Because it deals with atoms, and they are so incredibly small, the study of chemistry is essential for using very large and very small numbers. For example, if you determine the total number of atoms in a sample of matter, the value will be very large. If, on the other hand, you determine an atom’s diameter or the mass of an atom, the value will be extremely small. The method of reporting an ordinary, expanded number in scientific notation is very handy for both of these things.

**Scientific Notation** refers to the method of representing numbers in exponential form. Exponential numbers have two parts: Consider the following example: 2.45 becomes $2.45 	imes 10^1$ in scientific notation.

Convention states that the first portion of a value in scientific notation should always be expressed as a number between 1.0 and 10.0. This portion is called the **mantissa** or the **decimal portion**.

The second portion is the **exponential** or the **base-10** raised to some power. It is called the **exponent** or the **scientific notation**. 2.45 $\times$ $10^1$.

A **positive** exponent in the ordinate indicates a **large number** in scientific notation, while a **negative** exponent indicates a **small number**.

In fact, the exponent indicates the number of 10s that must be multiplied together to arrive at the number represented by the scientific notation. If the exponents are negative, the exponent indicates the number of tenths that must be multiplied together to arrive at the number.

In other words, the exponent indicates the number of places the decimal point must be moved to the **right** if the exponent is positive, or to the **left** if the exponent is negative.

**Scientific Notation involves moving decimals.**

A **positive** exponent indicates the number of places the decimal must be moved to the **right**.

1. $1.5 \times 10^1 = 15$.
2. $6.8 \times 10^4 = 680000$.
3. $0.0006 = 6 \times 10^{-4}$.

A **negative** exponent indicates the number of places the decimal must be moved to the **left**.

1. $1.8 \times 10^{-2} = 0.018$.
2. $0.000058 = 5.8 \times 10^{-5}$.

**Practice**

1. Change the following numbers from scientific notation to expanded notation.
   (a) $2.35 \times 10^5 = $ _______________
   (b) $5.143 \times 10^{-2} = $ _______________

2. Change the following numbers from expanded notation to scientific notation.
   (a) 69.54 = _______________
   (b) 0.001 68 = _______________
**SCIENTIFIC NOTATION**

Regular Notation (RN) - The _standard way_ that we write our numbers.  
*Ex: Two Hundred and Eight Million is written:_ 208,000,000  

Scientific Notation (SN) - A _short-hand way_ of writing really large or really small numbers. In SN a number is written as the _product_ of  _two factors_  
*Ex: 200,000,000 can be written in scientific notation as: 2.0 × 10^8 _

**First Factor**  
A number that is _≤ 10_.  
It may or may not be _decimal_.  
*Ex. 2.8 × 10^5  
2 × 10^4  

**Second Factor**  
Is always a _10^n_.  
The power of the exponent tells you to _move_ the decimal point.  
The _sign_ of the exponent tells you which _direction_ to move it.

**Regular Notation → Scientific Notation**  
- If Decimal is moved _left_, exponent will be _positive_.  
- If Decimal is moved _right_, exponent will be _negative_.  
- “Big #” _exp_  
- “Small #” _exp_  

<table>
<thead>
<tr>
<th>Regular Notation</th>
<th>How to Change</th>
<th>Scientific Notation</th>
</tr>
</thead>
</table>
| 420,000.00       | Move the decimal after the 4 and before the 2.  
                  | Multiply 4.2 by 10 to the 5th power. | 4.2 × 10^5 |
| 735,000,000.00   | Move the decimal after the 7 and before the 3.  
                  | That is 8 places to the left.  
                  | Multiply 7.35 by 10 to the 8th power. | 7.35 × 10^8 |
| 0.00897          | Move the decimal after the 8 and before the 9.  
                  | That is 3 places to the right.  
                  | Multiply 8.97 by 10 to the -3rd power. | 8.97 × 10^-3 |
| 0.0000014        | Move the decimal after the 1 and before the 4.  
                  | That is 6 places to the right.  
                  | Multiply 1.4 by 10 to the -6th power. | 1.4 × 10^-6 |
## Scientific Notation → Regular Notation

