Calculations In Chemistry (ChemReview Modules)

How To Use this E-Book

This PDF contains Modules 1 and 2 of the *Calculations in Chemistry* tutorials for General and AP Chemistry. To learn from these tutorials, it is important that you *read* each page and *work* the problems on each page.

The lessons can be done by reading the screen without printing any pages -- but are easier to complete if you print just a *few* pages. To try the "print a few pages" approach:

- Scroll to **PDF page 47** of this 58 page PDF.
- On your computer printer, **print PDF pages 47 to 50**. Next, return to this first page, scroll to **PDF page 8** (which says "page 1" at the bottom) and start the lessons, reading from the screen.

Problems in the lessons are printed in *black* ink and green ink.

- When you come to a *problem* in black ink, *answer* in your spiral problem notebook.
- If a problem is green, find it on your *printed* pages and write answers in the space provided.

Black ink problems require some space to solve. Green ink are short, "quick answer after the question" problems.

The printing of the "print pages" is not required: if you do not have access to a printer, you can answer green ink questions in your notebook. But writing green ink answers on the "print pages" will help you see the relationship between the question and its answer.

Print more "print pages"as you need them.

For all problems, answers are provided at the end of each lesson.

More Tutorials:

2. All modules in the Table of Contents (covering most topics in General/AP chemistry) are available as paperback books in 3 volumes. These books can be purchased one at a time as you need them. For details, see

   http://www.ChemReview.Net/CalculationsBook.htm

   The cost of each volume is $28 plus shipping.

3. An ebook version of all 39 modules is also available for $30. This version has the green ink questions and "print pages" at the end for all 39 modules. For details:

   http://books.wwnorton.com/books/978-0-393-92222-6/

If you have difficulty securing either the books or ebook, contact ChemReviewTeam@ChemReview.Net .

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How to Use These Lessons

1. ***Read* the lesson and *work* the questions (Q).** As you read, use this method.

   - As you start a new page, *if* you see 5 red stars (* * * * *) on the page, ***scroll*** so that the text *below* the stars is *hidden*.
   - In your problem notebook or your printed pages, write your answer to the question (**Q**) above the * * * * *. Then scroll so that the text below the * * * * * shows and check your answer. If you need a hint, read a part of the answer, then scroll up so that the * * * * * are at the bottom of the screen (to hide the answer) and try the problem again.

2. ***First* learn the rules, *then* do the Practice.**

   The goal in learning is to move rules and concepts into *memory*. To begin, when working questions *(***Q***)* in a lesson, you may look back at the rules, but make an effort to commit the rules to memory before starting the **Practice** problems.

   Try every *other* problem of a **Practice** set on the first day and the remaining problems in your next study session. This spacing will help you to remember new material. On both days, try to work the **Practice** without looking back at the rules.

   Answers to the **Practice** are at the end of each lesson. If you need a hint on a problem, read a part of the answer and try again.

3. **How many Practice problems should you do?** It depends on your background. These lessons are intended to

   - refresh your memory on topics you once knew, and
   - fill-in gaps for topics that are less familiar.

   If you know a topic well, read the lesson for review, then do a *few* problems on each **Practice** set. Be sure to do the last problem (usually the most challenging).

   If a topic is unfamiliar, do more problems.

4. **Work Practice problems at least 3 days a week.** Chemistry is cumulative: What you learn in early lessons you will need in memory later. To retain what you learn, *space* your study of a topic over several days.

   Science has found that your memory tends to retain what it uses repeatedly, but to remember for only a few days what you do not practice over several days. If you wait until a quiz deadline to study, what you learn may remain in memory for a day or two, but on later tests and exams, it will tend to be forgotten.

   Begin lessons on new topics early, preferably before the topic is covered in lecture.

5. **Memorize what must be memorized.** Use flashcards and other memory aids.

The key to success in chemistry is to *commit to memory* the facts and rules, *practice* solving problems at least 3 days a week, and watch for the *relationships* that build conceptual understanding.

> If you have previously taken a course in chemistry, many topics in Modules 1 to 4 will be review. Therefore: if you can pass the *pre-test* for a lesson, skip the lesson. If you need a bit of review to refresh your memory, do the last few problems of each **Practice** set. On topics that are less familiar, complete more **Practice**.

Module 1 – Scientific Notation

Calculators and Exponential Notation

To multiply 492 x 7.36, the calculator is a useful tool. However, when using exponential notation, you will make fewer mistakes if you do as much exponential math as you can without a calculator. These lessons will review the rules for doing exponential math "in your head."

The majority of problems in Module 1 will *not* require a calculator. Problems that require a calculator will be clearly identified.

Notation Terminology

When values are expressed as "regular numbers," such as 123 or 0.00024, they are said to be in **fixed-decimal** or **fixed** notation.

In science, we often deal with very large and very small numbers. These are more clearly expressed in **exponential notation:** writing a *number* times **10** to an integer power.

Example:

Instead of writing "an atom of neon has an empirical radius of **0.0000000070** cm," we express the value as "**7.0 x 10^{-9}** cm."

Values represented in exponential notation can be described as having three parts.

For example, in **$-$ 6.5 x 10^{-4}**,

- The $-$ in front is the *sign*.
- the ***6.5*** is termed the *significand*, *decimal*, *digit* , *mantissa,* or *coefficient*.
- The ***10^{-4}*** is the *exponential* term: the *base* is **10** and the *exponent* (or *power*) is **-4**.

Because decimal, digit, mantissa, and coefficient have other meanings, in these lessons we will refer to the parts of exponential notation as the **sign**, **significand** and **exponential** term.

sign ↓
$-$ 6.5 x 10^{-4}
↑ ↑
significand exponential

You should also learn (and use) any alternate terminology preferred in your course.

Additional Math Topics

Powers and *roots* of exponential notation are covered in Lesson 28B.

Complex units such as → are covered in Lesson 17C.

$$\frac{\text{atm} \bullet \text{L}}{(\text{mole})\left(\frac{\text{atm} \bullet \text{L}}{\text{mole} \bullet \text{K}}\right)}$$

Those lessons may be done at any time after Module 1.

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Lesson 1A: Moving the Decimal

Pretest: Do *not* use a calculator. If you get a perfect score on this pretest, skip to Lesson 1B. Otherwise, complete Lesson 1A. Answers are provided at the end of each *lesson*.

1. Write these in *scientific* notation.

   a. $9{,}400 \times 10^3$ = ____________________ b. 0.042×10^6 = __________________

   c. -0.0067×10^{-2} = __________________ d. -77 = __________________

2. Write these answers in fixed-decimal notation.

   a. $14/10{,}000$ = b. 0.194×1000 = c. 47^0=

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Working With Powers of 10

Below are the numbers that correspond to powers of 10. Note the relationship between the *exponents* and position of the *decimal point* in the fixed-decimal numbers as you go down the sequence.

10^{6} = 1,000,000
10^{3} = 1,000 = 10 x 10 x 10
10^{2} = 100
10^{1} = 10
10^{0} = **1** (*any* positive number to the *zero* power equals *one*.)
10^{-1} = 0.1
10^{-2} = 0.01 = $1/10^{2}$ = 1/100
10^{-3} = 0.001

Moving the Decimal

The rules are

1. To change a power of 10 (such as 10^{3}) to a fixed-decimal *number*, from 1.0, move the decimal by the number of places *equal* to the exponent. For a *positive* exponent, move *right*, for a negative exponent, move left.

   Examples: $10^{2} = 100$ $10^{-2} = 0.01$

2. When *multiplying* or *dividing* a number by 10, 100, 1000, etc., move the decimal by the number of *zeros*. When *multiplying*, move *right*, when dividing, move left.

   Examples: $-0.0624 \times 1{,}000 = -62.4$ $0.47/100 = 0.0047$

3. When writing a number that has a value between -1 and 1, always place a *zero* in *front* of the *decimal* point.

   Example: Do *not* write .42 or $-.74$; *do* write **0.42** or $-$**0.74**

   During written calculations, the zero in front helps in seeing your decimals.

4. To convert from exponential notation (such as -4×10^{3}) to fixed-decimal notation ($-4{,}000$), use these rules.

   a. The sign in front (+ or $-$) does not change.

   b. Move the decimal by the number of places *equal* to the exponent. For a *positive* exponent, move *right*, for a negative exponent, move left.

   Examples: $2.5 \times 10^{2} = 250$ $-7{,}653.8 \times 10^{-1} = -765.38$

Practice A: Write your answers, then check them at the end of this *lesson*.

1. (Rule 1) Write these as fixed-decimal numbers without an exponential term.

   a. $10^{7} =$ b. $10^{-5} =$ c. $10^{0} =$

2. (Rule 2) When dividing by 10,000 move the decimal to the ________________ by _____ places.

3. (Rule 2) Write these answers as fixed-decimal numbers.

   a. $0.42 \times 1000 =$ b. $63/100 =$ c. $-74.6/10{,}000 =$

4. (Rule 4) Convert these values to fixed-decimal notation.

   a. $3 \times 10^{3} =$ b. $5.5 \times 10^{-4} =$

   c. $0.77 \times 10^{6} =$ d. $-95 \times 10^{-4} =$

Converting to Scientific Notation

In chemistry, it is often required that numbers that are very large or very small be written in **scientific** notation. Scientific notation makes values easier to compare: there are many equivalent ways to write a value in exponential notation, but only one correct way to express a value in scientific notation.

Scientific notation is simply a special case of exponential notation in which the significand is *1 or greater*, but *less* than *10*, and is multiplied by 10 to a whole-number power. Another way to say this: in scientific notation, the *decimal point* in the significand must be *after* the first digit that is not a zero.

> Example: In scientific notation, $-0.057 \text{x } 10^{-2}$ is written as $-\mathbf{5.7} \text{ x } 10^{\mathbf{-4}}$.
>
> The decimal must be moved to after the first number that is not a zero: the 5.

Add the following rules to the list above.

5. To convert from exponential notation to *scientific* notation,
   - move the decimal in the significand to *after* the first digit that is not a zero,
   - then adjust the exponent to keep the same numeric value.

6. When moving a decimal point, the steps are:
   a. The *sign* in front does not change.
   b. If you move the decimal Y times, change the power of 10 by a *count* of Y**.**
   c. If you make the significand *larger,* make the exponent *smaller.*
   If you make the significand *smaller,* make the exponent *larger.*

   Examples: Converting exponential to *scientific* notation:

   $0.045 \text{ x } 10^{5} = 4\mathbf{.}5 \text{ x } 10^{\mathbf{3}}$ $\qquad -8{,}544 \text{ x } 10^{-7} = -8\mathbf{.}544 \text{ x } 10^{\mathbf{-4}}$

   In the second case: the decimal must be after the 8. Move the decimal 3 places to the left. This makes the significand 1000 times smaller. To keep the same numeric value, increase the exponent by 3. This makes the 10^{x} value 1000 times larger.

   Remember, $10^{\mathbf{-4}}$ is 1,000 times *larger* than $10^{\mathbf{-7}}$.

It helps to *recite*, every time you move a decimal, for the terms after the sign in front:

"If one gets *smaller*, the other gets *larger*. If one gets larger, the other gets smaller."

7. To convert regular (fixed-decimal) numbers to exponential *or* scientific notation, use these rules.
   - Any positive number to the zero power equals one.

     Examples: $2^{\mathbf{0}} = \mathbf{1}$. $42^{\mathbf{0}} = \mathbf{1}$. Exponential notation most often uses $\mathbf{10^{0} = 1}$.

- Since any number can be multiplied by one without changing its value, any number can be multiplied by $10^{\mathbf{0}}$ without changing its value.

  Example: 42 = 42 x 1 = 42 x $\mathbf{10^0}$ in exponential notation

  = 4.2 x $10^{\mathbf{1}}$ in *scientific* notation.

8. To convert fixed notation to *scientific* notation, the steps are
   a. Add **x 10^0** after the fixed-decimal number.
   b. Apply the rules that convert exponential to scientific notation.
      - Do not change the sign in *front*.
      - Write the decimal after the first digit that is not a zero.
      - Adjust the power of 10 to compensate for moving the decimal.

   Example: Converting to scientific notation,

   a. **943** = 943 x 10^0 = **9.43 x 10^2** .

   b. **— 0.00036** = — 0.00036 x 10^0 = **— 3.6 x 10^{-4}**

9. When converting to scientific notation, a positive fixed-decimal number that is
   - *larger* than *one* has a *positive* power of 10 (zero and above) in scientific notation;
   - *between* zero and one (such as 0.25) has a *negative* power in scientific notation; and
   - the number of *places* that the decimal moves in the conversion is the *number* after the sign of the scientific notation exponent.

   These same rules apply to numbers *after* a negative sign in front. The sign in front is independent of the numbers after it.

   Note how these rules apply to the two examples above.

   Note also that in both exponential and scientific notation, whether the sign in front is positive or negative has no relation to the sign of the *exponential* term. The sign in front determines whether a value is positive or negative. The exponential term indicates only the position of the decimal point.

Practice B:

1. Convert these values to scientific notation.

   a. 5,420 x 10^3 =

   b. 0.0067 x 10^{-4} =

   c. 0.00492 x 10^{-12} =

   d. — 602 x 10^{21} =

2. Which lettered parts in Problem 3 below must have powers of 10 that are negative when written in scientific notation?

3. Write these in scientific notation.

   a. 6,280 =

   b. 0.0093 =

c. 0.741 = d. $-1{,}280{,}000$ =

4. Complete the problems in the *pretest* at the beginning of this lesson.

Study Summary

In your problem notebook,

- write a list of rules in this lesson that were unfamiliar or you found helpful.
- Condense your wording, number the points, and write and recite the rules until you can write them from memory.

Then complete the problems below.

Practice C: Check (✓) and do every *other* letter. If you miss one, do another letter for that set. Save a few parts for your next study session.

1. Write these answers in fixed-decimal notation.

   a. 924/10,000 = b. 24.3 x 1000 = c. $-0.024/10$ =

2. Convert to scientific notation.

   a. 0.55×10^5 b. 0.0092×100 c. 940×10^{-6} d. 0.00032×10

3. Write these numbers in scientific notation.

   a. 7,700 b. 160,000,000 c. 0.023 d. 0.00067

ANSWERS (Use a sticky note as a bookmark to make answer pages easy to locate.)

