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How Do You Know? Let's Try With Math

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How Do You Know? Let's Try With Math can be used as a main text for preparatory courses or as a supplement to a core textbook in survey and general chemistry courses. Many students needing help apart from the classroom in chemistry may find How Do You Know? Let's Try With Math, useful as a self-paced learning guide. How Do You Know? Let's Try With Math, take a look at chemistry and mathematics. Its purpose is to teach students the basic concepts of chemistry and problem solving techniques. Teachers and Students need not have a science background or extensive math skills to use this curriculum. Most calculations in chemistry involve only simply algebra. There are two basic approaches for solving these equations. The first is the use of the factor-label method to convert information from one set of units into another. Second is the use of a memorized equation or law into which data for all variables except one are inserted. The one remaining variable is the unknown for the problem. Correct use of the second approach also requires that all unites be shown to ensure that they cancel properly to yield the desired units for the numerical answer.

Scientific calculators simplify mathematical operations to the touch of a few keys. Understanding the principles and concepts of chemistry enables us to decide in which order to press those keys. Understanding numbers tells us how to properly interpret the answer that appears on the calculator screen. See (Data Analysis and Statistical Approach to the Equation of Line)

Accuracy and Precision

The accuracy of a measurement refers to the closeness between the measurement obtained and the true value. Since scientists rarely know the true value, it is generally impossible to determine the accuracy completely. One approach to evaluating accuracy is to make a measurement by two completely independent methods. If the results from independent measurements agree, scientists have more confidence in the accuracy of their results.

Accuracy is affected by determinate errors, that is, errors due to poor technique or incorrectly calibrated instruments. Careful evaluation of an experiment may eliminate determinate errors.

Precision refers to the closeness of repeated measurements to each other. If the mass of an object is determined as 35.43 grams, 35.41 grams, and 35.44 grams in three measurements, the result may be considered precise because they differ only in the last of the four digits. There is no guarantee that they are accurate, however, unless the balance was properly calibrated and the correct methods were used in weighing the object. With proper techniques, precise results infer, but do not guarantee, accurate results.

Precision is affected by indeterminate errors, that is, errors that arise in estimating the last, uncertain digit of a measurement. Indeterminate errors are random errors and cannot be eliminated. Statistical analysis deals with the theory of random errors.

Significant Figures

Every experimental measurement is made in such a way as to obtain the most information possible from whatever instrument is used. As a result, measurements involve numbers in which the last digit is uncertain, Scientists characterize a measured number based on the number of significant figures it contains.

The number of significant figures in a measurement includes all digits in that number from the first nonzero digit on the left to the last digit on the right. For exponential numbers, the number of significant figures is determined from the digits to the left of the multiplication sign. Thus, 3.456 X 104 has four significant figures.

Sometimes there are trailing zeros on the right side of a number. If the number contains a decimal point, trailing zeros are always significant. Trailing zeros that are used to complete a number, however, may or may not be significant. Scientists avoid writing a number such as 12,000 since it does not definitely indicate the number of significant figures. Scientific notation is used instead. Twelve thousand can be written as 1.2 X 104, indicating two, three, four and five significant figures, respectively. It is the responsibility of the experimenter to write numbers in such a way that there is not ambiguity.

Some numbers are exact numbers, which involve no uncertainty. The number of plates set on a table for dinner can be determined exactly. If five plates are observed and counted, that measurement is exactly five. In chemistry many defined equalities are exact. For instance, there are exactly 4.184 joules in each calorie and exactly two hydrogen atoms in each water molecule. Other exact numbers are stoichiometri coefficients and subscripts in chemical formulas.

The reason for determining the number of significant figures in a measured value is that this number tells us how to write the answers to calculations based on that value.

Uncertainty

There are two types of uncertainty, absolute uncertainty and relative uncertainty. The absolute uncertainty is the uncertainty of the last digit of a measurement. For example 45.47 milliliters is a measurement of volume, and the last digit is uncertain. The absolute uncertainty is ± 0.01 milliliter. The measurement should be regarded as somewhere between 45.46 and 45.48 milliliters.

The relative uncertainty of a number is found by dividing the absolute uncertainty of the measurement by the number itself. For the above example, the relative uncertainty

0.01 mL/45.47 mL=2 X 10-4

The absolute uncertainty governs the principles used for addition and subtraction. The relative uncertainty governs the principles used for multiplication and division.