<table>
<thead>
<tr>
<th>Scientific Notation</th>
<th>How to Change</th>
<th>Regular Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$7.5 \times 10^5$</td>
<td>Exponent is positive 5. Move the decimal 5 places to the right.</td>
<td>$750,000$</td>
</tr>
<tr>
<td>$3.8 \times 10^4$</td>
<td>Exponent is positive 4. Move the decimal 4 places to the right.</td>
<td>$38,000$</td>
</tr>
<tr>
<td>$4.2 \times 10^{-3}$</td>
<td>Exponent is Negative 3. Move the decimal 3 places to the left.</td>
<td>$0.0042$</td>
</tr>
<tr>
<td>$7.51 \times 10^{-5}$</td>
<td>Exponent is Negative 5. Move the decimal 5 places to the left.</td>
<td>$0.0000751$</td>
</tr>
</tbody>
</table>

## Chemistry Homework
### Assignment #7: Scientific Notation Practice Questions
Complete the following questions in the space provided.

<table>
<thead>
<tr>
<th>Change from Regular Notation to Scientific Notation:</th>
<th>Change from Scientific Notation to Regular Notation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. $45,000$</td>
<td>1. $9.46 \times 10^{-6}$</td>
</tr>
<tr>
<td>2. $9,000,000$</td>
<td>2. $2.5 \times 10^3$</td>
</tr>
<tr>
<td>3. $7,450$</td>
<td>3. $1.6 \times 10^{-2}$</td>
</tr>
<tr>
<td>4. $0.000378$</td>
<td>4. $4 \times 10^{-5}$</td>
</tr>
<tr>
<td>5. $0.5$</td>
<td>5. $7.25 \times 10^4$</td>
</tr>
<tr>
<td>6. $670,400$</td>
<td>6. $3.2456 \times 10^{-3}$</td>
</tr>
<tr>
<td>7. $7,070,000,000$</td>
<td>7. $6 \times 10^{-3}$</td>
</tr>
<tr>
<td>8. $0.00000089$</td>
<td>8. $9.7 \times 10^7$</td>
</tr>
<tr>
<td>9. $1.89000097$</td>
<td>9. $5.06 \times 10^{-4}$</td>
</tr>
<tr>
<td>10. $579,000,000$</td>
<td>10. $8 \times 10^3$</td>
</tr>
</tbody>
</table>
### Scientific Notation

#### Convert Each Number in Scientific Notation to Regular Notation

<table>
<thead>
<tr>
<th>Number in Scientific Notation</th>
<th>Number in Regular Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. $2.47 \times 10^{-3}$</td>
<td>0.00247</td>
</tr>
<tr>
<td>2. $9.3 \times 10^7$</td>
<td>93,000,000</td>
</tr>
<tr>
<td>3. $8.5 \times 10^{-5}$</td>
<td>0.000085</td>
</tr>
<tr>
<td>4. $2.07 \times 10^6$</td>
<td>2,070,000</td>
</tr>
<tr>
<td>5. $7 \times 10^{-8}$</td>
<td>0.00000007</td>
</tr>
<tr>
<td>6. $3 \times 10^2$</td>
<td>300</td>
</tr>
<tr>
<td>7. $4.5 \times 10^{-5}$</td>
<td>0.000045</td>
</tr>
<tr>
<td>8. $5.5 \times 10^5$</td>
<td>550,000</td>
</tr>
<tr>
<td>9. $6.3 \times 10^{-1}$</td>
<td>0.63</td>
</tr>
<tr>
<td>10. $1.98 \times 10^4$</td>
<td>19,800</td>
</tr>
<tr>
<td>11. $2.4 \times 10^{-5}$</td>
<td>0.000024</td>
</tr>
<tr>
<td>12. $9.2 \times 10^7$</td>
<td>92,000,000</td>
</tr>
</tbody>
</table>

#### Convert Each Number in Regular Notation to Scientific Notation

<table>
<thead>
<tr>
<th>Number in Regular Notation</th>
<th>Number in Scientific Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 0.0024</td>
<td>$2.4 \times 10^{-3}$</td>
</tr>
<tr>
<td>2. 5,604</td>
<td>$5.604 \times 10^3$</td>
</tr>
<tr>
<td>3. 693.75</td>
<td>$6.9375 \times 10^2$</td>
</tr>
<tr>
<td>4. 0.087</td>
<td>$8.7 \times 10^2$</td>
</tr>
<tr>
<td>5. 8,550,000</td>
<td>$8.55 \times 10^6$</td>
</tr>
<tr>
<td>6. 12,000,000</td>
<td>$1.2 \times 10^7$</td>
</tr>
<tr>
<td>7. 0.0000035</td>
<td>$3.5 \times 10^{-6}$</td>
</tr>
<tr>
<td>8. 45,993</td>
<td>$4.5993 \times 10^4$</td>
</tr>
<tr>
<td>9. 754.298</td>
<td>$7.54258 \times 10^2$</td>
</tr>
<tr>
<td>10. 0.00088</td>
<td>$8.8 \times 10^{-3}$</td>
</tr>
<tr>
<td>11. 18.907</td>
<td>$1.8 \times 10^1$</td>
</tr>
<tr>
<td>12. 25,009</td>
<td>$2.5009 \times 10^4$</td>
</tr>
</tbody>
</table>
**Multiplication and Division in Scientific Notation**

