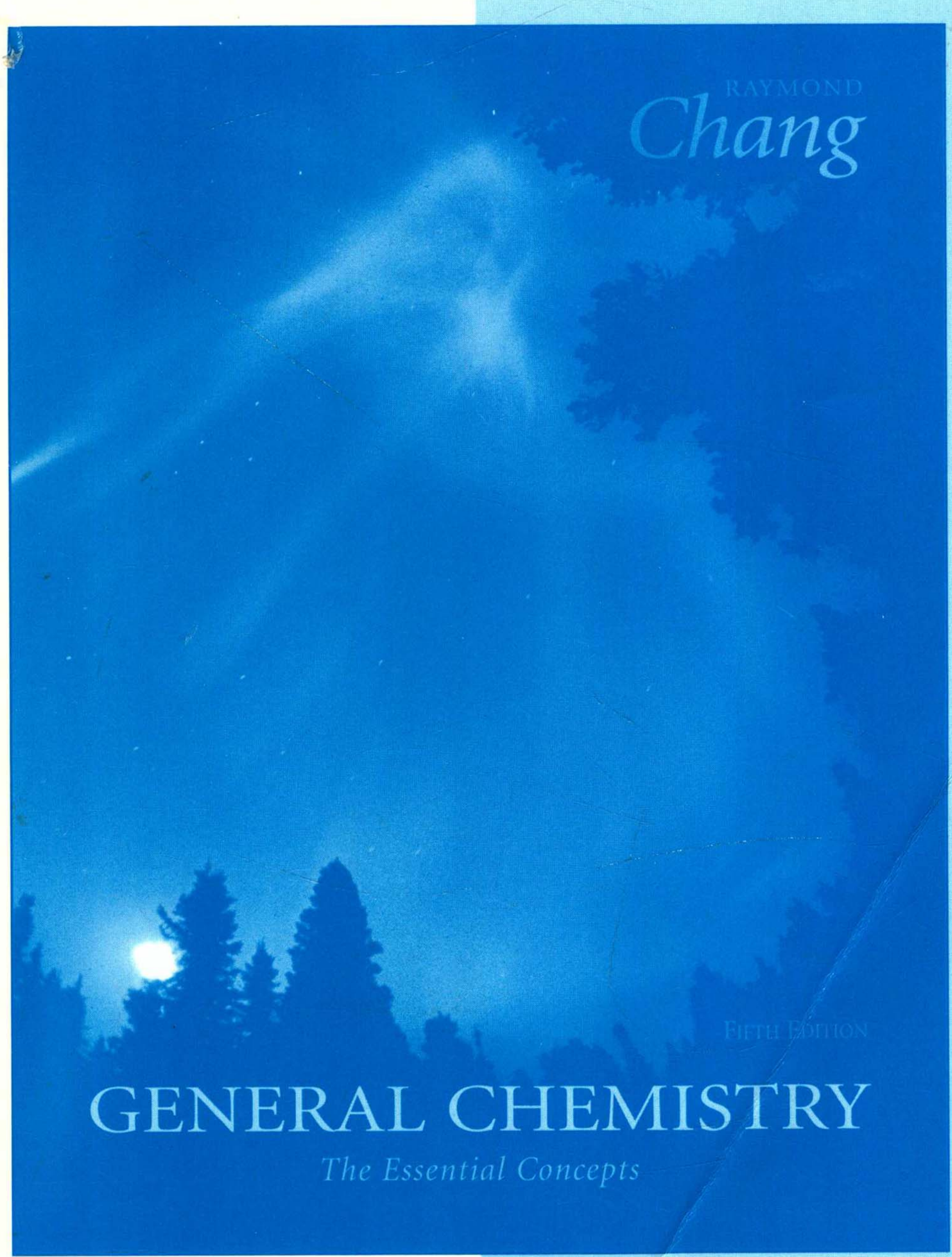
Problem-Solving Workbook

to accompany



Prepared by
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Problem-Solving Workbook

to accompany

General Chemistry: *The Essential Concepts*

Fifth Edition

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PROBLEM-SOLVING WORKBOOK to accompany
GENERAL CHEMISTRY: THE ESSENTIAL CONCEPTS
RAYMOND CHANG AND BRANDON J. CRUICKSHANK

