. A tube which has a diameter of 20 centimeters and is 30 centimeters high, is half full of a liquid. If the empty tube weighs 34 grams and the density of the liquid is 2.2 g/cm^3, what is the total mass of the tube and its contents? (10,396 g)
8. We have 27 kilograms of a liquid whose density is 1.21 g/cm^3. How many cubic cm of another liquid with a density of .87 g/cm^3 would be have to be added to bring the total weight to 35 kilograms? (9195 cm^3)
9. What would be the density of the resulting solution if 1 liter of water was added to 1000 grams of a liquid which has a density of 3 g/cm^3? (2 g/cm^3)
10. Liquid "A" has a density of 3 g/cm^3 and liquid "B" has a density of 2 g/cm^3. Given 1500 grams of liquid "A", how many grams of liquid "B" would have to be added to it to obtain a mixture of a density 2.4 g/cm^3? (1500 grams)

We should now familiarize the students with the use of lab equipment and lab safety procedures. He should be taught to read the triple beam balance with accuracy, and to read the scale on a graduated cylinder, noting the meniscus. This can best be accomplished by weighing and measuring a rarity of materials.

It is also necessary to review percentages with the class. While the following presentation may seem very elementary, I have found that a little time spent now saves a great many problems later on.

The word percent (%) means "out of 100". To find what percent any part is of its whole, we must first make a fraction and then multiply it by 100.

For example, suppose we have a pie cut in 4 equal pieces. If two are eaten, what percent is gone? 2 out of a possible 4 are gone, or 2/4. The percent would be 2/4 x 100 = 50%. Similarly, if we had eaten 3 pieces, we would have had 3 out of 4 gone, or 3/4 x 100 = 75%.

In chemistry labs it is usually necessary to check our results against some standard. We do this by computing percentage of error. This means, how many part per hundred are we off from the correct or accepted result.

Example: We are given a chain of pure aluminum. We are asked to find its density experimentally, using only a balance, a graduated cylinder and water. We are then asked to cheek our results against the accepted density of aluminum, 2.7 g/cm^3.

First, we must solve our problem finding the density in the

let

Step 1	Unknown density of chain
	In order to find density, we know we must have mass and volume because D= M/V. We can easily find the mass by weighing our chain on the balance. We can find the volume of the chain by displacement of water in a graduated cylinder.
Step 2	Because 1 ml of water is the same as 1 cm3, if we drop a chain in a cylinder partly filled with water, the volume of the chain will be the difference between the beginning volume in the cylinder and the final reading. Once we have these facts we can easily compute our density.
Step 3	Mass of chain = 85.7 g
	Volume of chain = initial level of water = 25 m1 Final level of water chain= 58.2 m1 chain 58.2 25 = 33.2 ml (33.2 cm ^{3})

(figure available in print form)

Step 4	Is our method logical? Are our measurements correct? Have we handled units correctly? Can we verify our calculations’

Knowing that the correct or accepted density of aluminum is 2.7 g/cm ^{3} , we can now calculate our percentage of error. First, we must know what our error is. This will be the difference between our accepted value and our experimental value. In this case, the accepted density was 2.7 g/cm3 and our experimental findings were 2.58 g/cm ^{3} . Our error will be as follows 2.7 g/cm ^{3} 2.58 g/cm ^{3} = .12 g/cm ^{3} .

We were in error .12 parts of a possible 2.7, or .12/2.7. Now to make this fraction a percent, we multiply by 100. % error=.12 x 100 = 4.44%.

2.7

We can generalize this, and use the following formula for all percent of error calculations.

Error = accepted value experimental value

(figure available in print form)

Activity Density.

Students should be given several cylinders and blocks of known density. They should calculate the density using careful measurements and calculations and al80 by displacement of water for volume. They should then be asked to compute the percentage of error between their density and the accepted density.

Students will also find it interesting to try to identify objects of unknown metal by finding their density in the lab and using a density or specific gravity table. An abbreviated table will be found at the conclusion of this unit.

Temperature and Heat

Just as density is one property by which we can identify substances, specific heat is another. Temperature and heat are not the same thing. Most students will think the terms are interchangeable. Temperature is a measure of how hot or cold something is, not how much heat energy it contains. Heat tends to be transferred from one object to another until the object and its surroundings are the same temperature.

Scientists measure temperature on the Celsius scale. 0° C. is the freezing point of water. 100° C. is the boiling point of water. The interval between freezing and boiling is divided into 100 equal parts called Celsius degrees.

