DONALD W. GALLUP

Study Guide for EASTMAN General Chemistry: Experiment and Theory

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HOLT, RINEHART AND WINSTON, INC.
New York / Chicago / San Francisco / Atlanta / Dallas
Montreal / Toronto / London / Sydney

SBN: 03-083052-4

Printed in the United States of America

1 2 3 4 5 6 7 8 9

Note to the Student

This Study Guide is written to help you successfully complete the course in freshman chemistry. The guide is to be used as a *supplement* to Eastman, *General Chemistry: Experiment and Theory* and to the lectures, and is not intended as a substitute for the textbook. It has two specific purposes: (1) to provide you with a review of the basic terminology and theory that is developed in the textbook and (2) to provide you with an analysis of the basic types of problems that you will encounter during the course. The treatment in the Introduction and in Chapters 2, 3, and 5 is more extensive than in other chapters because the material presented here is a fundamental base upon which many of the other chapters depend.

Important in testing your understanding of basic chemistry is your ability to solve problems; this Study Guide contains many examples of problems, with their solutions worked out step-by-step. The solutions are offered so that you can see the logical, organized progression that leads to the answer, and can apply the same kind of approach and reasoning to the problems that you are asked to solve.

Study the assigned material in the textbook and then go over the corresponding material in the Study Guide. The list of objectives at the beginning of each chapter gives you a clear idea of just what you should derive from its study and the specific things you should be able to do after completing the chapter. As you work through each chapter in the guide, do the problems in order and check your answers against those that appear at the end of the chapter. If you cannot follow the solution, review the examples and explanations given in the guide. You will of course have to set yourself a time limit in your study of the text and Study Guide, but remember that the more problems you solve—or attempt to solve—the better the test of your comprehension. At the end of each chapter in the guide is a summary test, on which you can grade yourself as indicated in the Appendix containing the answers to these tests. With a time limit of one hour, the average student should score about 50 percent on the summary tests. In referring to data tables, you should be aware that values for such things as pK_a may vary slightly from one source to another, and that your answers thus may not match exactly those given in this guide.

Keep in mind that the general purpose of the Study Guide is to aid you in your comprehension of the material of the course. Do not rely on memorization in your review of the text or in the solution of problems; rather, try to understand the basic ideas involved. Essential to this, in turn, is your clear understanding of the terminology used in chemistry; its importance was stated by Antoine Lavoisier in 1790: ". . . . the impossibility of separating the nomenclature of a science from the science itself is owing to this, that every branch of the physical science must consist of three things: the series of facts which are the objects of the science, the ideas which represent these facts, and the words by which these ideas are expressed. Like three impressions of the same seal, the word ought to produce the idea, and the idea to be a picture of the facts."

I wish to thank the many teachers and students who have helped me in developing these ideas; special acknowledgment goes to Richard H. Eastman for his encouragement and help. I wish to dedicate the Study Guide to two future students, Cynthia Dawn and Wendy Jo Gallup.

June 1970

D. W. G.

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Introduction

OBJECTIVES

1. State the difference between a count and a measurement and recognize the limitations involved in measurements.
2. Do simple arithmetic operations with numbers according to the Law of Signs.
3. Solve algebraic equations and carry out algebraic operations on related quantities.
4. Write numbers in the five different forms: decimal, scientific notation, single exponents, double exponents, and as logs to the base 10.
5. Multiply and divide numbers using the different forms listed in objective 4.
6. Determine the number of significant figures in a measurement and use significant figures in calculations.
7. Estimate approximate answers to problems.
8. Use the metric system of measurement in terms of the fundamental units, the use of prefixes, and how to make conversions from one to the other.
9. Use the concept of density in determining the relationship between mass and volume.
10. Use specific gravity of solids, liquids, and gases to determine density.
11. Calculate and use the concept of solubility as a physical property.
12. Recognize intensive and extensive properties of a substance.
13. Convert temperatures from one scale to another by reasoning.
14. Use logical reasoning in the solution of a problem showing a step by step analysis.
15. Differentiate and identify phases and components in a system.
16. Apply the Law of Conservation of Mass to quantities involved in a chemical reaction.
17. Apply the Law of Definite Composition to determine the percent composition of a chemical compound.
18. Analyze a series of experiments to determine if the Law of Definite Composition or the Law of Multiple Proportions applies.