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FOR THE STUDENT

The *Problem-Solving Workbook* is intended for use with the fifth edition of Raymond Chang's *General Chemistry*. For this manual to be of maximum assistance, you should incorporate it into your overall plan for studying general chemistry. The *Problem-Solving Workbook* contains material to help you develop problem-solving skills, material to practice your problem-solving skills, and solutions to the even-numbered problems in the text. Each chapter in the manual corresponds to one in the text. Every chapter of the manual contains the following main features:

Problem-Solving Strategies

You will encounter several different types of problems in each chapter. To make your problem-solving task easier, we will break down each chapter into the most common problem types. We will present step-by-step methods for solving each problem type.

Example Problems

Incorporated into each problem type are example problems with detailed step-by-step tutorial solutions. These example problems and tutorial solutions are intended to reinforce the problem-solving strategy presented with each problem type. The solutions often contain further explanation of important concepts.

Practice Exercises

Throughout all chapters are numerous practice exercises to allow you to test your problem-solving skills and your knowledge of the material. Answers to the practice exercises are found at the end of the problem-solving strategy section of each chapter.

Text Solutions

Solutions to all the even-numbered text problems are presented following the problem-solving strategies for each chapter. Usually one text problem of each problem type is solved in the step-by-step tutorial manner presented in the problem-solving strategy section. The problems with tutorial solutions refer back to the problem type presented in the strategy section. This will allow you to refer back to the appropriate material if you are having difficulty solving the problem.

Similar Problems

Following each problem type is a list of similar even-numbered problems in the text. Problems in bold-face type are solved in the step-by-step tutorial manner presented in the problem-solving strategy section. Similar problems are listed to allow you to practice more problems that follow a comparable strategy.

I hope that the *Problem-Solving Workbook* helps you succeed in general chemistry. I have attempted to present detailed problem-solving strategies to help you become a better problem-solver. Improved problem-solving will not only help you succeed in general chemistry, but also in many other courses throughout your college career. Probably one of the best ways to learn general chemistry is to work through, and sometimes struggle through, the problems assigned by your instructor. It always looks easy when your instructor solves a problem in class, but you really do not learn the material until you prove to yourself that you can solve the problem.

When solving problems, always try to be flexible. Please do not think that all problems that you encounter in general chemistry will fall into one of the problem types presented in each chapter. However, take the knowledge that you gain from the tutorial solutions and learn to apply that knowledge to different and perhaps more difficult problems. Also, try to work a few problems *every* day. (OK, you can take Friday off!) You cannot afford to fall behind in a general chemistry course.

If you have any comments or suggestions regarding the *Problem-Solving Workbook*, I would like to hear from you. My e-mail address is Brandon.Cruickshank@nau.edu or you can write to me at the following address:

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Good luck in all your college endeavors! And try to enjoy chemistry. You might be pleasantly surprised.

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Brandon J. Cruickshank

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PROBLEM TYPE 1: DENSITY CALCULATIONS

Density is the mass of an object divided by its volume.

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

$$d = \frac{m}{V}$$

Densities of solids and liquids are typically expressed in units of grams per cubic centimeter (g/cm^3) or equivalently grams per milliliter (g/mL). Because gases are much less dense than solids and liquids, typical units are grams per liter (g/L).

EXAMPLE 1.1
A lead brick with dimensions of 5.08 cm by 10.2 cm by 20.3 cm has a mass of 11,950 g. What is the density of lead in g/cm^3?

Strategy: You are given the mass of the lead brick in the problem. You need to calculate the volume of the lead brick to solve for the density. The volume of a rectangular object is equal to the length × width × height.