Heat is measured in units called calories. A calorie is the amount of heat required to raise the temperature of 1 cm3 of water 1° C.

The specific heat of a substance is the number of calories needed to raise the temperature of 1 gram of that substance 1° C. Therefore, the specific heat of water would be 1 calorie. Using this information we should now be able to solve problems involving calories and specific heat. Once again, two or three problems such as the examples which follow, should be worked through in class with the students before assigning a number of problems for them to solve alone.

Example 1	How many calories are required to raise the temperature of 10 grams of water from the freezing point to the boiling point.
Step 1	unknown calories required
	data substance is water, therefore freezing point (f.p.) is 0° C. and boiling point (b.p.) is 100° C.
	Mass of water 10 grams.
Step 2	To compute the number of calories needed to raise a given amount of any substance a specified number of degrees, we need to know how much it takes to raise 1 gram of the substance 1 degree, or the specific heat. We know that the specific heat of water is 1 calorie. We are given the mass of the water (10 grams). We can calculate the change in temperature. The Greek letter delta is used to symbolize “a change in”, and t denotes temperature.

(figure available in print form)

We can reason that if 1 calorie (c) will raise the temperature of 1 gram by 1 degree, then it would take 100 calories to raise the temperature of one gram by 100 degrees, In our problem however, we do not have just one gram, we have 10. It will then be necessary to multiply the number of calories it takes to raise one gram the specified number of degrees by the number of grams that are involved.

The following formula should do these things calories = t x specific heat x mass in grams

Step 3	Substance water	Specific heat 1 c/g mass 10 grams initial t = 0° C final t =100° C.
	t = final t initial t = 100 ° C 0° C = 100 0 C.	
	calories =	t x specific heat x mass
		= 100 x 1 c/g x 10 g
		= 1000 c
Step 4	Check our work	

Example 2 If adding 1000 calories to 500 grams of a given substance raises its temperature from 28 C. to 32 C., what is the specific heat of that substance?

Step 1	unknown specific heat	
	data mass = 500 grams	calories = 1000
	initial t = 28° C	final t = 32° C.
Step 2	We know that specific heat is the number of calories required to raise the temperature of 1 gram of the substance by 1 degree. If we know how many grams we have and how many calories were added, we can compute how many calories were added per gram by dividing the number of calories by the number of grams. In this case it would be 1000 c / 500 g = 2 c/g. Adding these 2 calories per gram changed the temperature from 28° to 32°, or 4°. If 2 calories will change the temperature by 4 degrees, then 1/4th of 2 calories should change the temperature by 1 degree. We now have a formula to solve our problem, or any other like it.	

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Step 3

(figure available in print form)

Problems (answers in parentheses)

1. How many calories would be needed to raise the temperature of 750 grams of water from 4° C. to 81° C? (57750 c)
2. How many calories would change the temperature of 300 grams of a metal with a specific heat of .63 calories from 2¼ C to 43¼C (8505 c)
3. Find the specific heat of a cylinder whose mass is 740 grams, if the addition of 600 calories raises the temperature from 10° C to 11.5¼ C. (.54 calories)
4. What is the mass of a piece of metal if its specific heat is .88 calories and the addition of 1000 calories raises the temperature from 10° C to 25° C. (75.76 g)

This section should be completed by asking the students to experimentally determine the specific heat of samples of aluminum, copper, iron and lead. An outline for this lab procedure is attached, along with an abbreviated table of the physical properties of some common metals. Samples of these metals should be readily available in any high school physics or chemistry lab.

As we complete this unit, it is hoped that both teacher and student will have established a pattern that can be used as each new concept is introduced during the year. We should have now reviewed all the mathematics necessary for a high school chemistry course, and the repeated need to use this math should make further review, as such, unnecessary.

Experiment The specific heat of metals.

Purpose: To measure and compare the specific heats of several metals and to compute the experimental percent of error. The following materials will be necessary to complete the experiment: samples of A1, Cu, Fe, and Pb; balance: beakers (2 250 ml); bunsen burner; graduated cylinder (100 ml); paper towels; ring stand and ring; thermometer; utility clamp; wire gauze.

Procedure : The following method is to be used to measure the specific heat of each of the four samples given.