Rounding

Calculations, especially those done using an electronic calculator, often generate more, but sometimes fewer, significant figures or decimal places than are required.

These answers must be rounded to the proper number of significant figures or decimal places.

Significant Figures in Atomic and Molar Masses

All of the atomic masses listed in the Periodic Table have four or more significant figures. These are measured values and must be included in the determination of the correct number of significant figures in any calculation that uses them. However, most calculations involve fewer than four significant figures, and the significant figures in atomic and molar masses usually do not affect the number of significant figures in the answers. As a result, atomic and molar masses are often rounded to the nearest whole number. One exception is chlorine, which usually has its atomic mass rounded to 35.5.

Graphs

A graph is used to illustrate the relationship between two variables. Graphs are often a more effective method of communication than tables of data. A graph has two axes: a horizontal axis, called the x-axis (abscissa), and a vertical axis, called the y-axis (ordinate).

It is customary to use the x-axis for the independent variable, and the y-axis for the dependent variable, in an experiment. An independent variable is one that the experimenter selects. For instance, the concentrations of standard solutions that a chemist prepares are independent variables since any concentrations may be chosen. The dependent variable is a measured property of the independent variable. For instance, the dependent variable may be the amount of light that each of the standard solutions prepared by the chemist absorbs, since the absorbed light is dependent of the concentration. Each data point is xy pair representing the value of the independent variable and the value of the dependent variable determined in the experiment.

The first step in constructing a graph is to label the x and y axes to indicate the identity of the independent and dependent variables. Next, the axes are numbered, usually from zero to the largest value expected for each variable. Finally, each data point is plotted by drawing a horizontal line at the value of the independent variable. The intersection of these two line determines where that data point belongs on the graph as shown below.

(figure available in print form)

Most graphs show a linear relationship between tow variables. Others, such as kinetic curves, have curved lines. In both cases, data points are plotted on the graph and then the best smooth line is drawn through the pints. Lines are never drawn by connecting the data points with straight lines. In very accurate work a statistical analysis called the method of least squares is used to determine the best straight line for the data. In most cases, however, the line is drawn by eye,attempting to have all data points as close as possible to the line. The usual results is a line that has the same number of data points above and below.

(figure available in print form)

The graph illustrates that it is incorrect to draw any line below the measured data points. The reason is that anything beyond the measured data is unknown. Extending the line implies information that has not been verified by experimental data.

The slope of a curve or line is often needed as an experimental result. To determine the slope of a line, two points on the line are chosen. The left-hand point has coordinates ($x1$, $y1$), and the right-hand point has coordinates ($x2$, $y 2$). The values of x and y at these points are determined from the graph, and the following equation is used to determine the slope:

Slope = $(x2 - x1)/(y2 - y1)$

In a graph with a curved line the slope is determined by drawing a tangent to the curve and then determining the slope of the tangent, as is done for a straight line.

Mathematical Literacy

As society changes, so must the school. How can we as mathematics educators prepare our students for the challenges of the 21st century? One important way is to expand our educational goals to reflect the importance of mathematical literacy. In order for students to become mathematically literate in the 21st century we must:

a. Prepare students for successful work lives in a changing society.
b. Equip students with reasoning tools they need as good citizens.
c. Develop students personal capacities to enjoy and appreciate mathematics.

Only then will students attain the mathematical literacy needed in a world where mathematics is rapidly growing and being applied to many diverse fields.

To address the growing concern about mathematical literacy, the National council of Teachers of Mathematics has recommended fundamental changes in the teaching and learning of mathematics. Its Curriculum and Evaluation Standards for School Mathematics calls for students to gain mathematical power, which is a student's ability "to explore, conjecture, and reason logically." (p.5) Most mathematics educators agree that mathematical power must be the central concern of mathematics education. Many state department of education are also calling for mathematics reform.

According to the Mathematics Framework for California Public School, "Mathematically powerful students think and communicate, drawing on mathematical ideas and using mathematical tools and techniques." (p.3)

In addition to the four dimensions of mathematical power, students are expected to work both individually and cooperatively, to appreciate mathematics in history and society, and to develop positive attitudes toward mathematics. Because society is demanding mathematical power from all citizens, it must be available for all students. Let's examine mathematical power in more detail.

1. Think refers to higher-order thinking skills such as classifying, analyzing, planning, comparing, conjecturing, deducing, inferring, hypothesizing, a synthesizing. These are characterized in the reasoning, problem solving, and connections standards in the NCTM standards.