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Solution:

$$\text{Volume} = \text{length} \times \text{width} \times \text{height}$$
$$\text{Volume} = 5.08\text{ cm} \times 10.2\text{ cm} \times 20.3\text{ cm} = \mathbf{1052\ cm^3}$$

Calculate the density by substituting the mass and the volume into the equation.

$$d = \frac{m}{V} = \frac{11{,}950 \text{ g}}{1052 \text{ cm}^3} = \mathbf{11.4 \text{ g/cm}^3}$$

PRACTICE EXERCISE

1. Platinum has a density of 21.4 g/cm^3. What is the mass of a small piece of platinum that has a volume of 7.50 cm^3?

Text Problem: 1.18

PROBLEM TYPE 2: TEMPERATURE CONVERSIONS

To convert between the Fahrenheit scale and the Celsius scale, you must account for two differences between the two scales.

(1) The Fahrenheit scale defines the normal freezing point of water to be exactly 32°F, whereas the Celsius scale defines it to be exactly 0°C.

(2) A Fahrenheit degree is 5/9 the size of a Celsius degree.

A. Converting degrees Fahrenheit to degrees Celsius

The equation needed to complete a conversion from degrees Fahrenheit to degrees Celsius is:

$$\mathbf{? \text{ °C} = (\text{°F} - 32\text{°F}) \times \frac{5\text{°C}}{9\text{°F}}}$$

32°F is subtracted to compensate for the normal freezing point of water being 32°F, compared to 0° on the Celsius scale. We multiply by (5/9) because a Fahrenheit degree is 5/9 the size of a Celsius degree.

EXAMPLE 1.2
Convert 20°F to degrees Celsius.

$$? \text{ °C} = (\text{°F} - 32\text{°F}) \times \frac{5\text{°C}}{9\text{°F}}$$

$$? \text{ °C} = (20\text{°F} - 32\text{°F}) \times \frac{5\text{°C}}{9\text{°F}} = \mathbf{-6.7\text{°C}}$$

B. Converting degrees Celsius to degrees Fahrenheit

The equation needed to complete a conversion from degrees Celsius to degrees Fahrenheit is:

$$\mathbf{? \text{ °F} = \left(\text{°C} \times \frac{9\text{°F}}{5\text{°C}}\right) + 32\text{°F}}$$

°C is multiplied by (9/5) because a Celsius degree is 9/5 the size of a Fahrenheit degree. 32°F is then added to compensate for the normal freezing point of water being 32°F, compared to 0° on the Celsius scale.

EXAMPLE 1.3
Normal human body temperature on the Celsius scale is 37.0°C. Convert this to the Fahrenheit scale.

$$? \text{ °F} = \left(\text{°C} \times \frac{9\text{°F}}{5\text{°C}}\right) + 32\text{°F}$$

$$? \text{ °F} = \left(37.0\text{°C} \times \frac{9\text{°F}}{5\text{°C}}\right) + 32\text{°F} = \mathbf{98.6°F}$$

PRACTICE EXERCISE

2. Convert –40°F to degrees Celsius.

Text Problems: 1.20, 1.38 d,e

PROBLEM TYPE 3: SCIENTIFIC NOTATION

Scientific notation is typically used when working with small or large numbers. All numbers can be expressed in the form

$$N \times 10^n$$

where N is a number between 1 and 10 and n is an exponent that can be a positive or negative integer, or zero.

A. Expressing a number in scientific notation

Strategy: Writing scientific notation as $N \times 10^n$, we determine n by counting the number of places that the decimal point must be moved to give N, a number between 1 and 10.

If the decimal point is moved to the left, n is a positive integer, the number you are working with is larger than 10. If the decimal point is moved to the right, n is a negative integer. The number you are working with is smaller than 1.

EXAMPLE 1.4
Express 0.000105 in scientific notation.

Solution: The decimal point must be moved four places to the right to give N, a number between 1 and 10. In this case,

$$N = \mathbf{1.05}$$

Since 0.000105 is a number less than one, n is a negative integer. In this case, $n = -4$ (The decimal point was moved four places to the right to give $N = 1.05$).

Combining the above two steps:

$$0.000105 = \mathbf{1.05 \times 10^{-4}}$$

Tip: The notation 1.05×10^{-4} means the following: Take 1.05 and multiply by 10^{-4} (0.0001).

$$1.05 \times 0.0001 = 0.000105$$

EXAMPLE 1.5
Express 4224 in scientific notation.