BASIC MATHEMATICS

NUMBERS AND MEASUREMENT

Chemistry is an experimental science based upon observations of both a qualitative (**what** is present) and a quantitative (**how much** is present) nature. Numbers are used in several different ways.

A Count In this case, the number designates how many objects.

0 0 0 0 Four (4) objects, in this case four 0's

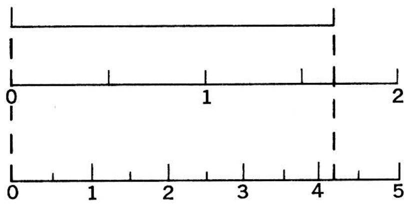
Accurate Arithmetical Numbers The number of digits used is limited only by the circumstances. For example the value of pi (π) can be written as 3.14159 . . . and can be continued on to as many digits as thought necessary.

Measured Quantities in Physical Numbers Any measured value is subject to limitations. For instance, what is the length of a line? First, what is the unit we wish to use for comparison? Second, how should we record the observation?

Line to be measured:

Reference scales: inches

centimeters



On the centimeter scale the value falls between 4.0 and 4.5 cm. We can estimate (educated guess) 4.2, 4.3 or 4.4 cm which shows uncertainty about the digit in the tenths place. We could safely say the value probably falls between the values 4.2 and 4.4 cm; therefore we can record 4.3 ± 0.1 cm. The ± 0.1 is called the *uncertainty of the measurement.*

LAW OF SIGNS

Numbers are either positive or negative and are indicated by a plus (+) or minus (−) sign. If a number is written without a sign it is understood to be positive. Rules for simple mathematical operations follow:

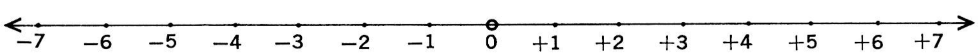
Addition To add numbers having like signs, the absolute values of the numbers are added with the sum having the common sign. When adding numbers with unlike signs, find the difference between their absolute values and prefix the sign of the number having the larger absolute value. This is called *algebraic summation.*

EXAMPLE Add +3 and +2 Answer +5
Add +4 and −6 Answer −2

Subtraction To subtract one signed number from another, change the sign of the number to be subtracted and proceed as in addition.

EXAMPLE Subtract −3 from +2. Change −3 to +3 then $+3$ and $+2 = +5$
or $+2 - (-3) = +2$ and $+3 = +5$
Subtract −3 from −2. Change −3 to +3 then $+3$ and $-2 = +1$
or $-2 - (-3) = -2$ and $+3 = +1$

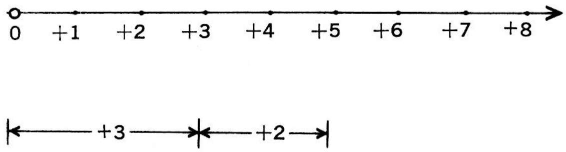
It may also be of some value to consider the use of the number line.



⟶ Positive numbers are measured to the right

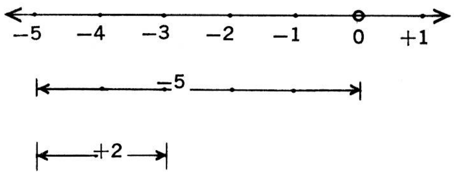
⟵ Negative numbers are measured to the left

EXAMPLE Add +3 and +2



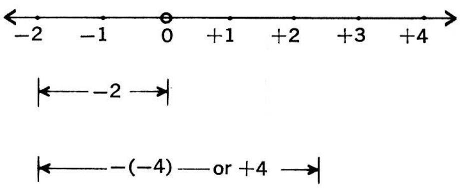
Answer +5

EXAMPLE Add −5 and +2



Answer −3

EXAMPLE Subtract −4 from −2



Answer +2

PROBLEM I-1 Add the following:

(a) −2.5 and +3.7 (b) −2.8 and −3.4 (c) +2.5 and −4.6

PROBLEM I-2 Subtract the following:

(a) −2.4 from +4.3 (b) +4.5 from −3.6 (c) −2.3 from −3.6

ALGEBRAIC CONCEPTS

1. An equation (proportion, ratio, relationship between numbers) is not changed by adding, subtracting, dividing, or multiplying *both sides* of the equation by the same quantity.