2. Communication refers to the verbal or written expression of understanding. As students work, they

communicate their understanding to themselves and others.

3. Ideas refer to the mathematical content. These are concepts such as proportional relationships, geometry, logic, and so on.

4. Tools and Techniques refer to literal tools, such as calculators, computers, and manipulative, and also figurative tools, such as computational procedures and mathematical representations.

Cooperation is necessary for full-time participation in society. It is relevant on a large scale, as nations interact with each other, and on a small scale, where individuals relate to their neighbors and their families. Cooperation is expected of workers in the workplace and of citizens in a democracy. IN our society, the diversity of our population dictates that individuals must be willing to work with people who differ from themselves. As part of society, our classrooms may be composed of students from many different cultural, ethnic, and language backgrounds. Regardless of their differences, all students must learn to cooperate for the common good.

Cooperative learning involves a small group of learners, working together as a team to accomplish a common goal. According to the NCTM standards, the goal should be to solve meaningful problems. Cooperative learning provides a structure in which students are given more responsibility for their own learning, while the teacher's responsibility shifts from the giver of knowledge to that of a facilitator or mentor.

Cooperative learning is not having students sit together in groups and work on problems individually. It is not having one student in the group do all the work while the other students listen. Teamwork is the key to effective cooperative learning. (See Good Decisions Through Teamwork Appendix)

Learning is an active process that is both and individual and a special experience. According to Judah L. Schwartz, professor of education at HGSE "learning takes place in the minds of the individual learners when they make connections to what they already know." Constructivist learning is enhanced by cooperative learning. An important component of cooperative learning is the communication that occurs among group members. According to the standards, "Small groups provide a forum in which students ask questions, discuss ideas, make mistakes, learn to listen to other ideas, offer constructive criticism, and summarize their discoveries in writing." (p. 79) These are valuable activities because they allow students to help each other make connections and discover their own meanings. Small groups are safe; students can take risks and make mistakes. Students have more chances to communicate, and feel more comfortable doing so, in small groups than in whole-class discussions. When students work in cooperative groups, they receive encouragement from their peers in their efforts to learn mathematical processes and concepts.

Another aspect of cooperative learning is that students create their own meaning when they are given many opportunities to experience and do mathematics through exploration. "This happens most readily when students work in groups, engage in discussion, make presentations, and in other ways in discussion, make presentations, and in other ways take charge of their own learning." (Everybody Counts, p.59) How do you know? Let's try with Math supports the strategy of cooperative learning.

How to Graph Scientific Data

Graphs are a useful tool for displaying scientific data because they show relationships among variables in a compact, visual form. You probably know how to make and interpret several types of graphs such as pie charts and bar graphs (or histograms). You may have also use X-Y graphs (or Cartesian graphs) in our math classes. However, you may not know how to use X-Y graphs to display experimental data in chemistry laboratory work.

The following guidelines will help

1. Determine the independent variable

-Determine which of the quantities that you will graphing is the independent variable and which are the dependent variable. The independent variable, denoted as x, is the variable whose values are chosen by the experimenter. The independent variable is plotted on the horizontal axis of the dependent variable are determined by the independent variable.

-For example, the data shown in the table to the left was gathered in an experiment in which the temperature of a gas was increased and the resulting volume increase was measured. In this case, temperature was the independent variable and volume was the dependent variable. In the graph for this experiment, temperature is plotted on the horizontal axis and volume is plotted not he vertical axis.

2. Scale of axes

-Each axis must have a scale with equal divisions.

-Allow as much room as possible between divisions.

-Each division must represent a whole number of units of the variable being plotted such as 1, 2, 5, 10 or some multiple of these. To decide which multiple to use for the horizontal axis, divide the maximum value of the independent variable by the number of major divisions on your graph paper. For example, Graph A,in the Appendix, shows 10 divisions along the grid on the horizontal axis. The data used to plot the curve for Graph A is shown in the Appendix. The maximum value of T is 480 K. divide the number of divisions into the maximum value of the variable to get 48 K/10 divisions or 48 K per division. To simplify, round up to allow 50 K per division on the horizontal axis.

-To scale the vertical axis follow the same procedure. The maximum value of the dependent variable, V, is 4L. The grid allows for 6 divisions. Round up to allow 1.0 L per division. Then there will be 2 divisions left over on the top of the vertical axis. Check Graph A to see how this looks.