Pretest: 1a. 9.4×10^6 1b. 4.2×10^4 1c. -6.7×10^{-5} 1d. -7.7×10^1

2a. 0.0014 2b. 194 2 c. 1

Practice A

1a. 10,000,000 1b. 0.00001. 1c. **1** 2. Dividing by 10,000 , move the decimal to the **left** by **4** places.

3a. 420 3b. **0.63** (must have zero in front) 3c. -0.00746

4a. 3,000 4b. 0.00055 4c. 770,000 4d. -0.0095

Practice B

1. 5.42×10^6 2. 6.7×10^{-7} 3. 2.0×10^1 4. -8.7×10^{-2} 5. 4.92×10^{-15} 6. -6.02×10^{23}

2. 2b and 2c 3a. 6.28×10^3 3b. 9.3×10^{-3} 3c. 7.41×10^{-1} 3d. -1.28×10^6

Practice C: 1a. 0.0924 1b. 24,300 1c. -0.0024

2a. 5.5×10^4 2b. 9.2×10^{-1} 2c. 9.4×10^{-4} 2d. 3.2×10^{-3}

3a. 7.7×10^3 3b. 1.6×10^8 3c. 2.3×10^{-2} 3d. 6.7×10^{-4}

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Lesson 1B: Calculations Using Exponential Notation

Pretest: If you can answer all three of these questions correctly, you may skip to Lesson 1C. Otherwise, complete Lesson 1B. Answers are at the end of this lesson.

Do *not* use a calculator. Convert your final answers to scientific notation.

1. $(2.0 \times 10^{-4})\ (6.0 \times 10^{23}) =$

2. $\dfrac{10^{23}}{(100)(3.0 \times 10^{-8})} =$

3. $(-6.0 \times 10^{-18}) - (-2.89 \times 10^{-16}) =$

* * * * *

Mental Arithmetic

In chemistry, you must be able to estimate answers without a calculator as a check on your calculator use. This mental math is simplified by using exponential notation. In this lesson, we will review the rules for doing exponential calculations "in your head."

Adding and Subtracting Exponential Notation

To add or subtract exponential notation without a calculator, the standard rules of arithmetic can be applied – *if* all of the numbers have the *same exponential* term.

Re-writing numbers to have the same exponential term usually results in values that are not in *scientific* notation. That's OK. During calculations, the rule is: *work* in exponential notation, to allow flexibility with decimal point positions, then to convert to scientific notation at the *final* step.

To add or subtract numbers with exponential terms, you may convert all of the exponential terms to *any* consistent power of 10. However, it usually simplifies the arithmetic if you convert all values to the *largest* of the exponential terms being added or subtracted.

The rule is

To add or subtract exponential notation by hand, make all of the exponents the same.

The steps are

<table><tr><td>
<u>To add or subtract</u> exponential notation without a calculator,

1. Re-write each number so that all of the significands are multiplied by the same power of 10. Converting to the highest power of 10 being added or subtracted is suggested.

2. Write the significands and exponentials in columns: numbers under numbers (lining up the decimal points), x under x, exponentials under exponentials.

3. Add or subtract the significands using standard arithmetic, then attach the common power of 10 to the answer.

4. Convert the final answer to scientific notation.
</td></tr></table>

Follow how the steps are applied in this

<u>Example:</u> $(40.71 \times 10^{8}) + (222 \times 10^{6}) = (40.71 \times 10^{8}) + (2.22 \times 10^{8}) =$

$$\begin{array}{rl} & 40.71 \times 10^{8} \\ + & \underline{2.22 \times 10^{8}} \\ & 42.93 \times 10^{8} = \boxed{\mathbf{4.293 \times 10^{9}}} \end{array}$$

Using the steps above and the method shown in the example, try the following problem with*out* a calculator. In this problem, do not round numbers during or after the calculation.

Q. $(32.464 \times 10^{1}) - (16.2 \times 10^{-1}) = ?$

* * * * * (See *How To Use These Lessons, Point 1,* on page 1)

A. $(32.464 \times 10^{1}) - (16.2 \times 10^{-1}) = (32.464 \times 10^{1}) - (\mathbf{0.162} \times 10^{\mathbf{+1}}) =$

$$\begin{array}{rl} & 32.464 \ \mathbf{x}\ \mathbf{10^{1}} \\ - & \underline{0.162 \ \mathbf{x}\ \mathbf{10^{1}}} \\ & 32.302 \ \mathbf{x}\ \mathbf{10^{1}} = \mathbf{3.2302 \times 10^{2}} \end{array}$$

($10^{\mathbf{1}}$ has a higher value than $10^{\mathbf{-1}}$)

Let's do problem 1 again. This time, first convert each value to *fixed-decimal* numbers, then do the arithmetic. Convert the final answer to scientific notation.

$$\begin{array}{rl} & 32.464 \times 10^{1} = \\ - & \underline{16.2 \times 10^{-1}} = \end{array}$$

* * * * *

$$\begin{array}{rlrl} & 32.464 \times 10^{1} = & & \mathbf{324.64} \\ - & \underline{16.2 \times 10^{-1}} = & - & \underline{\mathbf{1.62}} \\ & & & \mathbf{323.02} = \mathbf{3.2302 \times 10^{2}} \end{array}$$

This "convert to fixed-decimal numbers" method is an option when the exponents are close to 0. However, for exponents such as $10^{\mathbf{23}}$ or $10^{\mathbf{-17}}$, it is easier to use the method above that includes the exponential, but adjusts so that all of the exponentials are the same.

<u>Practice A:</u> Try these with*out* a calculator. On these, don't round. Do convert final answers to scientific notation. Do the odds first, then the evens if you need more practice.

1. $$\begin{array}{rl} & 64.202 \times 10^{23} \\ + & \underline{13.2 \times 10^{21}} \end{array}$$

2. $(61 \times 10^{-7}) + (2.25 \times 10^{-5}) + (212.0 \times 10^{-6}) =$

3. $(-54 \times 10^{-20}) + (-2.18 \times 10^{-18}) =$

4. $(-21.46 \times 10^{-17}) - (-3{,}250 \times 10^{-19}) =$

Multiplying and Dividing Powers of 10

The following boxed rules should be recited until they can be recalled from memory.

1. **When you *multiply* exponentials, you *add* the exponents.**

   Examples: $10^3 \times 10^2 = 10^{\mathbf{5}}$ $\quad 10^{-5} \times 10^{-2} = 10^{\mathbf{-7}}$ $\quad 10^{-3} \times 10^5 = 10^{\mathbf{2}}$

2. **When you *divide* exponentials, you *subtract* the exponents.**

   Examples: $10^3/10^2 = 10^{\mathbf{1}}$ $\quad 10^{-5}/10^2 = 10^{\mathbf{-7}}$ $\quad 10^{-5}/10^{-2} = 10^{\mathbf{-3}}$

   When subtracting, remember: $\boxed{\text{Minus a minus is a plus.}}$ $10^{6-(-3)} = 10^{6+3} = 10^9$

3. **When you take the reciprocal of an exponential, change the sign.**

   This rule is often remembered as:

   When you take an exponential term from the bottom to the top, change its sign.

   Example: $\dfrac{1}{\mathbf{10^3}} = \mathbf{10^{-3}}$; $1/\mathbf{10^{-5}} = \mathbf{10^5}$

   Why does this work? Rule 2: $\dfrac{1}{\mathbf{10^3}} = \dfrac{\mathbf{10^0}}{\mathbf{10^3}} = \mathbf{10^{0-3}} = \mathbf{10^{-3}}$

4. $\boxed{1/(1/X) = X \text{ because } (X^{-1})^{-1} = X; \text{ so } 1/(1/8) = 8 \text{ and } 1/(1/\text{grams}) = \text{grams.}}$

5. When fractions include several terms, it may help to simplify the numerator and denominator *separately*, then divide.

   Example: $\dfrac{10^{-3}}{10^5 \times 10^{-2}} = \dfrac{10^{-3}}{\mathbf{10^3}} = \mathbf{10^{-6}}$

Try the following problem.

Q. Without using a calculator, simplify the top, then the bottom, then divide.

$$\frac{10^{-3} \times 10^{-4}}{10^5 \times 10^{-8}} = \underline{\hspace{3cm}} =$$

* * * * *

Answer: $\dfrac{10^{-3} \times 10^{-4}}{10^5 \times 10^{-8}} = \dfrac{\mathbf{10^{-7}}}{\mathbf{10^{-3}}} = \mathbf{10^{-7-(-3)}} = \mathbf{10^{-7+3}} = \mathbf{10^{-4}}$

Practice B: Write answers as 10 to a power. Do *not* use a calculator. Do the odds first, then the evens if you need more practice.

1. $1/10^{23} =$

2. $10^{-5} \times 10^{-6} =$

3. $\dfrac{1}{1/10^{-4}} =$

4. $\dfrac{10^{-3}}{10^5} =$

5. $\dfrac{10^3 \times 10^{-6}}{10^{-2} \times 10^{-4}} =$

6. $\dfrac{10^5 \times 10^{23}}{10^{-1} \times 10^{-6}} =$

7. $\dfrac{100 \times 10^{-2}}{1{,}000 \times 10^6} =$

8. $\dfrac{10^{-3} \times 10^{23}}{10 \times 1{,}000} =$

Multiplying and Dividing in Exponential Notation

These are the rules we use most often.

1. When multiplying and dividing using exponential notation, handle the *significands* and *exponents separately*.

Do number math using number rules, and exponential math using exponential rules. Then combine the two parts.

Apply rule 1 to the following three problems.

a. Do not use a calculator: $(2 \times 10^3)\ (4 \times 10^{23}) =$

* * * * *

For numbers, use number rules. 2 times 4 is **8**

For exponentials, use exponential rules. $10^3 \times 10^{23} = 10^{\mathbf{3+23}} = 10^{\mathbf{26}}$

Then combine the two parts: $(2 \times 10^3)\ (4 \times 10^{23}) = \mathbf{8 \times 10^{26}}$

b. Do the *significand* math on a calculator but try the exponential math in your head for $(2.4 \times 10^{-3})\ (3.5 \times 10^{23}) =$

* * * * *

Handle significands and exponents separately.

- Use a calculator for the numbers. $2.4 \times 3.5 = \mathbf{8.4}$
- Do the exponentials in your head. $10^{\mathbf{-3}} \times 10^{\mathbf{23}} = 10^{\mathbf{20}}$
- Then combine.

$$(2.4 \times 10^{-3})\ (3.5 \times 10^{23}) = (2.4 \times 3.5) \times (10^{-3} \times 10^{23}) = \mathbf{8.4 \times 10^{20}}$$

We will review how much to round answers in Module 3. Until then, round numbers and significands in your answers to *two* digits unless otherwise noted.

c. Do significand math on a calculator but exponential math with*out* a calculator.

$$\frac{6.5 \times 10^{23}}{4.1 \times 10^{-8}} =$$

* * * * *

<u>Answer</u>: $\dfrac{6.5 \times 10^{23}}{4.1 \times 10^{-8}} = \dfrac{6.5}{4.1} \times \dfrac{10^{23}}{10^{-8}} = 1.585 \times [10^{23-(-8)}] = \mathbf{1.6 \times 10^{31}}$

2. When dividing, if an exponential term does *not* have a significand, add a **1 x** in front of the exponential so that the number-number division is clear.

Apply Rule 2 to the following problem. Do *not* use a calculator.

$$\frac{10^{-14}}{2.0 \times 10^{-8}} =$$

* * * * *

Answer: $\frac{10^{-14}}{2.0 \times 10^{-8}} = \frac{\mathbf{1}}{2.0} \mathbf{x} \frac{10^{-14}}{10^{-8}} = 0.50 \times 10^{-6} = \mathbf{5.0 \times 10^{-7}}$

Practice C

Study the two rules above, then apply them from memory to these problems. To have room for careful work, solve these in your notebook.

Do the odds first, then the evens if you need more practice. Try these *first* with*out* a calculator, then check your mental arithmetic with a calculator if needed. Write final answers in scientific notation, rounding significands to two digits.

1. $(2.0 \times 10^{1})\ (6.0 \times 10^{23}) =$
2. $(5.0 \times 10^{-3})\ (1.5 \times 10^{15}) =$
3. $\frac{3.0 \times 10^{-21}}{-2.0 \times 10^{3}} =$
4. $\frac{6.0 \times 10^{-23}}{2.0 \times 10^{-4}} =$
5. $\frac{10^{-14}}{-5.0 \times 10^{-3}} =$
6. $\frac{10^{14}}{4.0 \times 10^{-4}} =$
7. Complete the problems in the *pretest* at the beginning of this lesson.

The Role of Practice

Do as many **Practice** problems as you need to feel "quiz ready."

- If the material in a lesson is relatively easy review, do the *last* problem on each series of similar problems.
- If the lesson is less easy, put a check (✓) by every 2nd or 3rd problem, then work those problems. If you miss one, do some similar problem in the set.
- Save a few problems for your next study session -- and quiz/test review.

During Examples and **Q** problems, you *may* look back at the rules, but practice writing and recalling new rules from memory before starting the **Practice**.

If you use the **Practice** to learn the rules, it will be difficult to find time for all of the problems you will need to do. If you use the **Practice** to *apply* rules that are in memory, you will need to solve fewer problems to be "quiz ready."

Study Summary

In your problem notebook, write a list of rules in Lesson 1B that were unfamiliar, need reinforcement, or you found helpful. Then condense your list and add this new list to your numbered points from Lesson 1A. Write and recite your combined list until you can write all of the points from memory. Then work the problems below.

Practice D

Start by doing every *other* letter. If you get those right, go to the next number. If not, do a few more of that number. Save one part of each question for your next study session.