To multiply two numbers in scientific notation, we multiply the decimal parts and add their exponents. And state their product multiplied by 10, raised to a power that is the sum of the exponents.

\[(\times 10^a) \times (\times 10^b) = (\times 10^{a+b})\]

To divide two numbers in scientific notation, we divide one mantissa by the other and state their quotient multiplied by 10, raised to a power that is the difference between the exponents.

\[\frac{\times 10^a}{\times 10^b} = (\times 10^{a-b})\]

---

**Sample Problems — Multiplication and Division Using Scientific Notation**

Solve the following problems, expressing the answer in scientific notation.

1. \((5.2 \times 10^6) \times (3.2 \times 10^4) = \) __________

2. \((9.4 \times 10^3) \div (4 \times 10^2) = \) __________

---

**What to Think about**

**Question 1**

1. Find the product of the mantissas.
2. Raise 10 to the sum of the exponents to determine the order of magnitude.
3. State the answer as the product of the new mantissa and order of magnitude.

**Question 2**

1. Find the quotient of the mantissas. When no mantissa is shown, it is assumed that the mantissa is 1.
2. Raise 10 to the difference of the exponents to determine the order of magnitude.
3. State the answer as the product of the mantissa and order of magnitude.

**How to Do It**

\[
\begin{align*}
2.5 \times 3.2 &= 8.0 \\
10^3 \times 10^6 &= 10^{3+6} = 10^9 \\
&= 8.0 \times 10^9 \\
(9.4 \times 10^{-4}) \div (3 \times 10^{-8}) &= 9.4 \div 3 = 9.4 \\
10^{-4} \div 10^{-8} &= 10^{-4-(-8)} = 10^4 \\
&= 9.4 \times 10^4
\end{align*}
\]

---

**Practice — Multiplication and Division Using Scientific Notation**

Solve the following problems, expressing the answer in scientific notation, without using a calculator. Repeat the questions using a calculator and compare your answers. Compare your method of solving with a calculator with that of another student.

1. \((4 \times 10^2) \times (2 \times 10^3) = \) __________
2. \((9.9 \times 10^6) \div (3 \times 10^3) = \) __________
3. \((3 \times 10^7) \times (6 \times 10^3) \div (2 \times 10^6) = \) __________
4. \(10^3 \div (3 \times 10^2) = \) __________
5. \([4.5 \times 10^5] \div (1.5 \times 10^4) \times (2.5 \times 10^9) = \) __________
Addition and Subtraction in Scientific Notation

Remember that a number in proper scientific notation will always have a decimal in order to express a number in proper scientific notation.

Sometimes it becomes necessary to shift a decimal in order to express a number in proper scientific notation.

The number of places the decimal is shifted is indicated by an equivalent change in the value of the exponent. Shifting the decimal to the right causes the exponent to become smaller.

Another way to remember this is if the mantissa becomes smaller following a shift, the exponent becomes larger. Consequently, if the exponent becomes larger, the mantissa becomes smaller. Consider All E \times 10^n if the decimal is shifted to change the value of the mantissa by 10^n times, the value of n changes = n times.

For example, a number such as 18,235,000 (18.235 \times 10^6 in standard notation) requires the decimal to be shifted 4 places to the left to give a mantissa between 1 and 10, which is 1.8235. A shift of 4 places means the exponent in the ordinary becomes 4 values larger.

The correct way to express 18,235,000 \times 10^6 in scientific notation is 1.8235 \times 10^{8}.

Notice the new mantissa is 10^4 smaller, so the exponent becomes 4 numbers larger.

Express each of the given values in proper scientific notation in the second column. Now write each of the given values in expanded form in the third column. Then write each of your answers from the second column in expanded form, How do the expanded answers compare?