1, The mass of the metal sample should be determined to the nearest mg using the balance.
2. The metal should be suspended from a strong piece of thread hanging from the clamp above a 250 ml beaker half full of water. The clamp should then be lowered until the metal is completed submerged in the water, but does not touch the bottom. The clamp is also used to support the thermometer. The apparatus is shown in diagram 1 following this experiment.
3. Allow the water to come to a boil and keep it boiling until the metal is removed. Record the temperature of the boiling water.
4. Carefully measure out 100 ml of water in your graduated cylinder. Pour the water into the second 250 ml beaker, which should be carefully placed on a folded paper towel to insulate the beaker from the lab table. Since we know that 1 ml of water has a mass of 1 gram, we can safely assume that the mass of our water is 100 grams.
5. Carefully record the temperature of the 100 grams of water, carefully reading the thermometer to the closest .1 degree.
6. Quickly transfer the metal from the boiling water to the water in the second beaker.
7. Being very careful not to break the thermometer, stir the water around the metal and record the temperature to the nearest O.1 degree, as soon as the temperature stops rising.
8. Repeat this procedure with each of the 3 other samples.

The following table for the recording of data should be prepared before the experiment is begun. The data will need to be recorded four times, once for each type of metal.

Data Table

1. type of metal _________

2. mass of metal ____

3. t of boiling water and metal _________
4, mass of cool water ________
5. initial t of cool water ______

6. final t of cool water and metal ___
7. t. gain of cool water _________(final t of cool water and meta1 minus the initial t of cool water)
8. t loss of metal ___ (t of boiling water and metal minus final t of cool water and metal)

Calculations

1. We know the specific heat of water is 1 c/g. This allows us to calculate the total heat gained or lost by any mass of water undergoing heat change as calories = m x t
2. All heat lost by the metal should be gained by the water if we are careful to insulate the beaker so that other heat transfer will not occur. Since we have insulated our beaker with a paper towel, which does not conduct heat, we can safely use the formula specific heat =
(figure available in print form)
3. Compare the experiential specific heat with the accepted specific heat. (found in the following table of properties of common metals). Compute the percent of error in each case.

(figure available in print form)

BIBLIOGRAPHY

Because the students involved are senior high school students, and due to the nature of the subject, the following books are suitable for both student and teacher.

Bickel, Eigenfeld, Hogg. *Physical Science Investigations,* Houghton, Mifflin, Boston, 1973. This is a fairly elementary physical science book which treats the physical properties of matter, and which should be particularly helpful to the student who is having difficulty understanding the concepts involved.

Handbook of Physics and Chemistry An invaluable aid for both teacher and student in dealing with the physical sciences.

Metcalfe, Williams and Castka, *Exercises and Experiments in* Chemistry. Holt, Rinehard and Winston, New York, 1978. An excellent collection of experiments, problems and exercises relating to all phases of a high school chemistry program.

Metcalfe, Williams and Castka, *Modern Chemistry* . Holt, Rinehart and Winston, 1978. While no text is perfect, this book presents the most logical sequence of material in the clearest manner of an, that I have encountered. Both the student and the teachers' edition are exceptional.

Norse, Dr. Alan E. , Universe, Earth and Atom. *Harper and Row, New York, 1969. This is a readable, fascinating prose book about the* *how and why of things in the physical world. It is written in clear and non technical language and contains many interesting bits of information for both student and educator.*

Oberkrieser, Joseph V. *Chemica1 Arithmetic. D. Van Nostrand Co. Inc., 1962. This is a collection of problems from all phases of high school chemistry. The teacher should find it to be an extremely good source of problems. Step by step solutions are given, and answers to all problems are provided. They progress from easy to more difficult.*

Peterson, John M. Finite Mathematics *. Holt, Rinehart and Winston, New York, 1974. This treatment of logic, sets and probabilities will be more of interest to the teacher as background, than to the student. However, students may find the section on logic interesting, and it would certainly be helpful for them.*

Polya, G., How to Solve It. Princeton University Press, Princeton, 1973. This book should be a "must read" for all teachers and would be very helpful to the more advanced students. It includes a clear, reasonable method for solving problems, gives many examples from the point of view of both teacher and student, and presents problems that are challenging and fun to solve.

Slabaugh and Butler, *College Physical Science.* Prentice Hall, New Jersey, 1973. Intended as a text for the non science major in college, It presents an integrated approach to physical science and keeps the mathematics on a simple level. I have found it very helpful in obtaining ideas on how to present material.

Thomas and Thomas, *Finite Mathematics* , Allyn and Bacon, Boston, 1973. Very similar to the Peterson book mentioned above, in its treatment of logic, sets and probability.

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