1. Try these with*out* a calculator. Convert your final answers to scientific notation.

   a. $10^{-2} \times (6.0 \times 10^{23}) =$

   b. $(-0.5 \times 10^{-2})(6.0 \times 10^{23}) =$

   c. $\dfrac{3.0 \times 10^{24}}{6.0 \times 10^{23}} =$

   d. $\dfrac{1}{5.0 \times 10^{23}} =$

   e. $\dfrac{1.0 \times 10^{-14}}{4.0 \times 10^{-5}} =$

   f. $\dfrac{10^{10}}{2.0 \times 10^{-5}} =$

2. Use a calculator for the numbers but not for the exponents.

   a. $\dfrac{2.46 \times 10^{19}}{6.0 \times 10^{23}} =$

   b. $\dfrac{10^{-14}}{0.0072} =$

3. Do not use a calculator. Write answers as a power of 10.

   a. $\dfrac{10^{7} \times 10^{-2}}{10 \times 10^{-5}} =$

   b. $\dfrac{10^{-23} \times 10^{-5}}{10^{-5} \times 100} =$

4. Convert to scientific notation in the final answer. Do not round during these.

   a. $(74 \times 10^{5}) + (4.09 \times 10^{7}) =$

   b. $(5.122 \times 10^{-9}) - (-12{,}914 \times 10^{-12}) =$

ANSWERS

Pretest. In scientific notation: 1. 1.2×10^{20} 2. 3.3×10^{28} 3. 2.83×10^{-16}

Practice A: You may do the arithmetic in any way you choose that results in these final answers.

1.
$$\begin{array}{rl} & 64.202 \times 10^{23} \\ + & 13.2 \times 10^{21} \\ \hline \end{array} = \begin{array}{rl} & 64.202 \times 10^{23} \\ + & 0.132 \times \mathbf{10^{23}} \\ \hline & 64.334 \times \mathbf{10^{23}} \end{array} = \mathbf{6.4334 \times 10^{24}}$$

2.
$$\begin{array}{rl} & 0.61 \times \mathbf{10^{-5}} \\ & 2.25 \times \mathbf{10^{-5}} \\ + & 21.20 \times \mathbf{10^{-5}} \\ \hline & 24.06 \times \mathbf{10^{-5}} \end{array} = \mathbf{2.406 \times 10^{-4}}$$

(10^{-5} is the *highest* value of the three exponentials)

3. $(-54 \times 10^{-20}) + (-2.18 \times 10^{-18}) = (-\mathbf{0.54} \times \mathbf{10^{-18}}) + (-2.18 \times 10^{-18}) =$

$$\begin{array}{r} -\ 0.54 \times \mathbf{10^{-18}} \\ -\ \underline{2.18 \times 10^{-18}} \\ -\ \mathbf{2.72 \times 10^{-18}} \end{array}$$

(10^{-18} is *higher* in value than 10^{-20})

4. $(+ 32.50 \times 10^{-17}) - (21.46 \times 10^{-17}) = \mathbf{1.104 \times 10^{-16}}$

Practice B

1. 10^{-23} 2. 10^{-11} 3. 10^{-4} 4. 10^{-8} 5. 10^{3} 6. 10^{35}

7. $\dfrac{100 \times 10^{-2}}{1{,}000 \times 10^{6}} = \dfrac{10^{2} \times 10^{-2}}{10^{3} \times 10^{6}} = \dfrac{10^{0}}{10^{9}} = \mathbf{10^{-9}}$ 8. $\dfrac{10^{-3} \times 10^{23}}{10 \times 1{,}000} = \dfrac{10^{20}}{10^{4}} = \mathbf{10^{16}}$

(For 7 and 8, you may use different steps, but you must arrive at the same answer.)

Practice C

1. 1.2×10^{25} 2. 7.5×10^{12} 3. -1.5×10^{-24} 4. 3.0×10^{-19} 5. -2.0×10^{-12} 6. 2.5×10^{17}

Practice D

1a. 6.0×10^{21} 1b. -3.0×10^{21} 1c. $\mathbf{5.0 \times 10^{0}}$ or $\mathbf{5.0}$ 1d. 2.0×10^{-24} 1e. 2.5×10^{-10}

1f. $\dfrac{10^{10}}{2.0 \times 10^{-5}} = \dfrac{1}{2.0} \times \dfrac{10^{10}}{10^{-5}} = 0.50 \times 10^{15} = \mathbf{5.0 \times 10^{14}}$

2a. $0.41 \times 10^{-4} = \mathbf{4.1 \times 10^{-5}}$ 2b. $0.14 \times 10^{-11} = \mathbf{1.4 \times 10^{-12}}$

3a. $\dfrac{10^{7} \times 10^{-2}}{10^{1} \times 10^{-5}} = \dfrac{10^{5}}{10^{-4}} = \mathbf{10^{9}}$ 3b. $\dfrac{10^{-23} \times \cancel{10^{-5}}}{\cancel{10^{-5}} \times \mathbf{10^{2}}} = \mathbf{10^{-25}}$

4a. $(0.74 \times 10^{7}) + (4.09 \times 10^{7}) =$

$= \mathbf{4.83 \times 10^{7}}$

4b. $(5.122 \times 10^{-9}) + (12.914 \times 10^{-9}) =$

$= 18.036 \times 10^{-9} = \mathbf{1.8036 \times 10^{-8}}$

* * * * *

Lesson 1C: Estimating Exponential Calculations

Pretest: If you can solve both problems of these problems correctly, skip this lesson. Convert final answers to scientific notation. Check your answers at the end of this lesson.

1. Solve with***out*** a calculator. $\dfrac{(10^{-9})(10^{15})}{(4 \times 10^{-4})(2 \times 10^{-2})} =$

2. Use a calculator for the numbers, but solve the exponentials by mental arithmetic.

$$\frac{(3.15 \times 10^{3})(4.0 \times 10^{-24})}{(2.6 \times 10^{-2})(5.5 \times 10^{-5})} =$$

* * * * *

Complex Calculations

The prior lessons covered the fundamental rules for exponential notation. For longer calculations, the rules are the same. The challenges are keeping track of the numbers *and* using the calculator correctly. The steps below will help you to simplify complex calculations, minimize data-entry mistakes, and quickly *check* your answers.

Let's try the following calculation two ways.

$$\frac{(7.4 \times 10^{-2})(6.02 \times 10^{23})}{(2.6 \times 10^{3})(5.5 \times 10^{-5})} =$$

Method 1. Do numbers and exponents separately.

Work the calculation above using the following steps.

a. **Do the numbers on the calculator.** Ignoring the exponentials, use the calculator to multiply all of the *significands* on top. Write the result. Then multiply all the significands on the bottom and write the result. Divide, write your answer rounded to two digits, and then check below.

* * * * * (See *How To Use These Lessons, Point 1,* on page 1).

$$\frac{7.4 \times 6.02}{2.6 \times 5.5} = \frac{44.55}{14.3} = \boxed{\mathbf{3.1}}$$

b. **Then simplify the exponentials.** Starting from the original problem, look only at the powers of 10. Try to solve the exponential math "in your head" with*out* the calculator. Write the answer for the top, then the bottom, and then divide.

* * * * *

$$\frac{10^{-2} \times 10^{23}}{10^{3} \times 10^{-5}} = \frac{10^{21}}{10^{-2}} = 10^{21-(-2)} = \boxed{\mathbf{10^{23}}}$$

c. **Now combine** the significand and exponential and write the final answer.

* * * * *

3.1×10^{23}. By grouping the numbers and exponents separately, you did not need to enter the exponents into your calculator. To multiply and divide powers of 10, you can simply add and subtract whole numbers.

Let's try the calculation a second way.

Method 2. All on the calculator.

Enter *all* of the numbers and exponents into your calculator. (Your calculator manual, which is usually available online, can help.) Write your final answer in scientific notation. Round the significand to two digits.

On most calculators, you will need to use an $\boxed{\text{E } or \text{ EE } or \text{ EXP or \^{}}}$ key, rather than the multiplication key, to enter a "10 to a power" term.

* * * * *

Your calculator answer, rounded, should be the same as with Method 1: **3.1** x $10^{\mathbf{23}}$.

Note how your calculator *displays* the exponential term in answers. The exponent *may* be set apart at the far right, sometimes with an **E** in front.

Which way was easier? "Numbers, then exponents," or "all on the calculator?" How you do the arithmetic is up to you, but "numbers, then exponents" is often quicker and easier.

Checking Calculator Results

Whenever a complex calculation is done on a calculator, you must do the calculation a second time, using different steps, to catch errors in calculator use.

"Mental arithmetic estimation" is often the fastest way to check a calculator answer. To learn this method, let's use the calculation that was done in the first section of this lesson.

$$\frac{(7.4 \times 10^{-2})(6.02 \times 10^{23})}{(2.6 \times 10^{3})(5.5 \times 10^{-5})} =$$

Apply the following steps to the problem above.

1. ***Estimate* the numbers first.** Ignoring the exponentials, *round* and then multiply all of the top significands, and write the result. Repeat for the bottom significands. Then write a *rounded estimate* for dividing those two numbers.

* * * * *

Your rounding might be

$$\frac{7 \times \cancel{6}}{3 \times \cancel{6}} = \frac{7}{3} \approx \mathbf{2} \qquad \text{(the } \approx \text{ sign means } \textit{approximately equals}\text{)}$$

If your mental arithmetic is good, you can estimate without a calculator. The estimate needs to be fast, but does *not* need to be exact. *Practice* the arithmetic "in your head."

2. **Simplify the exponents.** Try without a calculator.

* * * * *

$$\frac{10^{-2} \times 10^{23}}{10^{3} \times 10^{-5}} = \frac{10^{21}}{10^{-2}} = 10^{21-(-2)} = \mathbf{10^{23}}$$

3. **Combine** the estimated number and exponential. Compare this estimate to the answer found when you used a calculator in the section above. Are they close?

* * * * *

The estimate is 2×10^{23}. The answer with the calculator was 3.1×10^{23}. Allowing for rounding, the two results are close.

If your fast, rounded, "done in your head" answer is *close* to the calculator answer, it is likely that your calculator answer is correct. If the two answers are far apart, check your work.

Estimating Number Division

If you know your multiplication tables, and if you memorize these simple **decimal equivalents** to help in estimating division, you should be able to do many numeric estimates without a calculator.

1/2 = 0.50	1/3 = 0.33	1/4 = 0.25	1/5 = 0.20	2/3 = 0.67	3/4 = 0.75	1/8 = 0.125

The method used to get your *final* answer should be slow and careful. Your *checking* method should use different calculator keys or rounded numbers and mental arithmetic.

On timed tests, you may want to do the exact calculation first, and then go back at the end, if time is available, and use rounded numbers as a check. When doing a calculation the second time, try not to look back at the first answer until *after* you write the estimate. If you look back, by the power of suggestion, you will often arrive at the first answer whether it is correct or not.

For complex operations on a calculator, work each calculation a *second* time using rounded numbers and/or different calculator steps or keys.

Practice

For problems 1-3, you will need to know the "fraction to decimal equivalent" conversions in the box above. If you need practice, try this.

- On paper, draw 5 columns and 7 rows. List the fractions down the middle column.
- Write the decimal equivalents of the fractions at the far right.
- Fold over those answers and repeat at the far left. Fold over those and repeat.

		1/2		
		1/3		
		1/4		
		…		

To start, complete the even numbered problems. If you get those right, go to the next lesson. If you need more practice, do the odds.

Then try these next three with*out* a calculator. Convert final answers to scientific notation. Round the significand in the answer to two digits.

1. $\dfrac{4 \times 10^3}{(2.00)(3.0 \times 10^7)} =$

2. $\dfrac{1}{(4.0 \times 10^9)(2.0 \times 10^3)} =$

3. $\dfrac{(3 \times 10^{-3})(8.0 \times 10^{-5})}{(6.0 \times 10^{11})(2.0 \times 10^{-3})} =$

For Problems 4-7 below, in your notebook

- First write an *estimate* based on rounded numbers, then exponentials. Try to do this estimate without using a calculator.
- Then calculate a more precise answer. You may
  - o plug the entire calculation into the calculator, or
  - o use the "numbers on calculator, exponents on paper" method, or
  - o experiment with both approaches to see which is best for you.

Convert both the estimate and the final answer to scientific notation. Round the significand in the answer to two digits. Use the calculator that you will be allowed to use on quizzes and tests.

4. $\dfrac{(3.62 \times 10^{4})(6.3 \times 10^{-10})}{(4.2 \times 10^{-4})(9.8 \times 10^{-5})} =$

5. $\dfrac{10^{-2}}{(750)(2.8 \times 10^{-15})} =$

.6. $\dfrac{(1.6 \times 10^{-3})(4.49 \times 10^{-5})}{(2.1 \times 10^{3})(8.2 \times 10^{6})} =$

7. $\dfrac{1}{(4.9 \times 10^{-2})(7.2 \times 10^{-5})} =$

8. For additional practice, do the two *Pretest* problems at the beginning of this lesson.

ANSWERS

Pretest: 1. 1.25×10^{11} *or* 1.3×10^{11} 2. 8.8×10^{-15}

Practice: You may do the arithmetic using different steps than below, but you must get the same *answer*.

1. $\dfrac{4 \times 10^{3}}{(2.00)(3.0 \times 10^{7})} = \dfrac{4}{6} \times 10^{3-7} = \dfrac{2}{3} \times 10^{-4} = 0.667 \times 10^{-4} = \mathbf{6.7 \times 10^{-5}}$

2. $\dfrac{1}{(4.0 \times 10^{9})(2.0 \times 10^{3})} = \dfrac{1}{8 \times 10^{12}} = \dfrac{1}{8} \times 10^{-12} = \mathbf{0.125 \times 10^{-12}} = \mathbf{1.3 \times 10^{-13}}$

3. $\dfrac{(\cancel{3} \times 10^{-3})(8.0 \times 10^{-5})}{(2\,\cancel{6.0} \times 10^{11})(2.0 \times 10^{-3})} = \dfrac{8}{4} \times \dfrac{10^{-3-5}}{10^{11-3}} = 2 \times \dfrac{10^{-8}}{10^{8}} = 2 \times 10^{-8-8} = \mathbf{2.0 \times 10^{-16}}$

4. First the estimate. The rounding for the *numbers* might be

$\dfrac{\cancel{4} \times 6}{\cancel{4} \times 10} = \mathbf{0.6}$ For the *exponents*: $\dfrac{10^{4} \times 10^{-10}}{10^{-4} \times 10^{-5}} = \dfrac{10^{-6}}{10^{-9}} = 10^{9} \times 10^{-6} = \mathbf{10^{3}}$

$\approx 0.6 \times 10^{3} \approx \mathbf{6 \times 10^{2}}$ (*estimate*) in scientific notation.