<table>
<thead>
<tr>
<th>Given Value</th>
<th>Proper Notation</th>
<th>Expanded Form</th>
<th>Expanded Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 60345 \times 10^8</td>
<td>6.01451 \times 10^8</td>
<td>6.01451</td>
<td>X</td>
</tr>
<tr>
<td>2. 6.001 \times 10^7</td>
<td>1.6 \times 10^4</td>
<td>16000</td>
<td>X</td>
</tr>
<tr>
<td>3. 39 325.3 \times 10^{-4}</td>
<td>3.83253 \times 10^{-4}</td>
<td>0.000383253</td>
<td></td>
</tr>
<tr>
<td>4. 6.4796 \times 10^{-3}</td>
<td>4.196 \times 10^{-5}</td>
<td>0.00004196</td>
<td></td>
</tr>
</tbody>
</table>

When adding or subtracting numbers in scientific notation, it is important to realize that we add or subtract only the mantissa. Do not add or subtract the exponents.

Steps for Adding + Subtracting in Scientific Notation

1) Shift the decimal to obtain the same value for the exponent in the order of both numbers to be added or subtracted.
2) Sum or take the difference of the mantissas (decimal # only)
3) Convert back to proper scientific notation when finished. (if needed) => # | < 10
Sample Problems — Addition and Subtraction in Scientific Notation

Solve the following problems, expressing the answer in proper scientific notation.

1. \( (5.19 \times 10^5) - (3.14 \times 10^5) = \)

2. \( (2.17 \times 10^7) + (6.49 \times 10^3) = \)

What to Think about

Example #1

1. Begin by shifting the decimal of one of the numbers and changing the exponent so that both numbers share the same exponent.

   For consistency, adjust one of the numbers so that both numbers have the larger of the two exponents. The goal is for both mantissas to be multiplied by \(10^7\). This means the exponent in the second number should be increased by one. Increasing the exponent requires the decimal to shift to the left (so the mantissa becomes smaller).

2. Once both exponents are the same, the mantissas are simply subtracted.

Example #1 — Alternate Approach

1. It is also okay to note that we could have altered the first number slightly so that case \(5.19 \times 10^7\) would have become \(51.9 \times 10^0\).

2. In this case, the difference results in a number that is not in proper scientific notation as the mantissa is greater than \(10\).

3. Consequently, a further step is needed to convert the answer back to proper scientific notation. Shifting the decimal one place to the left (mantissa becomes smaller) requires an increase of \(1\) to the exponent.

Example #2

1. As with differences, begin by shifting the decimal of one of the numbers and changing the exponent to both numbers share the same exponent.

   The larger exponent in this case is \(10^7\).

2. Increasing the exponent in the second number from \(-5\) to \(-3\) requires the decimal to be shifted two to the left (makes the mantissa smaller).

3. Once the exponents agree, the mantissas are simply summed.

\[ \begin{align*}
5.19 \times 10^5 & - 3.14 \times 10^5 \\
& = 2.05 \times 10^5
\end{align*} \]

\[ \begin{align*}
2.17 \times 10^{-3} & + 6.49 \times 10^{-3} \\
& = 8.66 \times 10^{-3}
\end{align*} \]
**Practice**

Addition and Subtraction in Scientific Notation

Solve the following problems, expressing the answer in scientific notation, without using a calculator. Repeat the questions using a calculator and compare your answers. Compute your use of the exponential notation on the calculator with that of a partner.

1. \(8.62 \times 10^5 + 4.14 \times 10^6\)
2. \(6.228 \times 10^4 + 4.602 \times 10^5\)
3. \(4.901 \times 10^4 + 4.901 \times 10^2\)

**Scientific Notation and Exponents**

Occasionally a number in scientific notation will be raised to some power. When such a case arises, it's important to remember when one exponent is raised to the power of another, the exponents are multiplied:

\[(A \times 10^a)^b = A^b \times 10^{ab}\]

Consider a problem like \((10^3)^2 = 10^6\).

This is really just \((10 \times 10 \times 10)^2\) or \((10 \times 10 \times 10 \times 10 \times 10 \times 10)^1\). So we see this is the same as \((10^3)^2\) or \(10^6\).

**Assignment #8: Scientific Notation Topic Review**

Complete the following questions in the space provided. Be sure to SHOW FULL WORKING OUT!