EXAMPLE If $\lambda = \frac{hc}{E}$, solve for c.

Multiply both sides of the equation by E,

$$\lambda E = \frac{hcE}{E}$$

Then divide both sides of the equation by h,

$$\frac{\lambda E}{h} = \frac{hcE}{hE}$$

Divide out like factors in the divisor and the dividend,

$$\frac{\lambda E}{h} = c$$

EXAMPLE If we have the statement that 0.364 A is related to the quantity 2.16 B, then how is 12.6 A related to B?

Basic statement relating numbers: 0.364 A is related to 2.16 B

Divide both sides by 0.364

$\frac{0.364}{0.364} A$ is related to $\frac{2.16}{0.364} B$

Multiply both sides by 12.6

$$\frac{12.6 \times 0.364}{0.364} A \text{ is related to } \frac{12.6 \times 2.16}{0.364} B$$

Dividing out we obtain 12.6 A is related to 74.8 B

2. If a quantity is involved in more than one equation, the value of that quantity in one equation can be used in any other equation having the same quantity.

If $\lambda = \frac{hc}{E}$ and $E = h\nu$ then $\lambda = \frac{hc}{h\nu}$ or $\lambda = \frac{c}{\nu}$

If the problem was to solve for c, given the values of λ and ν, then it is better to solve the expression for c first and then substitute the values for lambda (λ) and nu (ν).

PROBLEM I-3 Solve the following expression for h,

$$m = \frac{h\nu}{c^2}$$

If $E = h\nu$, what is E in terms of m and c?

PROBLEM I-4 Solve the following expression for h,

$$\lambda = \frac{hc}{E}$$

If $\lambda = \frac{c}{\nu}$, what is E in terms of h and ν?

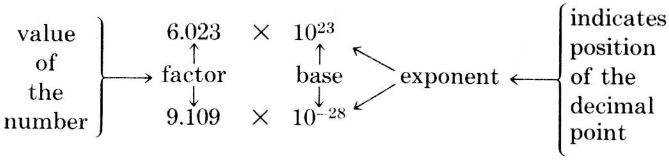
PROBLEM I-5 If 5.6 c is related to 0.65 D, how is 0.26 C related to D?

EXPONENTIAL (SCIENTIFIC) NOTATION

Large and small numbers can be written in a condensed form called the *exponential or scientific notation*. The digit expressing the value of the number is written so that it falls between 1 and 10, and the position of the decimal point (magnitude of the number) is indicated by multiplying or dividing by 10. For numbers larger than 10, for example 6950, we write $6.95 \times 10 \times 10 \times 10$ or more conveniently 6.95×10^3, where the superscript 3 is called an exponent and is the number of places the decimal point must be moved to the right to obtain the original arabic number. For numbers less than 1, for example 0.00695 (decimal form), we write

$$\frac{6.95}{10 \times 10 \times 10} \text{ or } \frac{6.95}{10^3} \text{ or better still } 6.95 \times 10^{-3}$$

The exponent -3 means that the decimal point must be moved that many times to the left to obtain the original decimal form.



Rules for Manipulation of Exponential Numbers

1. Addition and subtraction: Such numbers are added or subtracted by converting all numbers to the same power of the base and taking the sum or difference of the factors of this power.

EXAMPLE Add 5.640×10^3 and 3.27×10^2 and change to the same power, then aad

$$\begin{array}{r} 5.640 \times 10^3 \\ +0.327 \times 10^3 \\ \hline 5.967 \times 10^3 \end{array}$$

Subtract 1.26×10^{-3} from 3.240×10^{-2} and change to the same power, then subtract

$$\begin{array}{r} 3.240 \times 10^{-2} \\ -0.126 \times 10^{-2} \\ \hline 3.114 \times 10^{-2} \end{array}$$

2. Multiplication: Exponential numbers are multiplied by multiplying the factors and adding (remember the Law of Signs) the powers.