For the *precise* answer, doing numbers and exponents separately,

$\dfrac{(3.62 \times 10^{4})(6.3 \times 10^{-10})}{(4.2 \times 10^{-4})(9.8 \times 10^{-5})} = \dfrac{3.62 \times 6.3}{4.2 \times 9.8} = \boxed{0.55}$ The exponents are done as in the estimate above.

$= 0.55 \times 10^{3} = \boxed{\mathbf{5.5 \times 10^{2}}}$ (final) in scientific notation (and close to the estimate).

5. 4.8×10^{9} 6. 4.2×10^{-18} 7. 2.8×10^{5} 8a. 1.25×10^{11} 8b. 8.8×10^{-15}

* * * * *

SUMMARY – Scientific Notation

1. When writing a number between -1 and 1, place a *zero* in *front* of the decimal point. Do *not* write .42 or $-.74$; *do* write **0.**42 or $-$**0.**74
2. *Exponential* notation represents numeric values in three parts:
   - a *sign* in front showing whether the value is positive or negative;
   - a *number* (the significand);
   - times a *base* taken to a *power* (the exponential term).
3. In *scientific* notation, the significand must be a number that is 1 or greater, but less than 10, and the exponential term must be 10 to a whole-number power. This places the decimal point in the significand after the first number which is not a zero.
4. When moving a decimal in exponential notation, the sign in front never changes.
5. To keep the same numeric value when moving the decimal of a number in base 10 exponential notation, if you
   - move the decimal *Y times* to make the significand *larger*, make the exponent *smaller* by a *count* of Y;
   - move the decimal Y times to make the significand smaller, make the exponent larger by a count of Y.

   When moving the decimal, for the numbers after the sign in front,

   "If one gets *smaller*, the other gets *larger*. If one gets *larger*, the other gets *smaller*."
6. To *add or subtract* exponential notation by hand, all of the values must be converted to have the same exponential term.
   - Convert all of the values to have the same power of 10.
   - List the significands and exponential in columns.
   - Add or subtract the significands.
   - Attach the common exponential term to the answer.
7. In *multiplication and division* using scientific or exponential notation, handle numbers and exponential terms separately. Recite and repeat to remember:
   - Do numbers by number rules and exponents by exponential rules.
   - When you multiply exponentials, you add the exponents.
   - When you divide exponentials, you subtract the exponents.
   - When you take an exponential term to a power, you multiply the exponents.
   - To take the reciprocal of an exponential, change the sign of the exponent.
   - For any X: $1/(1/X) = X$
8. In calculations using exponential notation, try the significands on the calculator but the exponents on paper.
9. For complex operations on a calculator, do each calculation a *second* time using rounded numbers and/or a different key sequence on the calculator.

# # # #

Module 2 – The Metric System

Lesson 2A: Metric Fundamentals

Have you previously mastered the metric system? If you get a perfect score on the following *pretest*, you may skip to Lesson 2B. If not, complete Lesson 2A.

Pretest: Write answers to these, then check your answers at the end of Lesson 2A.

1. What is the mass, in kilograms, of 150 cm^3 of liquid water?
2. How many cm^3 are in a liter?
3. How many dm^3 are in a liter?
4. 2.5 pascals is how many millipascals?
5. 3,500 cg is how many kg?

* * * * *

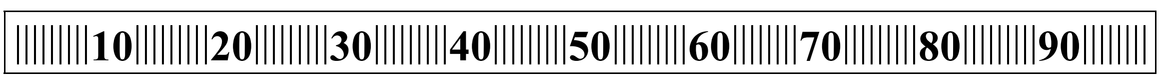
The Importance of Units

The fastest and most effective way to solve problems in chemistry is to focus on the **units** that measure quantities. In science, measurements and calculations are done using the **metric system**.

All measurement systems begin by defining **base units** that measure the **fundamental quantities**, including **distance**, **mass**, and **time**.

Distance

In the metric system, the base unit for distance is the **meter,** abbreviated **m**. One meter is about 39.3 inches, slightly longer than one yard. A meter stick is usually numbered in **centimeters.**



The relationships we will use most frequently in the metric system can be written based on the meter stick. Call this metric Rule

1. The "meter-stick" equalities

1 *meter* ≡ 10 **deci**meters ≡ 100 **centi** meters ≡ 1,000 **milli**meters

1000 meters ≡ 1 **kilo**meter

The symbol ≡ means "is *defined* as equal to" and/or "is *exactly* equal to."

Deci-, *centi-*, *milli-*, and *kilo-* are examples of **metric prefixes**.

To help in remembering Rule 1, picture the meter stick with 1 meter = 100 centimeters.

To help in remembering the kilometer definition, visualize 1,000 meter sticks in a row. That's a distance of one *kilo*meter. 1 kilometer ≡ 1,000 meter sticks.

Rule 1 defines the first three metric prefixes the "1 meter =" format. A second way to define the prefixes is using the "1-prefix" format in Rule 2.

2. The "one prefix" definitions

1 **milli**meter	≡ 10^{-3} meters	(≡ 1/1000th meter ≡ 0.001 meters)
1 **centi**meter	≡ 10^{-2} meters	(≡ 1/100th meter ≡ 0.01 meters)
1 **deci**meter	≡ 10^{-1} meters	(≡ 1/10th meter ≡ 0.1 meters)
1 **kilo**meter	≡ 10^{3} meters	(≡ 1,000 meters)

Because both the "1 meter =" and "1-prefix" formats are used in textbooks and calculations, you will need to write them both. Once you commit Rule 1 to memory, Rule 2 should be easy to write because it is mathematically equivalent. Rule 1 uses the "1 meter =" format and Rule 2 uses the "1-prefix" format.

Rules 1 and 2 are important because of Rule

3. You may substitute *any unit* for *meter* in the equalities above.

Rule 3 means that the prefix relationships that are true for meters are true for *any* units of measure. The three rules above allow us to write a wide range of equalities that we can use to solve science calculations, such as

1 *liter* ≡ 1,000 milli*liters* 1 centi*gram* ≡ 10^{-2} *grams* 1 kilo*calorie* ≡ 10^{3} *calories*

One prefix can be written in front of any metric base unit.

To use kilo- , deci-, centi- or milli- with *any* units, you simply need to be able to write or recall from memory the metric equalities in Rules 1 and 2 above.

Practice A: Write Rules 1 and 2 until you can do so from memory. Learn Rule 3. Then complete these problems without looking back at the rules.

1. From memory, add exponential terms to these blanks.

   a. 1 millimeter = ______meters b. 1 deciliter = _______ liter

2. From memory, add full metric *prefixes* to these blanks.

   a. 1000 grams = 1 _________gram b. 10^{-2} liters = 1 ___________liter

---

Volume

Volume is the amount of three-dimensional space that a material or shape occupies. Volume is termed a **derived quantity**, rather than a fundamental quantity, because it is derived from distance. Any volume unit can be converted to a distance unit cubed.

A cube that is 1 centimeter wide by 1 cm high by 1 cm long has a volume of one **cubic** centimeter (1 $\mathbf{cm}^3$). In biology and medicine, cm^3 is often abbreviated as "**cc**" but cm^3 is the abbreviation used in chemistry.

In chemistry, cubic centimeters are usually referred to as **milliliters,** abbreviated as **mL**. One milliliter is defined as exactly one cubic centimeter. Based on this definition, since

- 1,000 milli*meters* ≡ 1 *meter* , and 1,000 milli*anythings* ≡ 1 *anything*,
- 1,000 milli***liters*** is therefore defined as 1 **liter (1 L)**.

The mL is a convenient measure for smaller volumes, while the liter (about 1.1 quarts) is preferred when measuring larger volumes.

One liter is the same as **one cubic deci**<u>m</u>eter ($\mathbf{1\ dm^3}$). Note how these units are related.

- The volume of a cube that is 10 cm x 10 cm x 10 cm = 1,000 cm^3 = 1,000 mL
- Since 10 cm ≡ 1 dm, the volume of this *same* cube can be calculated as

  1 dm x 1 dm x 1 dm ≡ 1 cubic decimeter ≡ 1 dm^3

Based on the above, by definition, all of the following terms are *equal*.

1,000 cm^3 ≡ 1,000 mL ≡ 1 L ≡ 1 dm^3

What do you need to remember about volume? For now, just two more sets of equalities.

4. 1 milliliter (mL) ≡ 1 cm^3

5. 1 liter ≡ 1,000 mL ≡ 1,000 cm^3 ≡ 1 dm^3

<u>Mass</u>

Mass measures the amount of matter in an object. Mass and weight are not the same, but in chemistry, unless stated otherwise, we assume that mass is measured under constant gravity, so that mass and weight can be measured with the same instruments.

The metric base-unit for mass is the gram. One **gram** (**g**) was originally *defined* as the mass of *one cubic centimeter* of *liquid water* [$H_2O(\ell)$]at 4° Celsius, the temperature at which water has its highest density. The modern SI definition for one gram is a bit more complicated, but it is close to the historic definition. We will often use the historic definition in calculations involving liquid water if high precision is not required. For *most* calculations involving *liquid* water near room temperature, the following approximation may be used.

6. 1 $\mathbf{cm^3}$ H_2O(liquid) ≡ 1 **mL** $H_2O(\ell)$ ≈ 1.00 **gram** $H_2O(\ell)$ (≈ means *approximately*)

<u>Temperature</u>

Metric temperature scales are defined by the properties of water. The unit of the temperature scale is termed a **degree Celsius** (**ºC)**.

0ºC = the freezing point of water.

100ºC = the boiling point of water at a pressure of one atmosphere.

Room temperature is generally between 20ºC (which is 68ºF) and 25ºC (77ºF).

Time: The base unit for time in the metric system is the **second**.

Unit and Prefix Abbreviations

The following list of abbreviations should also be committed to memory. Given the unit or prefix, you need to be able to write the abbreviation, and given the abbreviation, you need to be able to write the prefix or unit.

Unlike other abbreviations, abbreviations for metric units do *not* have periods at the end.

Units: **m** = meter **g** = gram **s** = second

L = liter = **dm^3** = cubic decimeter **cm^3** = cubic centimeter = **mL** = "cc"

The most frequently used prefixes are: **k-** = kilo- **d-** = deci- **c-** = centi- **m-** = milli-

Additional metric system abbreviations for time units that we will use in these lessons include: minute = min, hour = hr, and year = yr.

Practice B: Write Rules 1 through 6 until you can do so from memory. Learn the unit and prefix abbreviations as well. Then complete the following problems without looking back at the lesson above.

1. Fill in the prefix abbreviations: 1 m = 10 ____m = 100 ____m = 1000 ____m
2. From memory, add metric prefix *abbreviations* to the following blanks.

   a. 10^3 g = 1 ____g b. 10^{-3} s = 1 ___s
3. From memory, add fixed-decimal numbers to these blanks.

   a. 1000 cm^3 = _________ mL b. 100 cm^3 $H_2O(\ell)$ ≈ _______ grams H_2O (ℓ)
4. Add fixed-decimal numbers: 1 liter ≡ ________ mL ≡ _______ cm^3 ≡ ________ dm^3

SI Units

The modern metric system (*Le **S**ystème **I**nternational d'Unités*) is referred to as the **SI system** and is based on what are termed the **SI units**. SI units are a subset of metric units that chooses **one** preferred metric unit as the standard for measuring each physical quantity.

The **SI standard** unit for distance is the meter, for mass is the kilogram, and for time is the second. Historically, the SI system is derived from what was termed the **mks system** because it measured **m**eters, **k**ilograms, and **s**econds.

In physics, and in many chemistry calculations that are based on relationships derived from physics, using *SI standard units* is essential to simplify calculations.

However, for dealing with laboratory-scale quantities, measurements and calculations frequently use units that are not SI but are metric. For example, in chemistry we generally measure volume in liters or milliliters instead of cubic meters. In Modules 4 and 5, you will learn to convert between the non-SI units often used in chemistry and the SI units that we will need to use for some types of chemistry calculations.

Learning the Metric Fundamentals

A strategy that can help in problem-solving is to start each homework assignment, quiz, or test by writing *recently* memorized rules at the top of your paper. By writing the rules at the beginning, you avoid having to remember them under time pressure later in the test.

We will use *equalities* to solve most initial chemistry calculations. The 7 metric basics define the equalities that we will use most often.

Metric Basics

1. 1 *meter* ≡ 10 decimeters
≡ 100 centimeters
≡ 1000 millimeters

1,000 meters ≡ 1 kilometer

2. **1 milli**meter ≡ **1 mm** ≡ 10^{-3} meter

1 centimeter ≡ **1 cm** ≡ 10^{-2} meter

1 decimeter ≡ **1 dm** ≡ 10^{-1} meter

1 kilometer ≡ **1 km** ≡ 10^{3} meter

3. Any word can be substituted for *meter* above.

4. 1 mL ≡ 1 cm^3 ≡ 1 cc

5. 1 liter ≡ 1000 mL ≡ 1000 cm^3 ≡ 1 dm^3

6. 1 cm^3 H_2O(liquid) **≡** 1 mL $H_2O(\ell)$

≈ 1.00 gram $H_2O(\ell)$

7. meter ≡ m ; gram ≡ g ; second ≡ s

A Note on Memorization

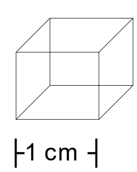
A goal of these lessons is to minimize what you must memorize. However, it is not possible to eliminate memorization from science courses. When there are facts which you must memorize in order to solve problems, these lessons will tell you. This is one of those times.

Memorize the table of metric basics in the box at the right. You will need to write them automatically, from memory, as part of most assignments in chemistry.

Memorization Tips

When you memorize, it helps to use as many *senses* as you can.

- *Say* the rules out loud, over and over, as you would to learn lines for a play.
- *Write* the equations several times, in the same way and order each time.
- *Organize* the rules into patterns, rhymes, or mnemonics.
- *Number* the rules so you know which rule you forgot, and when to stop.
- *Picture* real objects:
  - Sketch a meter stick, then write the first two metric rules and compare to your sketch.
  - For volume, mentally picture a 1 cm x 1 cm x 1 cm = ***1 cm³*** cube. Call it *one mL*. Fill it with water to make a *mass* of 1.00 *grams*.