-Label each axis with the quantity to be plotted and the units used to express each measurement. For example, the axes of Graph A are Volume (L) and Temperature (K.)

3. Plot the data

-Plot each data point by locating the proper coordinates for the ordered pair on the graph grid. If the data points look as they fall roughly on a straight line, use a transparent ruler to find the line of best fit for the data points. Draw the best-fit line through or between the points.

-If the data points clearly do not fall along a straight line, but appear to fit another smooth curve, lightly sketch in the smooth curve that connects the points.

-Once you have sketched a smooth curve, draw over it in ink.

4. Title your graph

-Title your graph to indicate the x and y variables. If you can also tell how the variables relate to one another without making the title too long, include this information. For example, "Volume Versus Temperature Change in a Gas" is a suitable title for Graph A. Write the title at the top of the graph.

5. Interpret your graph

-If your data points lie roughly along a straight line, the x and y variables have a linear relationship or are directly proportional. This means that as one variable increase, the other does too, in a constant proportion -- as x doubles, y doubles; as x triples, y triples; etc. Directly proportional quantities, x and y, relate to one another through mathematical equations of the form y = mx + b, where m is a constant and b is zero. The equation for the directly proportional linear relationship shown in Graph A is V=kT. Here, m= k and b= 0.

-If your data points lie along a curve that drops from left to right as shown in Graph B, then the quantities have an inverse relationship or are inversely proportional. In an inverse relationship, one quantity increases as the other decreases. Graph B shows that gas pressure and volume decreases. The mathematical relationship that expresses an inverse relationship is y=1/x. The expression relating gas pressure and volume follows the form PV = k. Note that inverse relationships are nonlinear because the increase of one variable is not accompanied by a constant rate of decrease in the other variable.

6. Use your graph

-Straight-line graphs are the easiest graphs to analyze and to express as equations. More complex graphs illustrate inversely proportional, exponential, or logarithmic relationships. It is often useful to replot a nonlinear graph to obtain a straight-line graph.

Graph C shows the inverse relationship PV = k replotted as a straight line. To obtain this graph, both sides of the equation PV = k were divided by P.

[PV/P=k/P]=[V=k*1/P]

The resulting equation, V = k * 1/P, has the same form as y = mx, which if plotted would produce a straight line that passes through the origin. To plot the actual data, the pressure values in the table must be converted to 1/P values. The fit pressure conversion is as follows.

1/0.100 = 10.0

V is plotted on the y axis and 1/P is plotted on the x axis.

How to Use Significant Figures and Scientific Notation

Scientists use significant figures to report information about the certainty of measurements and calculations. With this method, a measurement of 2.25 m means that while the 2 in the ones place and the 2 in the tenths place are certain, the 5 in the hundredth's place is an estimate. If this measurement is combined with several other measurements in a formula, there must be some way of tracking the amount of uncertainty in each measurement and in the final result. For example, using a calculator to find the volume of a cube that measures 2.25 m on a side, you get 11.390625 m3. This answer indicates far grater precision in the volume measurement than is realistic. Remember that the 5 in 2.25 is an estimated digit.

The rules and examples that follow will show you how to work with the uncertainty in measurements to express your results with an appropriate level of precision.

1. Determining the number of significant figures

The first set of rules shows you how to look at a measurement to determine the number of significant figures. A measurement expressed to the appropriate number of significant figure includes all digits that are certain and one digit in the measurement that is uncertain.

Rules for Determining the number of Significant Figures

Rule

The following are always significant

-All nonzero digits

-All zeros between nonzero digits

-Zeros to the right of a nonzero digit and left of a written

-Zeros to the right of a non-zero digit and right of a written decimal point

Example

673 has three, 2.8 has two

506 has three, 1.009 has four

34800. mL has five, 200. cm has three

4.0 kg has two, 57.50 K has four

2.90 x 103 has three

The following are never significant

Rule

-Zeros to the left of the decimal point in numbers less than one

-Zeros to the right of a decimal point, but to the left of the first non-zero digit

Example

0.984 kg has three, 0.6 has one

0.067 has two, 0.004 has one

Exceptions to the rules

Rule

Exact conversion factors are understood to have an unlimited number of significant figures

Counting numbers are understood to have an unlimited number of significant figures
Example

By definition there are exactly 100 cm in 1 m so the conversion factor 100 cm/1 m is understood to have an unlimited number of significant figures

There are exactly 30 days in June, not 30.1 or 20.005, so an unlimited number of significant figures is understood in the expression "30 days"

2. Calculating with significant figures

When measurements are used in calculations, you must apply the rules regarding significant figures so that your results reflect the number of significant figures of the measurements.