EXAMPLE $(3.2 \times 10^{-3}) \times (2.0 \times 10^{2}) = 6.4 \times 10^{-3+2} = 6.4 \times 10^{-1}$
$(3.2 \times 10^{-3}) \times (2.0 \times 10^{-2}) = 6.4 \times 10^{-3+(-2)} = 6.4 \times 10^{-5}$

3. Division: Exponential numbers are divided by dividing the factors of the dividend by the factors of the divisor and subtracting the powers of the divisor from the powers of the dividend (Law of Signs).

EXAMPLE

$$\frac{4.2 \times 10^{-2}}{2.1 \times 10^{-3}} = 2.0 \times 10^{-2-(-3)} = 2.0 \times 10^{1}$$

PROBLEM I-6 Write the following in the exponential form: 26800, 268, 0.000268.

PROBLEM I-7 Write the following numbers in the decimal (arabic) form: 5.6×10^4, 7.86×10^{-2}, 4.56×10^{-4}.

PROBLEM I-8 Convert the following numbers to the exponential form and carry out the indicated arithmetic expressing the answer in the exponential form:

(a) $0.000645 \times 0.00256 = ?$ (b) $\dfrac{0.000358}{284} = ?$ (c) $\dfrac{0.00345 \times 274}{0.000646 \times 29400} = ?$

SIGNIFICANT FIGURES AND CALCULATIONS

Significant figures appear in any measured quantity. In a measurement the first doubtful (estimated) figure is the last digit recorded. A significant number is one which is reliable to within a known range. An important consideration is how many significant figures should be retained in an answer.

Rule for Rounding Off Numbers A number is rounded off to the desired number of significant figures by dropping one or more digits to the right. When the first digit dropped is less than five, the last digit retained should remain unchanged; e.g. 167.4 or 167.48 can be rounded off to 167. When the first digit dropped is greater than five, one is added to the last digit retained; e.g. 167.6 or 167.56 to three significant figures is 168. When the digit to be dropped is exactly 5, add one to the digit retained if the digit is an odd number, otherwise (when the last digit is even) the five is dropped; e.g. 167.5 becomes 168 and 168.5 also becomes 168.

Rules for Addition and Subtraction The operation should not be carried out beyond the column containing the first doubtful digit. It may be necessary to *round off* numbers in the process.

EXAMPLE

$$\begin{array}{lrrlr}
\text{Addition:} & 3.26 & 3.26 & \text{Subtraction:} & 5.4273 \\
 & 1.3342 & 1.33 & & -1.2 \\ \cline{5-5}
 & 1.236 & 1.24 & & 4.2 \\ \cline{3-3}
 & & 5.83 & &
\end{array}$$

PROBLEM I-9 (a) Add 5.96 and 6.235 (b) Subtract 2.3642 from 8.4.

The one digit that can cause confusion in significant figures is the digit zero (0). In numbers less than one, such as 0.006750, the two zeros after the decimal point are there to indicate the position of the decimal point (magnitude of the number) and are not significant figures. But the zero after the 5 is recorded because it was measured, and is therefore a significant figure. In numbers larger than 10, for instance 34000, the zeros may be significant or they may only indicate position of the decimal point. One method to indicate the last significant figure is to place a bar over the last measured number, e.g. $340\bar{0}0$ indicates four significant figures with the first two zeros being significant and the last zero used only to indicate the position of the decimal point.

PROBLEM I-10 How many significant figures are in the following:

(a) 27.0 (b) 200.0 (c) 560000 (d) 0.00430 (e) 0.00045621

Rules for Multiplication and Division The answer can be no more reliable than the accuracy of the quantity containing the least number of significant figures. For example, in multiplying 27.02×1.3 the answer is 35.126 but only two significant figures should be retained because the value 1.3 has only two, therefore the answer is 35.

Take the example of multiplying 1.84 by π (pi), where π has the accurate value 3.14159 . . . (accurate numbers can have any number of significant figures). How should we carry out the multiplication? Assume that the next number after the four in 1.84 and the next number after the nine in 3.14159 are unspecified numbers and just assign the letter D for the next digit

$$\begin{array}{lr}
\text{A.} & 3.14159 \\
 & \times 1.84 \\ \hline
 & 1256636 \\
 & 2513272 \\
 & 314159 \\ \hline
 & 5.7805256
\end{array}
\qquad
\begin{array}{lr}
\text{B.} & 3.14159D \\
 & \times 1.84D \\ \hline
 & DDDDDDD \\
 & 1\,2\,5\,6\,6\,3\,6D \\
 & 2\,5\,1\,3\,2\,7\,2D \\
 & 3\,1\,4\,1\,5\,9D \\ \hline
 & 5.7\,8DDDDDD
\end{array}$$

Solving the problem as in A results in wasted effort. In B we can see that only three significant figures can be retained. Therefore we could more easily solve the problem by multiplying $3.14 \times 1.84 = 5.78$.