Solution: The decimal point must be moved three places to the left to give N, a number between 1 and 10. In this case,

$$N = \mathbf{4.224}$$

Since 4,224 is a number greater than one, n is a positive integer. In this case, $n = 3$ (the decimal point was moved three places to the left to give $N = 4.224$).

Combining the above two steps:

$$4224 = \mathbf{4.224 \times 10^3}$$

Tip: The notation 4.224×10^3 means the following: Take 4.224 and multiply by 10^3 (1000).

$$4.224 \times 1000 = 4{,}224$$

PRACTICE EXERCISE

3. Express the following numbers in scientific notation:

(a) 45,781 **(b)** 0.0000430

Text Problems: 1.22, 1.24

B. Addition and subtraction using scientific notation

Strategy: Let's express scientific notation as $N \times 10^n$. When adding or subtracting numbers using scientific notation, we must write each quantity with the same exponent, n. We can then add or subtract the N parts of the numbers, keeping the exponent, n, the same.

EXAMPLE 1.6

Express the answer to the following calculation in scientific notation. $(2.43 \times 10^1) + (5.955 \times 10^2) = ?$

Solution: Write each quantity with the same exponent, n. Let's write 2.43×10^1 in such a way that $n = 2$.

> **Tip:** We are *increasing* 10^n by a factor of 10, so we must *decrease* N by a factor of 10. We move the decimal point one place to the left.

$$2.43 \times 10^1 = \mathbf{0.243 \times 10^2}$$

(n was increased by 1. Move the decimal point one place to the left.)

Add or subtract, as required, the N parts of the numbers, keeping the exponent, n, the same. In this example, the process is addition.

$$\begin{array}{r} 0.243 \times 10^2 \\ +\ 5.955 \times 10^2 \\ \hline \mathbf{6.198 \times 10^2} \end{array}$$

C. Multiplication and division using scientific notation

Strategy: Let's express scientific notation as $N \times 10^n$. Multiply or divide the N parts of the numbers in the usual way. To come up with the correct exponent n, when multiplying, *add* the exponents, when dividing, *subtract* the exponents.

EXAMPLE 1.7

Divide 4.2×10^{-7} by 5.0×10^{-5}.

Solution: Divide the N parts of the numbers in the usual way.

$$4.2 \div 5.0 = 0.84$$

When dividing the 10^n parts, *subtract* the exponents.

$$0.84 \times 10^{-7-(-5)} = 0.84 \times 10^{-7+5} = \mathbf{0.84 \times 10^{-2}}$$

The usual practice is to express N as a number between 1 and 10. Therefore, it is more appropriate to move the decimal point of the above number one place to the right, decreasing the exponent by 1.

$$0.84 \times 10^{-2} = \mathbf{8.4 \times 10^{-3}}$$

> **Tip:** In the answer, we moved the decimal point to the right, *increasing* N by a factor of 10. Therefore, we must *decrease* 10^n by a factor of 10. The exponent, n, is changed from −2 to −3.

EXAMPLE 1.8

Multiply 2.2×10^{-3} by 1.4×10^{6}.

Solution: Multiply the *N* parts of the numbers in the usual way.

$$2.2 \times 1.4 = 3.1$$

When multiplying the 10^n parts, *add* the exponents.

$$3.1 \times 10^{-3+6} = \mathbf{3.1 \times 10^{3}}$$

PRACTICE EXERCISE

4. Express the answer to the following calculations in scientific notation. Try these without using a calculator.

   (a) $2.20 \times 10^{3} - 4.54 \times 10^{2} =$

   (b) $4.78 \times 10^{5} \div 6.332 \times 10^{-7} =$

Text Problem: 1.26

PROBLEM TYPE 4: SIGNIFICANT FIGURES

See Section 1.6 of the text for guidelines for using significant figures.

A. Addition and subtraction

Strategy: The number of significant figures to the right of the decimal point in the answer is determined by the lowest number of digits to the right of the decimal point in any of the original numbers.