After repetition, you will recall new rules *automatically*. That's the goal.

Practice C: Study the 7 rules in the *Metric Basics* table above, then write the table on paper from memory. Repeat until you can write all parts of the table from memory. Then cement your knowledge by answering these questions.

1. In your mind, picture a kilometer and a millimeter. Which is larger?
2. Which is larger, a kilojoule or a millijoule?
3. Name four units that can be used to measure volume in the metric system.
4. How many liters are in a kiloliter?
5. What is the mass of 15 milliliters of liquid water?
6. One liter of liquid water has what mass in grams?
7. What is the volume of one gram of ice?

ANSWERS

Pretest: 1. 0.15 kg 2. 1,000 cm^3 3. 1 dm^3 4. 2,500 millipascals 5. 0.035 kg

Practice A

1a. 1 millimeter = $\mathbf{10^{-3}}$ meters 1b. 1 deciliter = $\mathbf{10^{-1}}$ liter

2a. 1000 grams = 1**kilo**gram 2b. 10^{-2} liters = 1 **centi**liter

Practice B

1. 1 m = 10 **d**m = 100 **c**m = 1000 **m**m 2a. 10^3 g = 1 **k**g 2b. 10^{-3} s = 1 **m**s

3a. 1000 cm^3 = **1000** mL 3b. 100 cm^3 $H_2O(\ell)$ = **100** grams $H_2O(\ell)$

4. 1 liter ≡ **1000** mL ≡ **1000** cm^3 ≡ **1** dm^3

Practice C

1. A kilometer 2. A kilojoule
3. Possible answers include cubic centimeters, milliliters, liters, cubic decimeters, cubic meters, and any metric distance unit cubed.
4. 1,000 liters 5. 15 grams 6. 1,000 grams
7. These lessons have not supplied the answer. Water expands when it freezes. So far, we only know the answer for liquid water.

* * * * *

Lesson 2B: Metric Prefixes

Pretest: If you have previously mastered use of the prefixes in the table below, try the Practice B problems at the end of this lesson. If you get those right, you may skip this lesson.

* * * * *

Additional Prefixes

For measurements of very large or very small quantities, prefixes larger than *kilo-* and smaller than *milli-* may be used. The 13 prefixes encountered most frequently are listed in the table at the right. Note that

- Outside of the range between 3 and – 3, metric prefixes are abbreviations of powers of 10 that are divisible by **3**.
- When a full prefix name is written, the first letter is not normally capitalized.
- For prefixes above ***k-*** (*kilo-*), the *abbreviation* for a prefix must be capitalized.
- For the prefixes ***k-*** and below, all letters of the abbreviation must be lower case.

Prefix	Abbreviation	Means
tera-	T-	x 10^{12}
giga-	G-	x 10^{9}
mega-	M-	x 10^{6}
kilo-	k-	x 10^{3}
hecto-	h-	x 10^{2}
deka-	da-	x 10^{1}
deci-	d-	x 10^{-1}
centi-	c-	x 10^{-2}
milli-	m-	x 10^{-3}
micro-	μ- (mu) *or* u-	x 10^{-6}
nano-	n-	x 10^{-9}
pico-	p-	x 10^{-12}
femto-	f-	x 10^{-15}

Using Prefixes

A metric prefix is interchangeable with the exponential term it represents. For example, during measurements and/or calculations:

- An *exponential* term can be *substituted* for its equivalent metric prefix.

  Examples: 7.0 *milli*liters = 7.0 **x 10^{-3}** liters

  5.6 kg = 5.6 **x 10^{3}** g

  43 nanometers = 43 nm = 43 **x 10^{-9}** m

- A metric *prefix* can be substituted for its equivalent exponential term.

  Examples: 3.5 x 10^{-12} meters = 3.5 **pico**meters = 3.5 pm

  7.2 x 10^{6} watts = 7.2 **mega**watts

In calculations, we will often need to convert between a prefix and its equivalent exponential term. One way is to apply the prefix definitions.

Q1. From memory, fill in these blanks with prefixes (do not abbreviate).

a. 10^{3} grams = 1 __________gram b. 2 x 10^{-3} meters = 2 _________ meters

Q2. From memory, fill in these blanks with prefix *abbreviations*.

a. 2.6 x 10^{-1} L = 2.6 ____L b. 6 x 10^{-2} g = 6 ____g

Q3. Fill in these blanks with exponential terms (use the table above *if* needed).

a. 1 gigajoule = 1 x ________ joules b. 9 μm = 9 x _________ m

* * * * *

1a.	10^3 grams = 1 **kilo**gram	1b.	2×10^{-3} meters = 2 **milli**meters
2a.	2.6×10^{-1} L = 2.6 **d**L	2b.	6×10^{-2} g = 6 **c**g
3a.	1 gigajoule = 1 x $\mathbf{10^9}$ joules	3b.	9 μm = 9 $\mathbf{\times 10^{-6}}$ m

From the prefix definitions, even if you are not yet familiar with a unit or the quantity that the unit is measuring, you can convert between its *prefix*-unit value and its value using exponentials.

Science Versus Computer-Science Prefixes

Computer science, which calculates based on powers of 2, uses slightly different definitions for prefixes, such as *kilo-* = 2^{10} = 1,024 instead of 1,000. However, in chemistry and all other sciences, for all base units, the prefix to power-of-10 relationships in the metric-prefix table are *exact* definitions.

Learning the Additional Prefixes

To solve calculations, you will need to recall each of the rows in the table of 13 metric prefixes quickly and automatically. To begin, practice writing the table from memory. To help, look for patterns and memory devices. Note

- **T**era- = **T-** = 10^{Twelve} and **n**ano- (which connotes *small*) = **n-** = $\mathbf{10^{-\text{nine}}}$.

Focusing on those two can help to "anchor" the prefixes near them in the table.

Then make a self-quiz: on a sheet of paper, draw a table 3 columns across and 14 rows down. In the top row, write

Prefix	**Abbreviation**	**Means**

Fill in the table. Repeat writing the table until you can do so from memory, then try the problems below without looking back at your table.

Practice A: Use a sticky note to mark the answer page at the end of this lesson.

1. From memory, add exponential terms to these blanks.

   a. 7 microseconds = 7 x ______ seconds b. 9 fg = 9 x ________ g

   c. 8 cm = 8 x ________ m d. 1 ng = 1 x ________ **g**

2. From memory, add full metric *prefixes* to these blanks.

   a. 6×10^{-2} amps = 6 ____________ amps b. 45×10^9 watts = 45 ________watts

3. From memory, add prefix *abbreviations* to these blanks.

   a. 10^{12} g = 1 ____g b. 10^{-12} s = 1 ___s c. 5×10^{-1} L = 5 ____ L

4. When writing prefix abbreviations *by hand*, write so that you can distinguish between (add a prefix abbreviation) 5×10^{-3} g = 5 ____g and 5×10^6 g = 5 ____g

5. For which prefix abbreviations is the first letter always capitalized?

6. Write 0.30 gigameters/second without a prefix, in scientific notation.

Converting Between Prefix Formats

To solve calculations in chemistry, we will often use conversion factors that are constructed from metric prefix definitions. For those definitions, we have learned two types of equalities.

- Our "meter stick" equalities are based on what *one unit* is equal to:

1 meter ≡ 10 *deci*meters ≡ 100 *centi*meters ≡ 1,000 *milli*meters

- Our prefix definitions are based on what *one prefix* is equal to, such as *nano* = 10^{-9} .

It is essential to be able to correctly write *both* forms of the metric definitions, because work in science often uses both.

For example, to convert between milliliters and liters, we can use *either*

- 1 mL = $\mathbf{10^{-3}}$ L , based on what *1 milli-* means, *or*
- 1,000 mL = 1 L ; which is an easy-to-visualize definition of one liter.

Those two equalities are equivalent. The second equality is simply the first with the numbers on both sides multiplied by 1,000.

However, note that **1** mL = 10^{-3} L , but **1** L = 10^{3} mL . The numbers in the equalities change depending on whether the 1 is in front of the prefix or the unit. Which format should we use? How do we avoid errors?

In these lessons, we will generally use the *one prefix* equalities to solve problems. After learning the fundamental definitions for the 10 prefixes in the table, such as 1 milli- = $\mathbf{10^{-3}}$, using the definitions makes conversions easy to check.

Once those prefix, abbreviation, and meanings are in memory, we will then need to "watch where the 1 is." If you need to write or check prefix equalities in the "one **unit** =" format, you can derive them from the *one prefix* definitions, by writing the table if needed.

For example, 1 gram = ______ micrograms?

- The prefix table show that 1 **micro**-anything = $\mathbf{10^{-6}}$ anythings, so
- 1 microgram = 10^{-6} grams
- To get a 1 in front of gram, we multiply both sides by 10^{6}, so
- **1 gram = $\mathbf{10^{6}}$ micrograms** (**= $\mathbf{10^{6}}$ μg =** 1,000,000 micrograms **)**

The steps above can be summarized as the *reciprocal* rule for prefixes:

If **1 prefix- = $\mathbf{10^a}$** , 1 ***unit*** = $\mathbf{10^{-a}}$ *prefix*-units

In words:

To change a prefix definition between the "1 prefix- = " format and the "1 unit = " format, change the sign of the exponent.

If you need to check your logic, write a familiar example:

Since 1 *milli*liter = $\mathbf{10^{-3}}$ liter , then 1 liter = $\mathbf{10^3}$ milliliters = 1,000 mL

Fill in these blanks with exponential terms.

Q1. 1 nanogram = 1 x ______ grams , so 1 gram = 1 x ______ nanograms

Q2. 1 dL = 1 x ______ liters , so 1 L = 1 x ______ dL

* * * * *

A1. 1 nanogram = 1 x $\mathbf{10^{-9}}$ grams , so 1 gram = 1 x $\mathbf{10^9}$ nanograms

A2. 1 dL = 1 x $\mathbf{10^{-1}}$ liters , so 1 L = 1 x $\mathbf{10^1}$ dL = 10 dL

To summarize:

- When using metric prefix definitions, be careful to note whether the **1** is in front of the prefix or the unit.
- To avoid confusing the signs of the exponential terms in prefix definitions, memorize the table of 13 *one prefix* definitions. Then, if you need an equality with a "1 unit = $\mathbf{10^x}$ prefix-unit" format, reverse the sign of the prefix definition.

Practice B: Write the table of the 13 metric prefixes until you can do so from memory, then try to do these without consulting the table.

1. Fill in the blanks with exponential terms.

   a. 1 terasecond = 1 x ______ seconds , so 1 second = 1 x ______ teraseconds

   b. 1 μg = 1 x ______ grams , so 1 g = 1 x ______ μg

2. Apply the reciprocal rule to add exponential terms to these *one unit* equalities.

   a. 1 gram = _______ centigrams b. 1 meter = ___________ picometers

   c. 1 s = ___________ ms d. 1 s = ___________ Ms

3. Add exponential terms to these blanks. Watch where the 1 is!

   a. 1 micromole = _____ moles b. 1 g = 1 x _______ Gg

   c. 1 hectogram = 1 x _______ grams d. f. 1 fL = ________ L

ANSWERS

Practice A

1a. 7 x 10^{-6} seconds 1b. 9 x 10^{-15} g 1c. 8 x 10^{-2} m 1d. 1 x 10^{-9} **g**

2a. 6 **centi**amps 2b. 45 **giga**watts 3a. 1 **T**g 3b. 1 **p**s 3c. 5 **d**L

4. 5 **mg** and 5 **Mg** 5. **M-**, **G-**, and **T-**. 6. **3.0 x 10^8** meters/second

Practice B

1. a. 1 terasecond = 1 x 10^{12} seconds , so 1 second = 1 x 10^{-12} teraseconds
   b. 1 μg = 1 x 10^{-6} grams , so 1 g = 1 x 10^{6} μg
2. a. 1 gram = 10^2 centigrams (For " 1 *unit* = ", take reciprocal (reverse sign) of prefix meaning)
   b. 1 meter = 10^{12} picometers c. 1 s = 10^3 ms d. 1 s = 1 x 10^{-6} Ms
3. a. 10^{-6} moles 3b. 1 x 10^{-9} Gg 3c. 1 x 10^2 grams 3d. 10^{-15} L

* * * * *

Lesson 2C: Cognitive Science – and Flashcards

In this lesson, you will learn a *system* that will help you automatically recall the vocabulary needed to read science with comprehension and the facts needed to solve calculations.

Human Cognitive Architecture

Cognitive science studies how the mind works and how it learns. The model that science uses to describe learning includes the following fundamentals.

- The purpose of learning is to solve problems. You solve problems using information from your immediate environment and your memory.

The human brain contains different types of memory, including

- **Working** memory: the part of your brain where you solve problems.
- **Short-term** memory: information that you remember for only a few days.
- **Long-term** memory: information that you can recall for many years.

Working memory is limited, but human long-term memory has enormous capacity. The goal of learning is to move new information from short into long-term memory so that it can be recalled by working memory for years after initial study. If information is not moved into long-term memory, useful learning has not taken place.

Children learn speech naturally, but most other learning requires repeated *thought* about the meaning of new information, plus *practice* at recalling new facts and using new skills that is *timed* in ways that encourage the brain to move new learning from short to long-term memory.

The following principles of cognitive science will be helpful to keep in mind during your study of chemistry and other disciplines.

1. **Learning is cumulative.** Experts in a field learn new information quickly because they already have in long-term memory a storehouse of knowledge about the context

surrounding new information. That storehouse must be developed over time, with practice.

2. **Learning is incremental** (done in small pieces)**.** Especially for an unfamiliar subject, there is a limit to how much new information you can move into long-term memory in a short amount of time. Knowledge is extended and refined gradually. In learning, *steady* wins the race.

3. **Your brain can do parallel processing.** Though adding information to long term memory is a gradual process, studies indicate that your brain can work on separately remembering what something looks like, where you saw it, what it sounds like, how you say it, how you write it, and what it means, all at the same time. The cues associated with each separate type of memory can help to trigger the recall of information needed to solve a problem, so it helps to use multiple strategies. When learning new information: listen, see, say, write, and try to connect it to other information that helps you to remember its meaning.