PROBLEM I-11 Solve the following problems and express the answer in the decimal form and to the correct number of significant figures:

(a) $27.034 \times 2.34 = ?$ (b) 34.568 divided by 2.64 (c) $\dfrac{0.00340 \times 27.00}{0.0054} = ?$

LOGARITHMS

The logarithm ($\log_{10}$) of any number to the base 10 is the power to which ten must be raised to produce the given number, that is number $(n) = 10^{\log n}$. By definition, a logarithm is an *exponent* and the laws discussed under exponents apply to logarithms. Therefore, when you multiply numbers using logs, the logs are to be added just as the exponents were to be added in earlier examples.

$0.100 = 1.00 \times 10^{-1}$ $\log_{10} = \bar{1}.0000$

$1.00 = 1.00 \times 10^{0}$ $\log_{10} = 0.0000$

$10.0 = 1.00 \times 10^{1}$ $\log_{10} = 1.0000$

A log is composed of two parts:

1. The *characteristic* which locates the decimal point
2. The *mantissa* which expresses the value of the number when it is written as a number between one and ten. The procedure is the same as in the exponential way of writing a number.

Remember the characteristic may be either positive (for numbers larger than one) or negative (for numbers less than one) but that the mantissa must always be positive. The logs of numbers between one and ten will have mantissae ranging from 0 to 1 or in the same sense all numbers between one and ten can be expressed in the exponential form with the exponents being in the range of 0 to 1.

$\log_{10}1 = 0.0000$ or $10^{0.0000}$

$\log_{10}2 = 0.3010$ or $10^{0.3010}$

$\log_{10}5 = 0.6990$ or $10^{0.6990}$

A log table is set in the following form:

Number	0	1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551

The first two digits of the number are found in the column on the left and the third digit is found across the top. For the number 5.56 the log is 0.7451 and in the exponential form is $10^{0.7451}$. For the log of 556000, we convert to the exponential form (5.56×10^{5}). The power of ten gives us the characteristic and from the table we can locate the mantissa. Therefore, $\log_{10} 5.56 \times 10^{5}$ is 5.7451. The number can now be written as two powers of ten $10^{0.7451} \times 10^{5}$ and following the laws relating to exponents can also be written as a single exponent $10^{5.7451}$.

For the number 0.000556, following the same steps as above:

$\log_{10} 5.56 \times 10^{-4} = \bar{4}.7451$

The negative sign is placed over the four because only that portion of the log is negative. The mantissa 0.7451 is positive. The expression for the double exponent is $10^{0.7451} \times 10^{-4}$ and using the Law of Signs the single exponent would be written as $10^{-3.2549}$.

We can now write a number in several different forms:

1.	Arabic (decimal) form	563	0.00563
2.	Exponential form	5.63×10^{2}	5.63×10^{-3}
3.	Double exponent	$10^{0.7505} \times 10^{2}$	$10^{0.7505} \times 10^{-3}$
4.	Single exponent	$10^{2.7505}$	$10^{-2.2495}$
5.	$\log_{10}$	2.7505	$\bar{3}.7505$

The reverse process, finding a number that corresponds to a given logarithm, is called finding the antilog. If the $\log_{10}$ of a number is given as $\bar{4}.7536$ the antilog may be found by first converting to a double exponent obtaining $10^{0.7536} \times 10^{-4}$, then finding the mantissa 7536 in the log table and reading the first two digits of the number in the column on the left and the third digit on the top. The antilog of $\bar{4}.7536$ is 5.67×10^{-4} or 0.000567 in the decimal form. If you now encounter the number $\bar{4}.7536$ you should realize that it contains a mixed exponent and could be rewritten as $10^{-3.2464}$.

