TOOLS OF THE TRADE
LABORATORY WORK IN LIFE SCIENCES

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Week 2

MATH BASICS and SCIENTIFIC NOTATION

10 Before you enter a laboratory in life sciences, *you should be prepared for and knowledgeable about any lab exercises that are to be performed*. That means you should read your lab manual to know exactly what you will be doing.

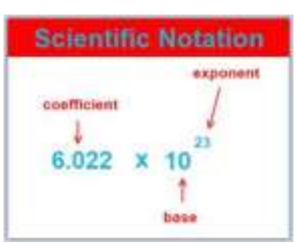
Lab safety rules are guidelines designed to help keep you safe when experimenting. Some equipment and chemicals in a biology laboratory can cause serious harm. It is always wise to follow all lab safety rules. Don't forget, the most helpful safety rule is to use plain old common sense.

Please read the LAB SAFETY GUIDELINES handed out to you before you do any experimentation!

MATH BASICS

Scientists use very large or very small numbers (that is lots of digits). For example, all individuals in a society may know how long 1 meter (m) is. But scientists use less commonly known units such as micrometer (µm), nanometer (nm), Angstrom (^{o}A), etc. when defining cells and molecules. These units are much smaller (million and billion times) than meter. However, some scientist conversely use very large numbers when they talk about a planet 4 million light-years away and so on.

Thus, scientists use a specific method for short description called "*scientific notation*" when dealing with very large or very small numbers.



Scientific notation

Scientific calculations are frequently handled by expressing quantities in scientific notation. Scientific notation is a way of writing numbers that are too big or too small to be conveniently written in standard form. Scientific notation has a number of useful properties and is commonly used in calculators and by scientists, mathematicians and engineers.

In scientific notation all numbers are written in the form of

$a \times 10^{b}$

(a times ten raised to the power of b), where the exponent b is an integer, and the coefficient a is any real number (however, see normalized notation below), called the significand or mantissa.

11

Standard decimal notation	Normalized scientific notation
2	2×10^{0}
300	3×10^{2}
4,321.768	4.321768×10^{3}
-53,000	-5.3×10^{4}
6,720,000,000	6.72×10^{9}
0.2	2×10^{-1}
0.00000000751	7.51×10^{-9}

$1= 10^{0}$	$0.000000001 = 10^{-9}$
$10=10^{1}$	$0.00000001 = 10^{-8}$
$100 = 10^{2}$	$0.0000001 = 10^{-7}$
$1,000= 10^{3}$	$0.000001 = 10^{-6}$
$10,000 = 10^{4}$	$0.00001 = 10^{-5}$
$100,000= 10^{5}$	$0.0001 = 10^{-4}$
$1,000,000= 10^{6}$	$0.001 = 10^{-3}$
$10,000,000= 10^{7}$	$0.01 = 10^{-2}$
$100,000,000= 10^{8}$	$0.1 = 10^{-1}$
$1,000,000,000= 10^{9}$	$1 = 10^{0}$

To write such numbers in your calculator, use the EXP button. For instance, to write 6.02×10^{23}:

6.02E23

dot (.) vs comma (,)

In quantitative science, there is even a big difference in punctuations and using one for another may cause huge misunderstandings. For instance, the role of *dot* and *comma* in numerical representations is different (although they may indicate the same thing for the layman).

In science,

1.000 is simply 1 (one)
1,000 however is 1000 (one thousand)

So using one for another is highly erroneous…

Additon, multiplication, division and subtstraction in scientific notation

Multiplication
(N x 10x) (M x 10y) = (N) (M) x 10^{x+y}

Example 1
Multiply 3×10^{4} with 1×10^{2}
$(3 \times 10^{4}) (1 \times 10^{2})$,
3 x 1=3
$(10^{4}) (10^{2}) = 10^{4+2} = 10^{6}$
3×10^{6}

Example 2
$(4 \times 10^{3}) (2 \times 10^{-4})$= ?

$8 \text{ x } 10^{3+(-4)} = 8 \text{ x } 10^{-1}$ *or 0.8*

Division

$N \text{ x } 10^{x} / M \text{ x } 10^{y} = N/M \text{ x } 10^{x-y}$

Example 1

$6 \text{ x}10^{5} / 2 \text{ x}10^{2} = ?$

$6/2 = 3$

$10^{5} / 10^{2} = 10^{5-2} = 10^{3}$

$3 \text{ x } 10^{3}$ or 3,000

Example 2

$8 \text{ x } 10^{-3} / 2 \text{ x } 10^{-2} = ?$

$8 / 2 = 4$

$10^{-3} / 10^{-2} = 10^{-3-(-2)}$

$4 \text{ x } 10^{-1}$ *or 0.4*

Addition

$(N \text{ x } 10^{x}) + (M \text{ x } 10^{x}) = (N + M) \text{ x } 10^{x}$

Example 1

$(2.3 \text{ x } 10^{-2}) + (3.1 \text{ x } 10^{-3}) = ?$

We see that the exponents are not equal. So, we sholl either -2 to -3 or -3 to -2. To change the exponent -2 to -3 we should re-write $2.3 \text{ x } 10^{-2}$ as $23 \text{ x}10^{-3}$. