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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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 "7.0×10^{-9} cm."

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

For example, in -6.5×10^{-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 coeffici

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: $10^2 = 100$ $\qquad$ $10^{-2} = 0.01$

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

   ‰ $\qquad$ n‰

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

   ‰ $\qquad$ n‰

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. $10^7 =$ $\qquad$ b. 10^{-}

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, -0.057×10^{-2} is written as -5.7×10^{-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,
   x move the decimal in the significand to after the first digit that is not a zero,
   x 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:

$0.045 \times 10^5 = 4.5 \times 10^3$ $\quad -8{,}544 \times 10^{-7} = -8.544 \times 10^{-4}$

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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^{-4} is 1,000 times largnTTAn[not.0001504 0.48Tm7)(nTw[n-2.85TD.0012 Tc.0002 Tw(I

- Since any number can be multiplied by one without changing its value, any number can be multiplied by 10^0 without changing its value.

  Example: $42 = 42 \times 1 = 42 \times 10^0$ in exponential notation

  $= 4.2 \times 10^1$ in scientific notation.

8. To convert fixed notation to scientific notation, the steps are
   a. Add $\times 10^0$ 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. $943 = 943 \times 10^0 = 9.43 \times 10^2$.

   b. $-0.00036 = -0.00036 \times 10^0 = -3.6 \times 10^{-4}$

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. $5{,}420 \times 10^3 =$ 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. $-1,280,000 =$

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

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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

> To add or subtract 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.

Multiplying and Dividing Powers of 10

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

1. $\boxed{\text{When you multiply exponentials, you add the exponents.}}$

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

2. $\boxed{\text{When you divide exponentials, you subtract the exponents.}}$

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

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

3. $\boxed{\text{When you take the reciprocal of an exponential, change the sign.}}$

   This rule is often remembered as:

   $\boxed{\text{When you take an exponential term from the bottom to the top, change its sign.}}$

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

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

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

Try the following problem.

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

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

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

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

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

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

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

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 without 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.

<u>The Role of Practice</u>

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 <u>Examples</u> 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."

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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

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

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

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

Practice B

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

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

(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. 5.0×10^{0} or 5.0 1d. 2.0×10^{-24} 1e. 2.5×10^{-10}

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

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

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

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

$= 4.83 \times 10^{7}$

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

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

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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.

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

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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

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.

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Your rounding might be

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

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.

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

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?

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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.

		1 / 2		
		1 / 3		
		1 / 4		
		…		

- Fold over those answers and repeat at the far left. Fold over those and repeat.

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 without a calculator. Convert final answers to scientific notation. Round the significand in the answer to two digits.

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

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

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

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
  - plug the entire calculation into the calculator, or
  - use the "numbers on calculator, exponents on paper" method, or
  - 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

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

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

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

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

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

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

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

$\approx 0.6 \times 10^{3} \approx 6 \times 10^{2}$ (*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.

$= 0.55 \times 10^{3} = \boxed{5.5 \times 10^{2}}$ (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}

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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 gre31 T 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 smallr by a count of Y;
   - move the decimal Y times to make the significand smalled, make the exponent larger by a count of Y.

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

“If one gets smallr , the other gets larger. If one gets larger, the other gets smalled.”

6. To add or subtract exponntial 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 sparately. 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 thponent.
   - 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 seque calculator.

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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 f.0004 7 measurement syste al004 T

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.

A cube that is 1 centimeter wide by 1 cm high by 1 cm long has a volume of one cubic centimeter (1 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 millimeters ≡ 1 meter , and 1,000 millianythings ≡ 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 (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

$$1 \text{ dm} \times 1 \text{ dm} \times 1 \text{ dm} \equiv 1 \text{ cubic decimeter} \equiv 1 \text{ dm}^3$$

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

$$1{,}000 \text{ cm}^3 \equiv 1{,}000 \text{ mL} \equiv 1 \text{ L} \equiv 1 \text{ dm}^3$$

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

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

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

A Note on Memorization

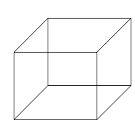
A goal of these lessons is to minimize what you must memorize. However, it is not possible to eliminate memorization from science courses. When there are facts which you must memorize in order to solve problems, these lessons will tell you. This is one of those times.

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 = $1\ cm^3$ cube. Call it one mL. Fill it with water to make a mass of 1.00 grams.



├1 cm ┤

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

1a. 10^3 grams = 1 kilogram

1b. 2×10^{-3} meters = 2 millimeters

2a. 2.6×10^{-1} L = 2.6 dL

2b. 6×10^{-2} g = 6 cg

3a. 1 gigajoule = 1×10^9 joules

3b. 9 μm = 9×10^{-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,

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 decimeters	100 centimeters	1,000 millimeters

- 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 = 10^{-3} L , based on what 1 milli

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

If 1 prefix- = 10^{a} , 1 *unit* = 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 milliliter = 10^{-3} liter , then 1 liter = 10^{3} milliliters = 1,000 mL

Fill in these blanks with exponential terms.

Q1.

ANSWERS

Practice A

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

2a. 6 centiamps 2b. 45 gigawatts 3a. 1 Tg 3b. 1 ps 3c. 5 dL

4. 5 mg and 5 Mg 5. M-, G-, and T-. 6. 3.0×10^{8} meters / second

Practice B

1. a. 1 terasecond = 1×10^{12} seconds , so 1 second = 1×10^{-12} teraseconds

   b. 1 μg = 1×10^{-6} grams , so 1 g = 1×10^{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 = 1×10^{-6} Ms

3. a. 10^{-6} moles 3b. 1×10^{-9} Gg 3c. 1×10^{2} grams 3d. 10^{-15}

* * * * *

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.

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. , 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, 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.

3. To make "two-way" cards, use the index cards as they are, without 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*

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

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.

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

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

3. a. $10^{-6} / 10^{-8} = 10^{-6+8} = 10^{2}$ 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 / 3S 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?

x Units give physical meaning to a quantity.

x

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 without 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.

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

This answer unit can also be written as $g \cdot s^{-1}$, 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. $6.0 \times 10^{-4}\ g \cdot m^3$
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 S r^3 = 4/3 S $(2.0\ cm)^3$ = 4/3 S (8.0 cm^3) = (32/3) S cm^3 = 3<u>3</u>.51 cm^3 = **34 cm^3**

(If you use S = 3.14 , your answer will be 3<u>3</u>.49 cm^3 = **33 cm^3**. That's OK. Doubful digits may vary.)

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

* * * * *

SUMMARY – The Metric System

1. 1 meter 10 decimeters
   100 centimeters
   1000 millimeters

   1,000 meters 1 kilometer

2. 1 millimeter 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 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 $H_2O(l) \equiv$ 1 mL $H_2O(l) \approx$ 1.00 g $H_2O(l)$

7. meter = m ; gram = g ; second = s
   10prefim

8. If prefix- = 10A

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. 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 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 without 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. $(-21.46 \times 10^{-17}) - (-3{,}250 \times 10^{-19}) =$

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. $100 \times 10^{-2} =$

8. $10^{-3} \times 10^{23} =$

Pages to print and write on

Pages to print and write on

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 $H_2O(l) \approx$ _______ 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.

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