Rules for Making Calculations with Significant Figures

Rule
Addition and subtraction
The answer must be rounded so that it contains the same number of significant figures to the right of the decimal point as there are in the measurement with the smallest number of digits to the right of the decimal point.

Example

2.89 m + 0.00043 m

= 2.89043 m

= 2.89 m

Rule
Multiplication

The product or quotient should be rounded off to the same number of significant figures as the measurement with the fewest number of significant figures.

Example

3.5293 mol x 34.2 g/mol

= 120.70206 g

= 121 g

3. Rounding answer to get the correct number of significant figures

To obtain the correct number of significant figure in a measurement or calculation, numbers must often be rounded.

Rules for Rounding

Rule

If the digit immediately to the right of the last significant figure you want to retain is:

Greater than 5, increase the digit by 1.

Less than 5, do not change the last digit.

5, followed by non-zero digit(s), increase the last digit by 1.

5, not followed by a non-zero digit and preceded by odd digit(s), increase the last digit by 1.

5, not followed by non-zero digit(s), and the preceding significant digit is even, do not change the last digit.

Example

56.87 g ® 56.9 g

12.02 L ® 12.0 L

3.7851 ® 3.79

2.835 s ® 2.84 s

2.65 mL ® 2.6 mL

4. Expressing numbers in scientific notation

Measurements made in chemistry often involve very large or small numbers. To express these numbers conveniently, scientific notation is used. In scientific notation, numbers are expressed in terms of their order or magnitude. For example, 54,000 can be expressed 5.4 X 104 in scientific notation, and the number 0.000008765 can be expressed as 8.765 X106.

As the preceding examples show, each value expressed in scientific notation has two parts. The first factor is always between 1 and 10, but it may have any number of digits. To write the first factor of the number, move the decimal point to the right or left sot that there is only one nonzero digit tot he left of it. The second factor of the number is written raised to an exponent of 10 that is determined by counting the number of places the decimal point must be moved. If the decimal point is moved to the left, the exponent is positive. If the decimal point is moved to the right, the exponent is negative.

Rules for Calculations with Numbers in Scientific Notation

Rule

Addition and Subtraction

All values must have the same exponent before they can be added or subtracted. The result is the sum or difference of the fist factors all with the same exponent of 10.

Example

4.5 X 106- 2.3 X 105 =

45 X 105 - 2.3 X 105

= 42.7 X 105

= 4.3 X 106

Rule

Multiplication

The first factors of the numbers are multiplied and the exponents of 10 are added.

Example

(3.1 X 103)(5.01 X 104) =

(3.1 X 5.01)X 104+3

=16 X 107 = 1.6 X 108

Rule

Division

The first factors of the number are divided, and the exponent of 10 in the denominator is subtracted from the exponent of 10 in the numerator.

Example

7.63 X 103/8.6203 X 104

= 7.63 X 103-4/8.6203

= 0.885 X 10-1

= 8.85 X 10-2

5. Expressing significant figures using scientific notation

Using scientific notation along with significant figures is especially useful for measurements such as 200 L, 2560 m, or 10 000 kg, because it is unclear which zeros are significant.

Rules for Expressing Scientific Notation with Significant Figures

Rule

Use scientific notation to eliminate all placeholding zeros. Convert the number to scientific notation and eliminate zeros before an unwritten decimal point that are not significant figures.

Example

2400®2.4 X 104 (if both zeros are not significant)

600®6.0 X 102 (if only one zero is significant)

750000®7.5000 X 105(if all zeros are significant)

Significant figures and scientific notation

1. How many significant figures are there in these expressions?

a. 470 km b. 0.0980m c. 30.8900g

d. 0.09709 kg e. 1000 g/1 kg f. 4.870 X 105

2. Perform the following calculations and express the answers in significant figures.

a. 32.89 g + 14.21 g b. 34.09 L - 1.230 L c 100 m + 0.7 m

d. 1.8940 cm X 0.0651 cm e. 24.897mi/0.8700 h f. 111.0 in X 1.020 in

3. Perform the following calculations.

a. (8.369 X 103 + 4.58 X 102 - 6.30 X 103)/4.156 X 107

b. (6.499 X 102)(5.915 X 104+ 3.4733 X 105)

c. (7.23780 X 10-3 - 3.65 X 10-5)(3.6792 X 102 + 2.67)

d. (2.1267 X 10-5)(3.3456 X 10-2 - 0.012)/(2.6 X 10-2 - 3.23 X 10-2)