EXAMPLE 1.9

Carry out the following operations and express the answer to the correct number of significant figures.

$$\mathbf{102.226 + 2.51 + 736.0 =}$$

Solution:

$$\begin{array}{r} 102.226 \\ 2.51 \\ +\ \underline{736.0\ \ } \\ 840.7\mathbf{36} \end{array}$$

← fewest digits to the right of the decimal point (736.0)

The 3 and 6 are nonsignificant digits, since 736.0 only has one digit to the right of the decimal point. The answer should only have one digit to the right of the decimal point.

The correct answer rounded off to the correct number of significant figures is **840.7**

Tip: To round off a number at a certain point, simply drop the digits that follow if the first of them is less than 5. If the first digit following the point of rounding off is equal to or greater than 5, add 1 to the preceding digit.

B. Multiplying and dividing

Strategy: The number of significant figures in the answer is determined by the original number having the smallest number of significant figures.

EXAMPLE 1.10

Carry out the following operations and express the answer to the correct number of significant figures.

$$\mathbf{12 \times 2143.1 \div 3.11 = ?}$$

Solution:

$$12 \times 2143.1 \div 3.11 = 8269.2 = 8.2\mathbf{692} \times 10^3$$

The 6, 9, and 2 (bolded) are nonsignificant digits because the original number 12 only has two significant figures. Therefore, the answer has only two significant figures.

The correct answer rounded off to the correct number of significant figures is $\mathbf{8.3 \times 10^3}$

PRACTICE EXERCISE

5. Carry out the following operations and express the answer to the correct number of significant figures.

(a) $90.25 - 83 + 1.0015 =$
(b) $55.6 \times 3.482 \div 505.34 =$

Text Problem: 1.30

PROBLEM TYPE 5: THE DIMENSIONAL ANALYSIS METHOD OF SOLVING PROBLEMS

In order to convert from one unit to another, you need to be proficient at applying dimensional analysis. See Section 1.7 of the text. Conversion factors can seem daunting, but if you keep track of the units, making sure that the appropriate units cancel, your effort will be rewarded.

Step 1: Map out a strategy to proceed from initial units to final units based on available conversion factors.

Step 2: Use the following method as many times as is necessary to ensure that you obtain the desired unit.

$$\text{Given unit} \times \left(\frac{\text{desired unit}}{\text{given unit}}\right) = \text{desired unit}$$

EXAMPLE 1.11
How long will it take to fly from Denver to New York, a distance of 1631 miles, at a speed of 815 km/hr?

Strategy: One conversion factor is given in the problem, 815 km/hr. This conversion factor can be used to convert from distance (in km) to time (in hr). If you can convert the distance of 1631 miles to km, then you can use the conversion factor (815 km/hr) to convert to time in hours. Another conversion factor that you can look up is

$$1 \text{ mi} = 1.61 \text{ km}$$

You should come up with the following strategy.

$$\text{miles} \rightarrow \text{km} \rightarrow \text{hours}$$

Solution: Carry out the necessary conversions, making sure that units cancel.

$$\textbf{? hours} = 1631 \text{ mi (given)} \times \frac{1.61 \text{ km (desired)}}{1 \text{ mi (given)}} \times \frac{1 \text{ h (desired)}}{815 \text{ km (given)}} = \mathbf{3.22\ h}$$

Tip: In the first conversion factor (km/mi), km is the desired unit. When moving on to the next conversion factor (h/km), km is now given, and the desired unit is h.

EXAMPLE 1.12
The *Voyager II* mission to the outer planets of our solar system transmitted by radio signals many spectacular photographs of Neptune. Radio waves, like light waves, travel at a speed of 3.00×10^8 m/s. If Neptune was 2.75 billion miles from Earth during these transmissions, how many hours were required for radio signals to travel from Neptune to Earth?

Strategy: One conversion factor is given in the problem, 3.00×10^8 m/s. This conversion factor will allow you to convert from distance (in m) to time (in seconds). If you can convert the distance of 2.75 billion miles to meters, then the speed of light (3.00×10^8 m/s) can be used to convert to time in seconds. Other conversion factors that you can look up are:

1 billion = 1×10^9	60 s = 1 min
1 mi = 1.61 km	60 min = 1 h
1 km = 1000 m	

You should come up with the following strategy.

miles → km → meters → seconds → min → hours

Solution: Carry out the necessary conversions, making sure that units cancel.

$$? \textbf{h} = (2.75 \times 10^9 \cancel{\text{mi}}) \times \frac{1.61 \cancel{\text{km}}}{1 \cancel{\text{mi}}} \times \frac{1000 \cancel{\text{m}}}{1 \cancel{\text{km}}} \times \frac{1 \cancel{\text{s}}}{3.00 \times 10^8 \cancel{\text{m}}} \times \frac{1 \cancel{\text{min}}}{60 \cancel{\text{s}}} \times \frac{1\ \text{h}}{60 \cancel{\text{min}}} = \textbf{4.10 h}$$

PRACTICE EXERCISES

6. On a certain day, the concentration of carbon monoxide, CO, in the air over Denver reached 1.8×10^{-5} g/L. Convert this concentration to mg/m^3.

7. Copper (Cu) is a trace element that is essential for nutrition. Newborn infants require 80 μg of Cu per kilogram of body mass per day. The Cu content of a popular baby formula is 0.48 μg of Cu per milliliter. How many milliliters should a 7.0 lb baby consume per day to obtain the minimum daily Cu requirement?

Text Problems: 1.32, 1.34, 1.36, 1.38, 1.40, 1.42

ANSWERS TO PRACTICE EXERCISES

1. 161 g Pt

2. –40°C

3. **(a)** 4.5781×10^4
(b) 4.30×10^{-5}

4. **(a)** 1.75×10^3
(b) 7.55×10^{11}

5. **(a)** 8
(b) 0.383

6. 18 mg/m^3

7. 530 mL/day

SOLUTIONS TO SELECTED TEXT PROBLEMS

1.8 **(a)** Physical change. The helium isn't changed in any way by leaking out of the balloon.

(b) Chemical change in the battery.

(c) Physical change. The orange juice concentrate can be regenerated by evaporation of the water.

(d) Chemical change. Photosynthesis changes water, carbon dioxide, etc., into complex organic matter.

(e) Physical change. The salt can be recovered unchanged by evaporation.

1.10 **(a)** extensive **(b)** intensive **(c)** intensive

1.12 **(a)** compound **(b)** element **(c)** compound **(d)** element

1.18 Density Calculation, Problem Type 1.

Strategy: We are given the density and volume of a liquid and asked to calculate the mass of the liquid. Rearrange the density equation, Equation (1.1) of the text, to solve for mass.

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Solution:

$$\textbf{mass} = \text{density} \times \text{volume}$$

$$\textbf{mass of Hg} = \frac{13.6\text{ g}}{1\ \cancel{\text{mL}}} \times 95.8\ \cancel{\text{mL}} = \mathbf{1.30 \times 10^3\ g}$$

1.20 Temperature Conversion, Problem Type 2.

Strategy: Find the appropriate equations for converting between Fahrenheit and Celsius and between Celsius and Fahrenheit given in Section 1.5 of the text. Substitute the temperature values given in the problem into the appropriate equation.

Solution:

(a) $\text{K} = (°\text{C} + 273°\text{C})\dfrac{1\text{ K}}{1°\text{C}}$

(i) $\mathbf{K} = 113°\text{C} + 273°\text{C} = \mathbf{386\ K}$

(ii) $\mathbf{K} = 37°\text{C} + 273°\text{C} = \mathbf{3.10 \times 10^2\ K}$

(iii) $\mathbf{K} = 357°\text{C} + 273°\text{C} = \mathbf{6.30 \times 10^2\ K}$

(b) $\text{K} = (°\text{C} + 273°\text{C})\dfrac{1\text{ K}}{1°\text{C}}$

(i) $\mathbf{°C} = \text{K} - 273 = 77\text{ K} - 273 = \mathbf{-196°C}$

(ii) $\mathbf{°C} = 4.2\text{ K} - 273 = \mathbf{-269°C}$

(iii) $\mathbf{°C} = 601\text{ K} - 273 = \mathbf{328°C}$

1.22 Expressing a number in scientific notation, Problem Type 3A.

Strategy: Writing scientific notation as $N \times 10^n$, we determine n by counting the number of places that the decimal point must be moved to give N, a number between 1 and 10.

If the decimal point is moved to the left, n is a positive integer, the number you are working with is larger than 10. If the decimal point is moved to the right, n is a negative integer. The number you are working with is smaller than 1.

(a) Express 0.749 in scientific notation.

Solution: The decimal point must be moved one place to give N, a number between 1 and 10. In this case,

$$N = 7.49$$

Since 0.749 is a number less than one, n is a negative integer. In this case, $n = -1$.

Combining the above two steps:

$$0.749 = \mathbf{7.49 \times 10^{-1}}$$

(b) Express 802.6 in scientific notation.

Solution: The decimal point must be moved two places to give N, a number between 1 and 10. In this case,

$$N = 8.026$$

Since 802.6 is a number greater than one, n is a positive integer. In this case, $n = 2$.

Combining the above two steps:

$$802.6 = \mathbf{8.026 \times 10^{2}}$$

(c) Express 0.000000621 in scientific notation.

Solution: The decimal point must be moved seven places to give N, a number between 1 and 10. In this case,

$$N = 6.21$$

Since 0.000000621 is a number less than one, n is a negative integer. In this case, $n = -7$.

Combining the above two steps:

$$0.000000621 = \mathbf{6.21 \times 10^{-7}}$$

1.24 **(a)** Express 3.256×10^{-5} in nonscientific notation.

For the above number expressed in scientific notation, $n = -5$. To convert to nonscientific notation, the decimal point must be moved 5 places to the left.

$$3.256 \times 10^{-5} = \mathbf{0.00003256}$$

(b) Express 6.03×10^{6} in nonscientific notation.

For the above number expressed in scientific notation, $n = 6$. The decimal place must be moved 6 places to the right to convert to nonscientific notation.

$$6.03 \times 10^{6} = \mathbf{6{,}030{,}000}$$

1.26 Scientific Notation, Problem Types 3B and 3C

(a) Addition using scientific notation.

Strategy: Let's express scientific notation as $N \times 10^n$. When adding numbers using scientific notation, we must write each quantity with the same exponent, n. We can then add the N parts of the numbers, keeping the exponent, n, the same.

Solution: Write each quantity with the same exponent, n.

Let's write 0.0095 in such a way that $n = -3$. We have decreased 10^n by 10^3, so we must increase N by 10^3. Move the decimal point 3 places to the right.

$$0.0095 = 9.5 \times 10^{-3}$$

Add the N parts of the numbers, keeping the exponent, n, the same.

$$\begin{array}{r} 9.5 \times 10^{-3} \\ +\ 8.5 \times 10^{-3} \\ \hline \mathbf{18.0 \times 10^{-3}} \end{array}$$

The usual practice is to express N as a number between 1 and 10. Since we must *decrease* N by a factor of 10 to express N between 1 and 10 (1.8), we must *increase* 10^n by a factor of 10. The exponent, n, is increased by 1 from −3 to −2.

$$18.0 \times 10^{-3} = \mathbf{1.8 \times 10^{-2}}$$

(b) Division using scientific notation.

Strategy: Let's express scientific notation as $N \times 10^n$. When dividing numbers using scientific notation, divide the N parts of the numbers in the usual way. To come up with the correct exponent, n, we *subtract* the exponents.

Solution: Make sure that all numbers are expressed in scientific notation.

$$653 = 6.53 \times 10^2$$

Divide the N parts of the numbers in the usual way.

$$6.53 \div 5.75 = 1.14$$

Subtract the exponents, n.

$$1.14 \times 10^{+2-(-8)} = 1.14 \times 10^{+2+8} = \mathbf{1.14 \times 10^{10}}$$

(c) Subtraction using scientific notation.

Strategy: Let's express scientific notation as $N \times 10^n$. When subtracting numbers using scientific notation, we must write each quantity with the same exponent, n. We can then subtract the N parts of the numbers, keeping the exponent, n, the same.

Solution: Write each quantity with the same exponent, n.

Let's write 850,000 in such a way that $n = 5$. This means to move the decimal point five places to the left.

$$850{,}000 = 8.5 \times 10^5$$