4. **The working memory in your brain is limited.** Working memory is where you think. Try multiplying 56 by 23 in your head. Now try it with a pencil, a paper, and your head. Because of limitations in working memory, manipulating multiple pieces of new information "in your head" is difficult. Learning stepwise procedures (standard algorithms) that write the results of middle steps is one way to reduce "cognitive load" during problem solving.

5. **"Automaticity in the fundamentals"** is another learning strategy that can help to overcome limitations in working memory. When you can recall facts quickly due to repeated practice, more working memory is available for higher level thought.

   You can do work that is *automatic* while you think (most of us can think while walking), but it is difficult to *think* about more than one problem at once.

6. **Concepts are crucial.** Your brain works to construct a "conceptual framework" to categorize knowledge being learned so that you can recall facts and procedures when you need them. The brain tends to store new information in long-term memory only if it is in agreement with your "mental models" of concepts. In addition, if you have a more complete and accurate understanding of "the big picture," your brain is better able to judge which information should be selected to solve a problem.

   Concepts do not replace the need to move key facts and procedures into your long-term memory, but knowing concepts speeds initial learning, recall, and appropriate application of your knowledge in long-term memory.

7. **"You can always look it up" is a poor strategy for problem-solving.** Your working memory is quite limited in how much information it can manipulate that is not in your long-term memory. The more information you must stop to look up, the less likely you will be able to follow your train of thought to the end of a complex problem.

Building Long-Term Memory

How can you promote the retention of needed fundamentals? It takes practice, but some forms of practice are more effective than others. Attention to the following factors can improve your retention of information in long-term memory.

1. **Overlearning.** If you practice until you can recall new information only one time, you will tend to recall that information for only a few days. To be able to recall new facts and skills for more than a few days, *repeated* practice to perfection (which cognitive scientists call overlearning) is necessary.
2. **The spacing effect.** To *retain* what you learn, 20 minutes of study spaced over 3 days is more effective than one hour of study for one day.

   Studies of "massed versus distributed practice" show that if the initial learning of facts and vocabulary is practiced over 3-4 days, then re-visited weekly for 2-3 weeks, then monthly for 3-4 months, it can often be recalled for decades thereafter.
3. **Effort.** Experts in a field usually attribute their success to "hard work over an extended period of time" rather than to "talent."
4. **Core skills.** The facts and processes you should practice most often are those needed most often in the discipline.
5. **Get a good night's sleep.** There is considerable evidence that while you sleep, your brain reviews the experience of your day to decide what to store in long-term memory. Sufficient sleep promotes retention of what you learn.

[For additional science that relates to learning, see Willingham, Daniel [2007] *Cognition: The Thinking Animal.* Prentice Hall, and Bruer, John T. [1994] *Schools for Thought*. MIT Press.]]

Practice A: These are "black ink" questions: Answer them in your spiral notebook.)

1. What is "overlearning?"
2. What is the "spacing effect?"
3. Define "automaticity" as it applies to cognition, and briefly explain why it is important.

Flashcards

Which is more important in learning: Knowing facts or concepts? Cognitive studies have found that you must know both. To "think as an expert," you need a storehouse of factual information in long-term memory that you can apply to new and unique problems, organized by concepts that add meaning to what you know .

In these lessons, we will use the following flashcard system to master fundamentals that need to be recalled automatically in order to efficiently solve problems. Using this system, you will make two types of flashcards:

- "One-way" cards for questions that make sense in *one* direction; and
- "Two-way" cards for facts that need to be recalled in both directions.

If you have access to about 30 3″ x 5″ index cards, you can get started now. Plan to buy tomorrow about 100-200 3x5 index cards, lined or unlined. (A variety of colors is helpful but not essential.) Complete these steps.

1. On 12-15 of your 30 initial cards (of the same color if possible), cut a triangle off the top-right corner, making cards like this:

These cards will be used for questions that go in *one* direction.

Keeping the notch at the *top right* will identify the *front* side.

2. Using the following table, cover the *answers* in the right column with a folded sheet or index card. For each question in the left column, verbally answer, then slide the cover sheet down to check your answer. Put a check beside questions that you answer accurately and without hesitation. When done, write the questions and answers with*out* checks onto the notched cards.

Front-side of cards (with notch at top right):	**Back Side -- Answers**
To convert to scientific notation, move the decimal to…	After the first number that is not a zero
If you make the significand larger	Make the exponent smaller
$42^{\mathbf{0}}$	Any positive number to the zero power = 1
To *add* or *subtract* in exponential notation	Make all exponents the same
Simplify 1/(1/*X*)	*X*
To divide exponentials (with the same base)	Subtract the exponents
To bring an exponent from the bottom of a fraction to the top	Change its sign
1 cc ≡ 1 ___ ≡ 1 ___	1 cc ≡ 1 cm^3 ≡ 1 mL
0.0018 in scientific notation =	1.8×10^{-3}
1 L ≡ ___ mL ≡ ___ dm^3	1 L ≡ 1000 mL ≡ 1 dm^3
To multiply exponentials (that have the same base)	Add the exponents
Simplify $1/10^X$	10^{-X}
74 in scientific notation =	7.4×10^1
The original definition of 1 gram	The mass of 1 cm^3 of liquid water at 4ºC.
8 x 7 =	56
42/6 =	7

If there is any multiplication or division up to 12 x 12 that you cannot answer *instantly*, add those to your list of one-sided cards. If you need a calculator to do number math, parts of chemistry such as “balancing an equation” will be frustrating. With flashcard practice, you will quickly be able to remember what you need to know.

3. To make "two-way" cards, use the index cards as they are, with*out* a notch cut.

   For the following cards, first cover the *right* column, then put a check on the left if you can answer the left column question *quickly* and correctly. Then cover the *left* column and check the right side if you can answer the right-side *automatically*.

   When done, if a row does not have *two* checks, make the flashcard.

   Two-way cards (with*out* a notch):

10^3 g or 1,000 g = 1 __g	1 kg = ____ g
Boiling temperature of water	100 degrees Celsius -- if 1 atm. pressure
1 nanometer = 1 x ___ meters	1 ____meter = 1 x 10^{-9} meters
Freezing temperature of water	0 degrees Celsius
4.7 x10^{-3} = _____________(number)	0.0047 = 4.7 x$10^{?}$

1 GHz =$10^{?}$ Hz	10^9 Hz = 1 __Hz
1 pL = $10^{?}$ L	10^{-12} L = 1 __L
3/4 = 0.?	0.75 = ? / ?
1/8 = 0.?	0.125 = 1 / ?

2/3 = 0.?	0.666… = ? / ?
1/80 = 0.?	0.0125 = 1 / ?
1 dm^3 = 1 ___	1 L = 1 __
1/4 = 0.?	0.25 = 1 / ?

More two-way cards (with*out* a notch) for the metric-prefix definitions.

mega- = x $10^{?}$	x 10^6 = ? Prefix
nano- = x $10^{?}$	x 10^{-9} = ? pref.
giga- = x $10^{?}$	x 10^9 = ? Prefix
micro- = x $10^{?}$	x 10^{-6} = ? pref.
deci- = x $10^{?}$	x 10^{-1} = ? pref.
tera- = x $10^{?}$	x 10^{12} = ? pref.
pico- = x $10^{?}$	x 10^{-12} = ? pref
hecto- = x $10^{?}$	x 10^2 = ? Prefix
deka- = x $10^{?}$	x 10^1 = ? Prefix
femto- = x $10^{?}$	x 10^{-15} = ? pref
M- = x $10^{?}$	x 10^6 = ? abbr.

d- = x $10^{?}$	x 10^{-1} = ? abbr.
m- = x $10^{?}$	x 10^{-3} = ? abbr.
T- = x $10^{?}$	x 10^{12} = ? abbr.
n- = x $10^{?}$	x 10^{-9} = ? abbr.
f- = x $10^{?}$	x 10^{-15} = ? abb
μ- = x $10^{?}$	x 10^{-6} = ? abbr.
G- = x $10^{?}$	x 10^9 = ? abbr.
da- = x $10^{?}$	x 10^1 = ? abbr.
p- = x $10^{?}$	x 10^{-12} = ? abb
c- = x $10^{?}$	x 10^{-2} = ? abbr.
h- = x $10^{?}$	x 10^2 = ? abbr.

micro =? abbr.	μ- = ? pref.
mega =? abbr.	M = ? pref.
deka =? abbr.	da = ? pref.
pico =? abbr.	p = ? prefix
deci =? abbr.	d = ? prefix
hecto =? abbr.	h = ? prefix
tera =? abbr.	T = ? prefix
milli =? abbr.	m = ? pref.
femto =? abbr.	f = ? prefix
giga =? abbr.	G = ? pref.
nano =? abbr.	n = ? prefix

   Which cards you need will depend on your prior knowledge, but when in doubt, make the card. On fundamentals, you need quick, confident, accurate recall -- every time.

4. **Practice** with one type of card at a time.

   - **For front-sided cards**, if you get a card right quickly, place it in the *got -it* stack. If you miss a card, say it. Close your eyes. Say it again. And again. If needed, write it several times. Return that card to the bottom of the *do* deck. Practice until every card is in the *got-it* deck.

- **For two-sided cards,** do the same steps as above in one direction, then the other.

5. Master the cards at least once, *then* apply them to the **Practice** on the topic of the new cards. Treat **Practice** as a practice test.
6. **For 3 days in a row,** repeat those steps. Repeat again before working assigned problems, before your next quiz, and before your next test that includes this material.
7. Make cards for new topics early: before the lectures on a topic if possible. Mastering fundamentals first will help in understanding lecture.
8. Rubber band and carry new cards. Practice during "down times."
9. After a few modules or topics, change card colors.

This system requires an initial investment of time, but in the long run it will save time and improve achievement.

The above flashcards are examples. As needed, add cards of your design and content.

Flashcards, Charts, or Lists?

What is the best strategy for learning new information? Use *multiple* strategies: numbered lists, mnemonics, phrases that rhyme, flashcards, reciting, and writing what must be remembered. Practice repeatedly, spaced over time.

For complex information, automatic recall may be less important than being able to methodically write out a *chart* for information that falls into *patterns*.

For the metric system, learning flashcards *and* the prefix chart *and* picturing the meter-stick relationships all help to fix these fundamentals in memory.

Practice B: Run your set of flashcards until all cards are in the "got-it" pile. *Then* try these problems. Make additional cards if needed. Run the cards again in a day or two.

1. Fill in the blanks.

Format: 1 prefix-	1 base unit
1 micrometer = ______ meters	1 meter = _______ micrometers
1 gigawatt = ______ watts	1 watt = ________ gigawatts
1 nanoliter = ______ liter	_______ nanoliters = 1 liter

2. Add exponential terms to these blanks. Watch where the 1 is!

   a. 1 picocurie = ___________ curies

   b. 1 megawatt = ___________watts

   c. 1 dag = ____________ g

   d. 1 mole = ___________ millimoles

e. 1 m = __________ nm f. 1 kPa = ___________ Pa

3. Answer these without using a calculator.

a. $10^{-6}/10^{-8}$ = b. 1/5 = ___.___ ___ c. 1/50 = ___.___ ___ ___

ANSWERS

Practice A

1. Repeated practice to perfection. 2. Study over several days gives better retention than "cramming."
3. Automaticity means practicing the recall of fundamentals and stepwise procedures (algorithms) until they can be recalled quickly and automatically. Automaticity overcomes limits in human working memory.

Practice B

1.

1 micrometer = $\mathbf{10^{-6}}$ meters	1 meter = $\mathbf{10^{6}}$ micrometers
1 gigawatt = $\mathbf{10^{9}}$ watts	1 watt = $\mathbf{10^{-9}}$ gigawatts
1 nanoliter = $\mathbf{10^{-9}}$ liters	$\mathbf{10^{9}}$ nanoliters = 1 liter

2. a. 1 picocurie = $\mathbf{10^{-12}}$ curies b. 1 megawatt = $\mathbf{10^{6}}$ watts c. 1 dag = $\mathbf{10^{1}}$ g

d. 1 mole = $\mathbf{10^{3}}$ millimoles e. 1 m = $\mathbf{10^{9}}$ nm f. 1 kPa = $\mathbf{10^{3}}$ Pa

3. a. $10^{-6}/10^{-8} = 10^{-6+8} = \mathbf{10^{2}}$ b. 1/5 = **0.20** c. 1/50 = **0.020**

* * * * *

Lesson 2D: Calculations With Units

Pretest: If you can do the following two problems correctly, you may skip this lesson. Answers are at the end of the lesson. Answer Q1 (black ink) in your notebook.

1. Find the volume of a sphere that is 4.0 cm in diameter. ($V_{sphere} = 4/3\pi r^3$).
2. Multiply: $2.0\ \frac{g \bullet m}{s^2} \bullet \frac{3.0\ m}{4.0 \times 10^{-2}} \bullet 6.0 \times 10^2\ s =$

* * * * *

(Except as noted, do the following lesson without a calculator,.)

Adding and Subtracting With Units

In science, calculations are nearly always based on measurements of physical quantities. A measurement consists of a numeric value *and* its unit.

When doing calculations in science, it is essential to write the *unit* after the numbers during both measurements and calculations. Why?

- Units give physical meaning to a quantity.
- Units are the best indicators of what steps are needed to solve problems, and
- Units provide a check that you have done a calculation correctly.

When solving calculations, the math must take into account *both* the numbers and their units. Use the following three rules.

Rule 1. When *adding* or *subtracting*, the *units must* be the *same* in the quantities being added and subtracted, and those same units must be added to the answer.

Rule 1 is logical. Apply it to these two examples.

A. 5 apples + 2 apples = ________ B. 5 apples + 2 oranges = _________

* * * * *

The example A answer is 7 apples. In example B, you can't add apples and oranges. By Rule 1, you can add numbers that have the same units, but you can*not* add numbers directly that do *not* have the same units.

Apply Rule 1 to this problem:

$$\begin{array}{r} 14.0 \text{ grams} \\ - \ \underline{\ \ 7.5 \text{ grams}} \end{array}$$

* * * * *

$$\begin{array}{r} 14.0 \text{ grams} \\ - \ \underline{\ \ 7.5 \text{ grams}} \\ \mathbf{6.5} \ \textit{\textbf{grams}} \end{array}$$

If the units are all the same, you can add or subtract numbers, but you must add the common unit to the answer.

Multiplying and Dividing With Units

The rules for *multiplying* and *dividing* with units is different, but logical.

Rule 2. When multiplying and dividing *units*, the units multiply and divide.

Rule 3. When multiplying and dividing, separate the numbers, exponentials, and units. Solve the three parts separately, then recombine the terms.

Apply Rules 2 and 3 to this problem: If a postage stamp has the dimensions 2.0 cm x 3.0 cm, the surface area of one side of the stamp = ___________

* * * * *

Area of a rectangle = l x w =

= 2.0 cm x 4.0 cm = **(2.0 x 3.0)** x (**cm x cm**) = **6.0 cm²** = 6.0 ***square*** centimeters

Apply Rules 2 and 3 to these. Solve without a calculator.

a. $\dfrac{12 \times 10^{-3} \text{ m}^4}{3.0 \times 10^{2} \text{ m}^2} =$

b. $\dfrac{9.0 \times 10^{3} \text{ m}^6}{3.0 \times 10^{-2} \text{ m}^6} =$

* * * * *

a. $\dfrac{12}{3.0} \bullet \dfrac{10^{-3}}{10^{2}} \bullet \dfrac{\text{m}^4}{\text{m}^2} = \mathbf{4.0 \times 10^{-5} \ m^2}$

b. $\dfrac{9.0 \ \times \ 10^{3} \ \cancel{\text{m}^6}}{3.0 \ \times \ 10^{-2} \ \cancel{\text{m}^6}} = \mathbf{3.0 \times 10^{5}}$ (with no unit.)

In science, the *unit math* must be done, and a *calculated* unit *must* be included as part of answers (except in rare cases such as *part b* above, when all of the units cancel).

If multiple units are part of a calculation, the math for each unit is done separately.

When solving calculations, you often need to use a calculator to do the number math, but both the *exponential* and *unit* math nearly always can (and should) be done with*out* a calculator. On this problem, use a calculator for the numbers. Do the exponential and unit math on paper but using mental arithmetic.

Q. Simplify: $4.8 \; \frac{g \cdot m}{s^2} \cdot 3.0 \; m \cdot \frac{6.0 \;\; s}{9.0 \times 10^{-4} \; m^2} =$

* * * * *

A. Do the math for numbers, exponentials, and then *each* unit separately.

$$= \frac{86.4}{9.0} \cdot \frac{1}{10^{-4}} \cdot \frac{g \cdot \cancel{m}}{s \cdot \cancel{s}} \cdot \cancel{m} \cdot \frac{\cancel{s}}{\cancel{m^2}} = \mathbf{9.6 \times 10^4 \; \frac{g}{s}}$$

This answer unit can also be written as $\mathbf{g \cdot s^{-1}}$, but you will find it helpful to use the **x/y** unit format until we work with mathematical equations later in the course.

Practice: Do *not* use a calculator, except as noted. If you need just a few reminders, do Problems 7 and 9. If you need more practice, do more. After completing each problem, check your answer. If you miss a problem, review the rules to figure out why before continuing.

1. $16 \; cm - 2 \; cm =$
2. $12 \; cm \cdot 2 \; cm^2 =$
3. $3.0 \; g \; / \; 9.0 \; g =$
4. $\frac{18.0 \;\; s^{-5}}{3.0 \;\; s^2} =$
5. $\frac{24 \; L^5}{3.0 \; L^{-4}} =$
6. $\frac{18 \times 10^{-3} \;\; g \cdot m^5}{3.0 \times 10^1 \;\; m^2} =$
7. $12 \times 10^{-2} \; \frac{L \cdot g}{s} \cdot 2.0 \; m \cdot \frac{2.0 \;\; s^3}{6.0 \times 10^{-5} \; L^2} =$
8. A rectangular box has dimensions of 2.0 cm x 4.0 cm x 6.0 cm. Without a calculator, calculate its volume.
9. In the Pretest at the beginning of this lesson, complete
   a. Problem 1 (use a calculator).
   b. Problem 2 (do not use a calculator).

ANSWERS

Both the number *and* the ***unit*** must be written and correct.

Pretest: See answers to Problems 9a and 9b below.

1. 14 cm 2. 24 cm^3 3. 0.33 (*no* unit) 4. 6.0 s^{-7} 5. 8.0 L^9 6. 6.0×10^{-4} $g \cdot m^3$

7. $8.0 \times 10^3 \; \frac{g \cdot m \cdot s^2}{L}$ 8. $V_{\text{rectangular solid}}$ = length *times* width *times* height = **48 cm^3**

9a. Diameter = 4.0 cm, *radius* = 2.0 cm.

$V_{sphere} = 4/3\ \pi\ r^3 = 4/3\ \pi\ (2.0\text{ cm})^3 = 4/3\ \pi\ (8.0\text{ cm}^3) = (32/3)\ \pi\ \text{cm}^3 = 3\underline{3}.51\text{ cm}^3 = \mathbf{34\ cm^3}$

(If you use π = 3.14 , your answer will be $3\underline{3}.49\text{ cm}^3$ = $\mathbf{33\ cm^3}$. That's OK. Doubful digits may vary.)

9b. $\frac{(2.0)(3.0)(6.0)}{4.0} \cdot 10^4 \cdot \frac{g \cdot m \cdot m \cdot s}{s^2} = \mathbf{9.0 \times 10^4\ \frac{g \cdot m^2}{s}}$

* * * * *

SUMMARY – The Metric System

1. 1 *meter* ≡ 10 decimeters
   ≡ 100 centimeters
   ≡ 1000 millimeters

   1,000 meters ≡ 1 kilometer
2. **1 milli**meter ≡ **1 mm** = $10^{\mathbf{-3}}$ meter

   1 centimeter ≡ **1 cm** = $10^{\mathbf{-2}}$ meter

   1 decimeter ≡ **1 dm** = $10^{\mathbf{-1}}$ meter

   1 kilometer ≡ **1 km** = $10^{\mathbf{3}}$ meter
3. Any unit can be substituted for *meter* above.
4. 1 cm^3 ≡ 1 mL ≡ 1 cc
5. 1 liter ≡ 1000 mL ≡ 1 dm^3
6. 1 cm^3 $H_2O(\ell)$ ≡ 1 mL $H_2O(\ell)$ ≈ 1.00 g $H_2O(\ell)$
7. meter = m ; gram = g ; second = s
8. If **prefix- = $\mathbf{10^a}$** , 1 ***unit*** = $\mathbf{10^{-a}}$ *prefix*-units
9. To change a prefix definition from a "1 prefix-unit = " format to a "1 base unit = " format, change the exponent sign.
10. Rules for units in calculations:
    a. When adding or subtracting, the *units must* be the *same* in the numbers being added and subtracted, and those same units must be added to the answer.
    b. When multiplying and dividing units, the units multiply and divide.
    c. When multiplying and dividing, *group* the numbers, exponentials, and units separately. Solve the separate parts, then recombine the terms.

Prefix	**Abbreviation**	**Means**
tera-	T	x 10^{12}
giga-	G	x 10^9
mega-	M	x 10^6
kilo-	k	x 10^3
hecto-	h	x 10^2
deka-	da	x 10^1
deci-	d	x 10^{-1}
centi-	c	x 10^{-2}
milli-	m	x 10^{-3}
micro-	μ (mu) or u	x 10^{-6}
nano-	n	x 10^{-9}
pico-	p	x 10^{-12}
femto-	f-	x 10^{-15}

\# # # # #

Module 1 – Scientific Notation

From Text Page **3** *(Lesson 1A)*

Pretest:

1. Write these in *scientific* notation.

   a. $9{,}400 \times 10^{3} =$

   b. $0.042 \times 10^{6} =$

   c. $-0.0067 \times 10^{-2} =$

   d. $-77 =$

2. Write these answers in fixed-decimal notation.

   a. 14/10,000 =

   b. $0.194 \times 1000 =$

   c. $47^{0} =$

Page 4 (Lesson 1A):

Practice A: Write your answers, then check them at the end of this *lesson*.

1. (Rule 1) Write these as fixed-decimal numbers without an exponential term.

   a. $10^{7} =$

   b. $10^{-5} =$

   c. $10^{0} =$

2. (Rule 2) When dividing by 10,000 move the decimal to the _______________ by _____ places.

3. (Rule 2) Write these answers as fixed-decimal numbers.

   a. $0.42 \times 1000 =$

   b. 63/100 =

   c. $-74.6/10{,}000 =$

4. (Rule 4) Convert these values to fixed-decimal notation.

   a. $3 \times 10^{3} =$

   b. $5.5 \times 10^{-4} =$

   c. $0.77 \times 10^{6} =$

   d. $-95 \times 10^{-4} =$

Page 6 (Lesson 1A):

Practice B:

1. Convert these values to scientific notation.

   a. $5{,}420 \times 10^{3} =$

   b. $0.0067 \times 10^{-4} =$

   c. $0.00492 \times 10^{-12} =$

   d. $-602 \times 10^{21} =$

2. Which lettered parts in Problem 3 below must have powers of 10 that are negative when written in scientific notation?

3. Write these in scientific notation.

   a. 6,280 =   b. 0.0093 =

   c. 0.741 =   d. $-$1,280,000 =

4. Complete the problems in the *pretest* at the beginning of this lesson.

Page 7 (Lesson 1A):

Practice C: Check (✓) and do every *other* letter. If you miss one, do another letter for that set. Save a few parts for your next study session.

1. Write these answers in fixed-decimal notation.

   a. 924/10,000 =   b. 24.3 x 1000 =

   c. $-$0.024/10 =

2. Convert to scientific notation.

   a. 0.55×10^{5} b. 0.0092×100

   c. 940×10^{-6} d. 0.00032×10

3. Write these numbers in scientific notation.

   a. 7,700   b. 160,000,000

   c. 0.023   d. 0.00067

Page 8 (Lesson 1B):

Pretest: Do *not* use a calculator. Convert your final answers to scientific notation.

1. $(2.0 \times 10^{-4})\,(6.0 \times 10^{23}) =$

2. $\dfrac{10^{23}}{(100)(3.0 \times 10^{-8})} =$

3. $(-6.0 \times 10^{-18}) - (-2.89 \times 10^{-16}) =$

Page 9 (Lesson 1B):

Q. $(32.464 \times 10^{1}) - (16.2 \times 10^{-1}) =$ **?**

Page 9   (Lesson 1B):

Let's do problem 1 again. This time, first convert each value to *fixed-decimal* numbers, then do the arithmetic. Convert the final answer to scientific notation.

$$\begin{array}{rl} 32.464 \times 10^{1} & = \\ -\ \underline{16.2 \times 10^{-1}} & = \end{array}$$

Page 9   (Lesson 1B):

Practice A: Try these with*out* a calculator. On these, don't round. Do convert final answers to scientific notation. Do the odds first, then the evens if you need more practice.

1. $$\begin{array}{r} 64.202 \times 10^{23} \\ +\ \underline{13.2 \times 10^{21}} \end{array}$$

2. $(61 \times 10^{-7}) + (2.25 \times 10^{-5}) + (212.0 \times 10^{-6}) =$

3. $(-54 \times 10^{-20}) + (-2.18 \times 10^{-18}) =$

4. $(-21.46 \times 10^{-17}) - (-3{,}250 \times 10^{-19}) =$

Page 10   (Lesson 1B):

Q. Without using a calculator, simplify the top, then the bottom, then divide.

$$\frac{10^{-3} \times 10^{-4}}{10^{5} \times 10^{-8}} = \underline{\qquad\qquad} =$$

Page 10   (Lesson 1B):

Practice B: Write answers as 10 to a power. Do *not* use a calculator. Do the odds first, then the evens if you need more practice.

1. $1/10^{23} =$

2. $10^{-5} \times 10^{-6} =$

3. $\dfrac{1}{1/10^{-4}} =$

4. $\dfrac{10^{-3}}{10^{5}} =$

*Page **11**   (Lesson 1B):*

5. $\dfrac{10^{3} \times 10^{-6}}{10^{-2} \times 10^{-4}} =$

6. $\dfrac{10^{5} \times 10^{23}}{10^{-1} \times 10^{-6}} =$

7. $\dfrac{100 \times 10^{-2}}{1{,}000 \times 10^{6}} =$

8. $\dfrac{10^{-3} \times 10^{23}}{10 \times 1{,}000} =$

*Page **11** (Lesson 1B):*

Apply rule 1 to the following three problems.

a. Do not use a calculator: $(2 \times 10^{3})\ (4 \times 10^{23}) =$

b. Do the *significand* math on a calculator but try the exponential math in your head for $(2.4 \times 10^{-3})\ (3.5 \times 10^{23}) =$

c. Do significand math on a calculator but exponential math with*out* a calculator.

$\dfrac{6.5 \times 10^{23}}{4.1 \times 10^{-8}} =$

Page 12:

Apply Rule 2 to the following problem. Do *not* use a calculator.

$\dfrac{10^{-14}}{2.0 \times 10^{-8}} =$

Page 12:

Practice C

1. $(2.0 \times 10^{1})\ (6.0 \times 10^{23}) =$

2. $(5.0 \times 10^{-3})\ (1.5 \times 10^{15}) =$

3. $\dfrac{3.0 \times 10^{-21}}{-2.0 \times 10^{3}} =$

4. $\dfrac{6.0 \times 10^{-23}}{2.0 \times 10^{-4}} =$

5. $\dfrac{10^{-14}}{-5.0 \times 10^{-3}} =$

6. $\dfrac{10^{14}}{4.0 \times 10^{-4}} =$

7. Complete the problems in the *pretest* at the beginning of this lesson.

Page 13 (Lesson 1B):

Practice D

Start by doing every *other* letter. If you get those right, go to the next number. If not, do a few more of that number. Save one part of each question for your next study session.