Good Decisions Through Teamwork

Students will use basic concepts of probability and statistics to collect, organize, display and analyze data, simulate and test hypotheses. Good Decisions Through Teamwork will assure that students:

1. Estimate probabilities, predict outcomes and test hypotheses using statistical techniques.

2. Design a sampling experiment, interpret the data, and recognize the role of sampling in statistical claims.

3. Use the law of large numbers to interpret data from a sample of a particular size.

4. Select appropriate measures of central tendency, dispersion and correlation.

5. Design and conduct a statistical experiment and interpret its results.

6. Draw conclusions from data and identify fallacious arguments or claims.

7. Use scatterplots and curve-fitting techniques to interpolate and predict from data.

8. Use relative frequency and probability to represent and solve problems involving uncertainty; and use simulations to estimate probabilities.

Data A **Table of Specific Heats, Petit and Dulong's**

Element	Specific heat (relative to water)	Relative weights of the atoms

Bismuth	0.0288	212.8
Lead	.0293	207.2
Gold	.0298	198.9
Platinum	.0314	178.6
Tin	.0514	117.6
Silver	.0557	108.0
Zinc	.0927	64.5
Tellurium	.0912	64.5
Copper	.0949	63.31
Nickel	.1035	59.0
Iron	.1100	54.27
Cobalt	.1498	39.36
Sulfur	.1880	32.19
	O=16	

Data B **Table of Specific Heats, Petit and Dulong's 1819**

Element	Specific heat (relative to water)	Relative weights of the atoms
Bismuth	0.0288	13.30
Lead	.0293	12.95
Gold	.0298	12.43
Platinum	.0314	11.16
Tin	.0514	7.35
Silver	.0557	6.75
Zinc	.0927	4.03
Tellurium	.0912	4.03
Copper	.0949	3.957
Nickel	.1035	3.69
Iron	.1100	3.392
Cobalt	.1498	2.46
Sulfur	.1880	2.011

1. H2Oº1 specific heat 2. Oº1 atomic mass

Use the products of the weight of each atom multiplied by the corresponding specific heat to find:

1. Mean
2. Standard Deviation
3. Tell how data A and data B vary in positive correlation.
4. Can you find the correlation coefficient.

Graphing

1. Draw a horizontal axis on graph paper that is suitable for plotting the following mass measurements: 20.5 g, 39.7 g, 61.0 g, 92.8 g.

2. Prepare a graph representing the solubilities of potassium nitrate, KNO_3, in water at the following temperatures. From your graph, estimate the solubility of KNO_3 at 65°C and at 105°C.

Temperature (°C)	Solubility (g solute/100 g water)
0	13.9
20	31.6
40	61.3
60	106
80	167
100	245

3. The pressure of 1 mol of ammonia gas was varied and the following volume measurements were made. Temperature was kept constant at 25°C.

Pressure (atm)	Volume (L)
0.100	245
0.200	122
0.400	61.0
0.800	30.4
2.00	12.2
4.00	5.98
8.00	2.92

a. Graph the data recorded in the table above.

b. Do you have an inverse or direct relation?

c. Write the equation that expresses the mathematical relationship between P and V.

d. Replot the data to obtain a straight-line graph. Write the equation that represents the linear relationship shown by your graph.

Table 1 Graph A

Temperature (K)*	Volume(L)*
120	1
240	2
360	3
480	4

* Values specified at standard pressure.

Graph A

Volume Versus Temperature Change in a Gas

(figure available in print form)

Table 2 Graph B

Pressure (atm)*	Volume (L)*
0.100	224
0.200	112
0.400	56.4
0.600	37.3
0.800	28.0
1.00	22.4

* Values specified at constant temperature

Graph B

Volume Versus Temperature Change in a Gas at Constant Temperature

(figure available in print form)

Table 3 Graph C

Pressure (atm)*	1/P (1/atm)	Volume (L)*
0.100	10.0	224
0.200	5.00	112
0.400	2.50	56.0
0.600	1.67	37.3
0.800	1.25	28.0
1.00	1.00	22.4

* Values specified at constant temperature

Volume Versus the Reciprocal of Pressure for a Gas at Constant Temperature

(figure available in print form)

Data Analysis and Statistical Approach to the Equation of Line

Purpose:

The purpose of this activity is to analyze data via statistical methods in order to determine the equation of a line. Given either a point and a slope, or two points, we will derive the equation of the line determined by the data. A brief discussion of linear regression by the least squares method will be included.