**Topic Review:**

Solve the following problems, expressing the answer in scientific notation, without the use of a calculator. Repeat the problems with a calculator and compare your answers.

1. \(1 \times 10^9\)
2. \(2 \times 10^3\)
3. \(3 \times 10^9\)
4. \((3 \times 10^5) \times (2 \times 10^4) = (6 \times 10^9) = (9 \times 10^8) \times (4 \times 10^6) = (36 \times 10^{15}) = 3.6 \times 10^{18}\)
5. \(10^{-2} \times 10^6\) (Convert the following numbers from scientific notation to expanded notation and vice versa. If the scientific notation is expressed correctly):

<table>
<thead>
<tr>
<th>Scientific Notation</th>
<th>Expanded Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(3.0 \times 10^3)</td>
<td>30,000</td>
</tr>
<tr>
<td>(9.6 \times 10^7)</td>
<td>9,600</td>
</tr>
<tr>
<td>(4.75 \times 10^{-3})</td>
<td>0.00475</td>
</tr>
<tr>
<td>(4.5 \times 10^{-4})</td>
<td>0.00045</td>
</tr>
<tr>
<td>(0.0062 \times 10^9)</td>
<td>620</td>
</tr>
</tbody>
</table>
6. Give the product or quotient of each of the following problems (express all answers in proper form scientific notation). Do not use a calculator.
   (a) \( (6.0 \times 10^5) \times (1.5 \times 10^7) = 9.0 \times 10^{12} \)
   (b) \( (1.5 \times 10^5) + (2.0 \times 10^6) = 2.5 \times 10^6 \) (75)
   (c) \( (3.5 \times 10^{-4}) \times (6.0 \times 10^1) = 2.1 \times 10^{-2} \)
   (d) \( (1.2 \times 10^4) \times (6.5 \times 10^{-6}) = 8.0 \times 10^{-2} \)

7. Give the product or quotient of each of the following problems (express all answers in proper form scientific notation). Do not use a calculator.
   (a) \( (3.5 \times 10^9) \times (3.0 \times 10^5) = 1.0 \times 10^{15} \)
   (b) \( (7.0 \times 10^9) - (1.25 \times 10^{10}) = 4.0 \times 10^7 \)
   (c) \( (2.5 \times 10^5) \times (8.5 \times 10^3) = 2.1 \times 10^8 \)
   (d) \( (1.2 \times 10^5) \times (6.5 \times 10^{-6}) = 8.0 \times 10^{-1} \)

8. Solve the following problems, expressing the answer in scientific notation, without using a calculator. Repeat the questions using a calculator and compare your answers.
   (a) \( 4.034 \times 10^{10} \) \( 3.114 \times 10^9 \) \( 2.602 \times 10^{10} \)
   (b) \( 2.301 \times 10^8 \) \( 2.099 \times 10^9 \)

9. Solve the following problems, expressing the answer in scientific notation, without using a calculator. Repeat the questions using a calculator and compare your answers.
   (a) \( 2.115 \times 10^8 \) \( -1.31 \times 10^7 \) \( -6.903 \times 10^3 \)
   (b) \( 9.332 \times 10^9 \) \( 1.002 \times 10^{-2} \) \( 6.180 \times 10^{-1} \)

10. Solve each of the following problems without a calculator. Express your answer in correct form scientific notation. Repeat the questions using a calculator and compare.
    (a) \( 1.0 \times 10^{-12} \) \( 1.6 \times 10^{-16} \) \( 4.9 \times 10^{14} \) \( 8 \times 10^7 \)
    (b) \( 1.0 \times 10^{-5} \) \( 2.0 \times 10^{-3} \) \( 3.1 \times 10^0 \)

11. Solve each of the following problems without a calculator. Express your answer in correct form scientific notation. Repeat the questions using a calculator and compare.
    (a) \( 6.4 \times 10^4 + 2.0 \times 10^7 + (2 \times 10^5 + 3 \times 10^0) = 2 \times 10^{10} \)
    (b) \( 3.8 \times 10^{-11} \times 1.5 \times 10^6 \)
    (c) \( (2 \times 10^9) \times (8.64 \times 10^9) \times (2.42 \times 10^9) = 1.6 \times 10^{16} \)
    (d) \( (3 \times 10^3) \times (4 \times 10^3) \times (1 \times 10^4) = 7 \times 10^9 \)

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