1. Try these with*out* a calculator. Convert your final answers to scientific notation.

   a. $10^{-2} \times (6.0 \times 10^{23}) =$

b. $(-0.5 \times 10^{-2})(6.0 \times 10^{23}) =$

c. $\dfrac{3.0 \times 10^{24}}{6.0 \times 10^{23}} =$

d. $\dfrac{1}{5.0 \times 10^{23}} =$

e. $\dfrac{1.0 \times 10^{-14}}{4.0 \times 10^{-5}}$

f. $\dfrac{10^{10}}{2.0 \times 10^{-5}} =$

2. Use a calculator for the numbers but not for the exponents.

a. $\dfrac{2.46 \times 10^{19}}{6.0 \times 10^{23}} =$

b. $\dfrac{10^{-14}}{0.0072} =$

3. Do not use a calculator. Write answers as a power of 10.

a. $\dfrac{10^{7} \times 10^{-2}}{10 \times 10^{-5}} =$

b. $\dfrac{10^{-23} \times 10^{-5}}{10^{-5} \times 100} =$

4. Convert to scientific notation in the final answer. Do not round during these.

a. $(74 \times 10^{5}) + (4.09 \times 10^{7}) =$

b. $(5.122 \times 10^{-9}) - (-12{,}914 \times 10^{-12}) =$

Page 14 (Lesson 1C):

Pretest: If you can solve both problems of these problems correctly, skip this lesson. Convert final answers to scientific notation. Check your answers at the end of this lesson.

1. Solve with***out*** a calculator. $\dfrac{(10^{-9})(10^{15})}{(4 \times 10^{-4})(2 \times 10^{-2})} =$

2. Use a calculator for the numbers, but solve the exponentials by mental arithmetic.

$$\frac{(3.15 \times 10^{3})(4.0 \times 10^{-24})}{(2.6 \times 10^{-2})(5.5 \times 10^{-5})} =$$

Page 17 (Lesson 1C):

Then try these next three with*out* a calculator. Convert final answers to scientific notation. Round the significand in the answer to two digits.

1. $$\frac{4 \times 10^{3}}{(2.00)(3.0 \times 10^{7})} =$$

2. $$\frac{1}{(4.0 \times 10^{9})(2.0 \times 10^{3})} =$$

3. $$\frac{(3 \times 10^{-3})(8.0 \times 10^{-5})}{(6.0 \times 10^{11})(2.0 \times 10^{-3})} =$$

4. $$\frac{(3.62 \times 10^{4})(6.3 \times 10^{-10})}{(4.2 \times 10^{-4})(9.8 \times 10^{-5})} =$$

5. $$\frac{10^{-2}}{(750)(2.8 \times 10^{-15})} =$$

6. $$\frac{(1.6 \times 10^{-3})(4.49 \times 10^{-5})}{(2.1 \times 10^{3})(8.2 \times 10^{6})} =$$

7. $$\frac{1}{(4.9 \times 10^{-2})(7.2 \times 10^{-5})} =$$

8. For additional practice, do the two *Pretest* problems at the beginning of this lesson.

# # # #

Module 2 – The Metric System

Page 20 (Lesson 2A):

Pretest: Write answers to these, then check your answers at the end of Lesson 2A.

1. What is the mass, in kilograms, of 150 cm^3 of liquid water?
2. How many cm^3 are in a liter?
3. How many dm^3 are in a liter?
4. 2.5 pascals is how many millipascals?
5. 3,500 cg is how many kg?

Page 21 (Lesson 2A):

Practice A: Write Rules 1 and 2 until you can do so from memory. Learn Rule 3. Then complete these problems without looking back at the rules.

1. From memory, add exponential terms to these blanks.

   a. 1 millimeter = ______meters   b. 1 deciliter = _______ liter

2. From memory, add full metric *prefixes* to these blanks.

   a. 1000 grams = 1 _________gram   b. 10^{-2} liters = 1 ___________liter

Page 23 (Lesson 2A):

Practice B: Write Rules 1 through 6 until you can do so from memory. Learn the unit and prefix abbreviations as well. Then complete the following problems without looking back at the lesson above.

1. Fill in the prefix abbreviations: 1 m = 10 ____m = 100 ____m = 1000 ____m
2. From memory, add metric prefix *abbreviations* to the following blanks.

   a. 10^3 g = 1 ____g   b. 10^{-3} s = 1 ___s

3. From memory, add fixed-decimal numbers to these blanks.

   a. 1000 cm^3 = _________ mL   b. 100 cm^3 $H_2O(\ell)$ ≈ _______ grams H_2O (ℓ)

4. Add fixed-decimal numbers: 1 liter ≡ ________ mL ≡ _______ cm^3 ≡ ________ dm^3

Page 25 (Lesson 2A):

Practice C: Study the 7 rules in the *Metric Basics* table above, then write the table on paper from memory. Repeat until you can write all parts of the table from memory. Then cement your knowledge by answering these questions.

1. In your mind, picture a kilometer and a millimeter. Which is larger?
2. Which is larger, a kilojoule or a millijoule?
3. Name four units that can be used to measure volume in the metric system.

4. How many liters are in a kiloliter?

5. What is the mass of 15 milliliters of liquid water?

6. One liter of liquid water has what mass in grams?

7. What is the volume of one gram of ice?

Page 26 (Lesson 2B):

Q1. From memory, fill in these blanks with prefixes (do not abbreviate).

a. 10^3 grams = 1 _________gram b. 2×10^{-3} meters = 2 ________ meters

Q2. From memory, fill in these blanks with prefix *abbreviations*.

a. 2.6×10^{-1} L = 2.6 ____L b. 6×10^{-2} g = 6 ____g

Q3. Fill in these blanks with exponential terms (use the table above *if* needed).

a. 1 gigajoule = 1 x _______ joules b. 9 μm = 9 x ________ m

Page 27 (Lesson 2B):

Practice A: Use a sticky note to mark the answer page at the end of this lesson.

1. From memory, add exponential terms to these blanks.

a. 7 microseconds = 7 x ______ seconds b. 9 fg = 9 x ________ g

c. 8 cm = 8 x ________ m d. 1 ng = 1 x ________ **g**

2. From memory, add full metric *prefixes* to these blanks.

a. 6×10^{-2} amps = 6 ____________ amps b. 45×10^9 watts = 45 ________watts

3. From memory, add prefix *abbreviations* to these blanks.

a. 10^{12} g = 1 ____g b. 10^{-12} s = 1 ___s c. 5×10^{-1} L = 5 ____ L

4. When writing prefix abbreviations *by hand*, write so that you can distinguish between

(add a prefix abbreviation) 5×10^{-3} g = 5 ____g and 5×10^6 g = 5 ____g

5. For which prefix abbreviations is the first letter always capitalized?

6. Write 0.30 gigameters/second without a prefix, in scientific notation.

Page 29 (Lesson 2B):

Fill in these blanks with exponential terms.

Q1. 1 nanogram = 1 x ______ grams , so 1 gram = 1 x ______ nanograms

Q2. 1 dL = 1 x ______ liters , so 1 L = 1 x ______ dL

Page 29 (Lesson 2B):

Practice B: Write the table of the 13 metric prefixes until you can do so from memory, then try to do these without consulting the table.

1. Fill in the blanks with exponential terms.

   a. 1 terasecond = 1 x ______ seconds , so 1 second = 1 x ______ teraseconds

   b. 1 μg = 1 x ______ grams , so 1 g = 1 x ______ μg

2. Apply the reciprocal rule to add exponential terms to these *one unit* equalities.

   a. 1 gram = _______ centigrams b. 1 meter = ___________ picometers

   c. 1 s = ___________ ms d. 1 s = ___________ Ms

3. Add exponential terms to these blanks. Watch where the 1 is!

   a. 1 micromole = _____ moles b. 1 g = 1 x _______ Gg

   c. 1 hectogram = 1 x _______ grams d. f. 1 fL = ________ L

Page 33 (Lesson 2C):

Front-side of cards (with notch at top right):	Back Side -- Answers
To convert to scientific notation, move the decimal to…	After the first number that is not a zero
If you make the significand larger	Make the exponent smaller
42^0	Any positive number to the zero power = 1
To *add* or *subtract* in exponential notation	Make all exponents the same
Simplify 1/(1/*X*)	*X*
To divide exponentials (with the same base)	Subtract the exponents
To bring an exponent from the bottom of a fraction to the top	Change its sign
1 cc ≡ 1 ___ ≡ 1 ___	1 cc ≡ 1 cm^3 ≡ 1 mL
0.0018 in scientific notation =	1.8×10^{-3}
1 L ≡ ___ mL ≡ ___ dm^3	1 L ≡ 1000 mL ≡ 1 dm^3
To multiply exponentials (that have the same base)	Add the exponents
Simplify $1/10^X$	10^{-X}
74 in scientific notation =	7.4×10^1
The original definition of 1 gram	The mass of 1 cm^3 of liquid water at 4ºC.
8 x 7 =	56
42/6 =	7

Page 34 (Lesson 2C):

Two-way cards (with*out* a notch):

10^3 g or 1,000 g = 1 __g	1 kg = ____ g
Boiling temperature of water	100 degrees Celsius -- if 1 atm. pressure
1 nanometer = 1 x ___ meters	1 ____meter = 1 x 10^{-9} meters
Freezing temperature of water	0 degrees Celsius
4.7 x10^{-3} = _____________(number)	0.0047 = 4.7 x$10^?$

1 GHz =$10^?$ Hz	10^9 Hz = 1 __Hz
1 pL = $10^?$ L	10^{-12} L = 1 __L
3/4 = 0.?	0.75 = ? / ?
1/8 = 0.?	0.125 = 1 / ?

2/3 = 0.?	0.666… = ? / ?
1/80 = 0.?	0.0125 = 1 / ?
1 dm^3 = 1 ___	1 L = 1 __
1/4 = 0.?	0.25 = 1 / ?

More two-way cards (without a notch) for the metric-prefix definitions.

mega- = x $10^?$	x 10^6 = ? Prefix
nano- = x $10^?$	x 10^{-9} = ? pref.
giga- = x $10^?$	x 10^9 = ? Prefix
micro- = x $10^?$	x 10^{-6} = ? pref.
deci- = x $10^?$	x 10^{-1} = ? pref.
tera- = x $10^?$	x 10^{12} = ? pref.
pico- = x $10^?$	x 10^{-12} = ? pref
hecto- = x $10^?$	x 10^2 = ? Prefix
deka- = x $10^?$	x 10^1 = ? Prefix
femto- = x $10^?$	x 10^{-15} = ? pref
M- = x $10^?$	x 10^6 = ? abbr.

d- = x $10^?$	x 10^{-1} = ? abbr.
m- = x $10^?$	x 10^{-3} = ? abbr.
T- = x $10^?$	x 10^{12} = ? abbr.
n- = x $10^?$	x 10^{-9} = ? abbr.
f- = x $10^?$	x 10^{-15} = ? abb
μ- = x $10^?$	x 10^{-6} = ? abbr.
G- = x $10^?$	x 10^9 = ? abbr.
da- = x $10^?$	x 10^1 = ? abbr.
p- = x $10^?$	x 10^{-12} = ? abb
c- = x $10^?$	x 10^{-2} = ? abbr.
h- = x $10^?$	x 10^2 = ? abbr.

micro =? abbr.	μ- = ? pref.
mega =? abbr.	M = ? pref.
deka =? abbr.	da = ? pref.
pico =? abbr.	p = ? prefix
deci =? abbr.	d = ? prefix
hecto =? abbr.	h = ? prefix
tera =? abbr.	T = ? prefix
milli =? abbr.	m = ? pref.
femto =? abbr.	f = ? prefix
giga =? abbr.	G = ? pref.
nano =? abbr.	n = ? prefix

Page 35 (Lesson 2C):

Practice B: Run your set of flashcards until all cards are in the "got-it" pile. *Then* try these problems. Make additional cards if needed. Run the cards again in a day or two.

1. Fill in the blanks.

Format: 1 prefix-	1 base unit
1 micrometer = _______ meters	1 meter = _______ micrometers
1 gigawatt = _______ watts	1 watt = ________ gigawatts
1 nanoliter = ________ liter	________ nanoliters = 1 liter

2. Add exponential terms to these blanks. Watch where the 1 is!

a. 1 picocurie = ___________ curies
b. 1 megawatt = ___________watts
c. 1 dag = ____________ g
d. 1 mole = ___________ millimoles
e. 1 m = ___________ nm
f. 1 kPa = ____________ Pa

3. Answer these without using a calculator.

a. $10^{-6}/10^{-8}$ =
b. 1/5 = ___.___ ___
c. 1/50 = ___.___ ___ ___ ___

Page 36 (Lesson 2D):

2. Multiply: $2.0\ \frac{g \bullet m}{s^2} \bullet \frac{3.0\ m}{4.0 \times 10^{-2}} \bullet 6.0 \times 10^2\ s =$

Page 36 (Lesson 2D):

A. 5 apples + 2 apples = _________
B. 5 apples + 2 oranges = __________

Page 37 (Lesson 2D):

Apply Rule 1 to this problem:

$$\begin{array}{r} 14.0\ \text{grams} \\ -\ \underline{\ \ 7.5\ \text{grams}} \end{array}$$

* * * * *

Apply Rules 2 and 3 to this problem: If a postage stamp has the dimensions 2.0 cm x 3.0 cm, the surface area of one side of the stamp = ____________

Page 37 (Lesson 2D):

Apply Rules 2 and 3 to these. Solve without a calculator.

a. $\dfrac{12 \times 10^{-3}\ m^4}{3.0 \times 10^2\ m^2} =$

b. $\dfrac{9.0 \times 10^3\ m^6}{3.0 \times 10^{-2}\ m^6} =$

Page 38 (Lesson 2D):

Practice: Do *not* use a calculator, except as noted.

1. $16\ cm - 2\ cm =$

2. $12\ cm \bullet 2\ cm^2 =$

3. $3.0\ g\ /\ 9.0\ g =$

4. $\dfrac{18.0\ s^{-5}}{3.0\ s^2} =$

5. $\dfrac{24\ L^5}{3.0\ L^{-4}} =$

6. $\dfrac{18 \times 10^{-3}\ g \bullet m^5}{3.0 \times 10^1\ m^2} =$

7. $12 \times 10^{-2}\ \dfrac{L \bullet g}{s} \bullet 2.0\ m \bullet \dfrac{2.0\ s^3}{6.0 \times 10^{-5}\ L^2} =$

8. A rectangular box has dimensions of 2.0 cm x 4.0 cm x 6.0 cm. Without a calculator, calculate its volume.

9. In the Pretest at the beginning of this lesson, complete

   a. Problem 1 (use a calculator).

   b. Problem 2 (do not use a calculator).

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