A four-place log table can be used to find the log of a number containing four digits by use of the right hand column marked proportional parts. The number 55.63 is first written in the exponential form

5.563×10^1 to obtain the characteristic, 1. The number 5.56 (as previously discussed) has the log 0.7451 and the number 5.57 has the log 0.7459. Under the number 3 (fourth digit of our number) in the proportional parts in the same row as the number 55 we see the number 2. This is to be added to the log of 5.56. Therefore the log of 5.563×10^1 is 1.7453. If the log table does not contain a proportional parts column we could reason the same result by seeing that the log of 5.56 and 5.57 differ by 8 (7459 − 7451) and that 5.563 is 3/10ths of the difference between 5.560 and 5.570. Therefore $0.3 \times 8 = 2.4$ which rounds off to 2 and this amount is to be added to the log of 5.56.

PROBLEM I-12 Complete the following chart using the rules and the log table. Express the exponential and decimal forms to three significant figures.

(a) decimal form	0.00742	______	______	______	______
(b) exponential form	______	8.42×10^4	______	______	______
(c) double exponent	______	______	$10^{0.4284} \times 10^{-4}$	______	______
(d) single exponent	______	______	______	$10^{3.5936}$	______
(e) $\log_{10}$	______	______	______	______	$\bar{2}.9657$

Solving problems by the use of a log table can save a considerable amount of time and there is no wasted effort in carrying out a complicated problem to too many significant figures. For instance,

$$\frac{98.3 \times 28500 \times 0.0810}{2640 \times 0.00364} \quad \begin{matrix} \longleftarrow \text{(dividend)} \\ \longleftarrow \text{(divisor)} \end{matrix}$$

1. Multiply the factors in the dividend by adding the logs:

$$\begin{aligned} \log_{10} 9.83 \times 10^1 &= 1.9926 \\ \log_{10} 2.85 \times 10^4 &= 4.4548 \\ \log_{10} 8.10 \times 10^{-2} &= \bar{2}.9085 \\ & \quad 5.3559 \end{aligned}$$

2. Multiply the factors in the divisor:

$$\begin{aligned} \log_{10} 2.64 \times 10^3 &= 3.4216 \\ \log_{10} 3.64 \times 10^{-3} &= \bar{3}.5611 \\ & \quad 0.9827 \end{aligned}$$

3. Subtract the log of the divisor from the log of the dividend:

$$\begin{aligned} \log_{10} \text{ of dividend} &= 5.3559 \\ -\log_{10} \text{ of divisor} &= 0.9827 \\ \log_{10} \text{ of answer} & \quad 4.3732 \end{aligned}$$

4. The antilog of 4.3732 is $10^{0.3732} \times 10^4$ or 2.36×10^4.

At this time it is advisable to learn to check answers to see if they are logical. Estimate the answer by rounding off numbers to the nearest whole number and expressing in the exponential form. Group the factors and the exponents and solve. For the problem just stated:

98.3 is approximately equal to 10^2
28500 is approximately equal to 3×10^4
0.0810 is approximately equal to 8×10^{-2}
2640 is approximately equal to 3×10^3
0.00364 is approximately equal to 4×10^{-3}

The problem now reduces to:

factors exponents

$$\frac{3 \times 8 \times 10^2 \times 10^4 \times 10^{-2}}{3 \times 4 \times 10^3 \times 10^{-3}}$$

and the estimated answer is 2×10^4 which is in agreement with the calculated answer.

PROBLEM I-13 Solve the following problems by means of logs and express the answer in the exponential form. Estimate the answer first.

(a) $\frac{0.0000687 \times 29400 \times 0.0124}{842 \times 0.00485 \times 0.946}$ (b) $\frac{205000 \times 0.000236 \times 0.0285}{485 \times 0.0000321 \times 392000}$

Logs can also be useful in multiplying a number by itself, that is "squaring the number." For example $(3.84)^2$ means 3.84×3.84 or $\log_{10}$ of 3.84 + $\log_{10}$ of 3.84 or

$(3.84)^2 = 2 \times \log_{10} 3.84 \times 10^0 = 2 \times 0.5843 = 1.1686$

The antilog of 1.1686 is 1.47×10^1 or 14.7

Similarly $(3840)^2$ would be $2 \times \log_{10} 3.84 \times 10^3 = 2 \times 3.5843 = 7.1686$ and the antilog of 7.1686 is 1.47×10^7.