Analytic Approach:

> In the real world we are often interested in testing hypotheses and predicting outcomes based on a known data set. For example, we might be interested in studying the relationship between performance, x, on a placement exam taken at the beginning of the semester and grade point average, y, at the conclusion of the semester. If such a relationship can be determined, it will be a useful tool in decision-making processes. One of the simplest relationships between two such variables is a linear equation of the form

$y = ax + b$. given a set of data points we can construct the scatter plot of the ordered pairs, (x,y), and estimate the equation of the line that best fits the data. The points need not lie on the line. It is necessary and sufficient to construct the line for which the sum of the squares of the distances of the data points from the line is minimized. The method by which this line is constructed via estimates for a and b is called the method of least squares.

Consider a set of data consisting of only tow points, (x1, y1) and (x2, y2). The regression line for this data is simply the line that passes through these two points. The slope of the line could be calculated algebraically. The resulting slope could then be substituted for a into the equation y = ax + b, and one of the given points could be substituted for (x, y). We could then solve the only unknown left, b. Although this is not a particularly difficult task to perform, it can become tedious. It is important to recognize that the regression analysis features of the TI calculators can be employed to focus our attention where it belongs, on the analysis of the data, rather than on the mathematical manipulation of numbers and equations in order to produce a solution. Understanding concept takes us beyond number crunching and makes us aware of the importance or recognizing patterns and relationships useful in predicting and correcting estimated data.

The statistics menu on the TI calculators can be found by pressing the

STAT

key. The features of this menu include various functions which are useful in editing lists, making calculations, and performing tests. We will be concerned only with those features that are necessary for graphing a line through two known points. However, the poser of the STAT features on the TI calculators will be quite evident in the examples that follow. It is the intent of this activity to encourage you to explore these features since they will be useful in many real world applications.

TI -83 Graphing Calculator Solution

STAT

Edit Calc Tests

1: Edit...

2: SortA(

3: SortD(

4: ClrList

5: SetUpEditor

STAT 1(:Edit...)

L1 L2 L3 1

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L1(1)=

STAT >

EDIT CALC TESTS

1: 1-Var Stats

2: 2-Var Stats

3: Med-Med

4: LinReg (ax+b)

5: QuadReg

6: CubicReg

7: QuartReg

Bibliography

Aliaga, Martha and Brenda Gunderson: Interactive Statistics, Preliminary Edition. Upper Saddle River, New Jersey: Prentice Hall, 1998 Artist, Alice F. and Claim M. Newman: How to Use Cooperative Learning in the Mathematics Class. Reston, Virginia: National Council of Teachers of Mathematics, 1990. Curriculum and Evaluation Standards for School Mathematics. National Council of Teachers of Mathematics, 1989. Brady, James E. and John R. Holum: Chemistry The Study of Matter and Its Changes. New York, John Wiley & Sons, INC. 1993 California Department of Education. Mathematics Framework for California Public School. Sacramento, California: California Department of Education, 1992 Coxford, Arthur: The Ideas of Algebra, K-12. Reston, Virginia: National Council of Teachers of Mathematics, 1988. Everybody Counts: A Report to the Nation on the Future of Mathematics Education, National Research Council 1989

00

Krantz, Les. What the Odds Are. New York: Harper Collins Publishers. 1992.

McMurry, John and Robert C. Fay: Chemistry, Second Edition. Upper Saddle River, New Jersey: Prentice Hall, 1998 Herr, Ted and Ken Johnson: Problem Solving Strategies: Crossing the River with Dogs. Martin Luther King Jr. Way, Berkeley, California: Key Curriculum Press. 1994. Hopkins, Nigel, J. et al: Go Figure! The Numbers You Need for Everyday Life. Detroit: Visible Ink Press. 1992. Landwhr, James M. and Ann E. Wathings: Exploring Data. Palo Alto, California: Dale Seymore Publications. 1986. Levadi, Barbara et al: Math A Rich Heritage. Upper Saddle River, New Jersey: Globe Fearon Educational Publisher. 1995.