Finally $(0.00384)^2$ would be $2 \times \log_{10} 3.84 \times 10^{-3} = 2 \times \bar{3}.5843 = \bar{5}.1686$ and the antilog of $\bar{5}.1686$ is 1.47×10^{-5}.

Another mathematical operation frequently encountered is taking the "square root" of a number. The sign $\sqrt{\ }$ means square root while the sign $\sqrt[3]{\ }$ means the cube root and so forth. The square root means we are to take the number to the $\frac{1}{2}$ power and the cube root means to the $\frac{1}{3}$ power. Therefore $\sqrt{2}$ is the same as $2^{1/2}$. The $\log_{10} 2^{1/2} = \frac{1}{2} \log 2 \times 10^0 = \frac{1}{2} \times 0.3010 = 0.1505$. The antilog of 0.1505 is 1.414 which is the square root of 2.

EXAMPLE: Take the square root of 3.84, 38.4 and 0.00384.

The $\log_{10} \sqrt{3.84} = \frac{1}{2} \log_{10} 3.84 \times 10^0 = \frac{1}{2} \times 0.5843 = 0.2922$
The antilog of $0.2922 = 10^{0.2922} \times 10^0 = 1.96 \times 10^0$ or 1.96

The $\log_{10} \sqrt{38.4} = \frac{1}{2} \log_{10} 3.84 \times 10^1 = \frac{1}{2} \times 1.5843 = 0.7922$
The antilog of $0.7922 = 10^{0.7922} \times 10^0 = 6.197 \times 10^0$ or 6.197

The $\log_{10} \sqrt{0.00384} = \frac{1}{2} \log_{10} 3.84 \times 10^{-3} = \frac{1}{2} \times \bar{3}.5843 = \bar{2}.7922$
The antilog of $\bar{2}.7922 = 10^{0.7922} \times 10^{-2} \times 6.197 \times 10^{-2}$

The last example points out again the fact that a logarithm is *two separate numbers*, the characteristic and the mantissa. We can arrive at the answer by the use of exponents:

(a) The number and operation: $\sqrt{0.00384} = (0.00384)^{1/2}$
(b) As a double exponent $(3.84 \times 10^{-3})^{1/2} = (10^{0.5843} \times 10^{-3})^{1/2}$
(c) As a single exponent $(10^{-2.4157})^{1/2} = 10^{-1.2078}$
(d) Back to a double exponent $10^{-1.2078} = 10^{0.7922} \times 10^{-2}$
(e) To the exponential form $10^{0.7922} \times 10^{-2} = 6.197 \times 10^{-2}$

PROBLEM I-14 Solve the following problems by the use of logs:

(a) $\sqrt[3]{5600}$ (b) $\sqrt{420}$ (c) $\sqrt{0.784}$ (d) $\sqrt{0.0644}$

PHYSICAL PROPERTIES AND MEASUREMENT

The properties of a substance may be put in two categories:

Extensive—dependent on sample size (mass, length, volume, energy)
Intensive—independent of sample size (pressure, density, concentration)

To express the properties in a quantitative manner, scientific measurements are made using the *metric system*. The fundamental units in the metric system are:

Unit of length	meter, m
Unit of mass	gram, g
Unit of volume	liter
Unit of time	second, sec

Multiples or fractional parts of the fundamental units are designated by prefixes and symbols which represent these parts:

Part	*Name*	*Symbol*	*Decimal Form*	*Exponential Form*
million million	tera	T	1,000,000,000,000	10^{12}
billion	giga	G	1,000,000,000	10^{9}
million	mega	M	1,000,000	10^{6}
thousand	kilo	k	1,000	10^{3}
hundred	hecto	h	100	10^{2}
ten	deka	dk	10	10^{1}
one unit	uni		1	10^{0}
tenth of	deci	d	0.1	10^{-1}
hundredth of	centi	c	0.01	10^{-2}
thousandth of	milli	m	0.001	10^{-3}
millionth of	micro	μ	0.000001	10^{-6}
billionth of	nano	n	0.000000001	10^{-9}
million millionth of	pico	p	0.000000000001	10^{-12}

Some important relationships for conversion within the metric system are:

1 ml = 1 cm^3 (cc is frequently used as an abbreviation for cubic centimeters)
1 liter = 1000 ml = 1000 cm^3
1 m = 100 cm = 1000 mm = $10^6\mu$ also 10^{10} Å (Angstrom units)
1 g = 1000 mg = 0.001 kg

And several English-Metric conversion factors are:

1 meter (m) = 39.37 inches   1 liter = 1.06 quart (qt)
1 kilogram (kg) = 2.205 pound (lb)

To solve problems involving a conversion from one unit to another follow the same sequence of steps as previously discussed in the section on algebraic concepts.

EXAMPLE Convert 1.50 pounds into grams.

(a) Number relationship: An established relationship is given in the English-Metric conversion table for pounds to kilograms.

2.205 lb = 1.000 kg

(b) Unit check. We want the unit grams in our answer and the unit given for our conversion factor is kilograms. Conversion within the Metric system involves only the placement of the decimal point and can be accomplished by replacing the prefix kilo with the exponential multiplier from the table on prefixes, which in this case is 10^3.

2.205 lb = 1.000×10^3 g

(c) Conversion to the number of pounds desired in the problem. To change the number 2.205 to 1.50 we follow two steps (1) reduce the number to one by dividing it by itself (2.205/2.205) and then (2) multiplying by the number desired (1.50). Recall that whatever we do to the number on the left side we must carry out the same mathematical operations on the number on the right side of the expression.

Therefore

$$\frac{1.50 \times 2.205}{2.205}\ \text{lb} = \frac{1.50 \times 1.000 \times 10^3}{2.205}\ \text{g}$$

Carry out the indicated arithmetic for a solution to the problem.

$$1.50 \text{ lb} = \frac{1.50 \times 1.000 \times 10^3}{2.205} \text{ g} = 6.80 \times 10^2 \text{ g}$$

set up answer solved answer

For converting units within the metric system:

1. A prefix may be replaced by substituting the exponential multiplier for the prefix. 1 *kilo* gram $= 1 \times 10^3$ gram
2. A prefix may be added by addition of the prefix and at the same time dividing by the exponential multiplier.

$$1 \text{ gram} = \frac{1}{10^{-3}} \textit{ milli} \text{ gram}$$

PROBLEM I-15 Solve the following conversion problems:

(a) 0.246 liter = ______ ml = ______ cm^3 = ______ qt
(b) 0.648 kg = ______ g = ______ mg = ______ lb
(c) 0.00468 m = ______ cm = ______ mm = ______ Å = ______ in.
(d) 4560 Å = ______ micron = ______ cm = ______ mm

PROBLEMS ON PHYSICAL PROPERTIES

Some important physical properties of a substance are density, solubility, and its melting and boiling points. This study guide will use a stepwise approach to the solution of problems as much as possible. The method involves five steps:

1. Definition of the problem. This will be a statement relating the given and unknown quantities.

EXAMPLE (a) 25.0 ml CCl_4 weighs ? g at 20°C
(b) 2.00 g of AgCl will dissolve in ? ml H_2O at 10°C

2. Is there any known or established relationship which we can use? This will generally be a definition or some basic chemical principle or a chemical property. This step usually involves recall information (things you should remember).

   (a) 1.00 ml CCl_4 weighs 1.594 g (density) at 20°C
   (b) 0.000089 g AgCl dissolves in 100 ml H_2O at 10°C

3. Do the units of the first two steps agree and are the conditions the same? If not, make conversions so that the units agree and the conditions are the same. In examples (a) and (b) both the units and conditions agree. If examples (b) had asked for liters of water, you would convert the 100 ml into liters.

4. Using the algebraic techniques described in the preceding sections, in particular, the idea that when two quantities are in some established relationship to each other, we may multiply or divide by any number as long as we treat both numbers the same. The usual procedure will be to divide a number by itself to reduce it to one and then multiply by the number desired as indicated in step 1.

(a) $\frac{1.00 \times 25.0}{1.00}$ ml CCl_4 weighs $\frac{25.0 \times 1.594}{1.00}$ g at 20°C

(b) $\frac{2.00 \times 0.000089}{0.000089}$ g AgCl dissolves in $\frac{100 \times 2.00}{0.000089}$ ml H_2O at 10°C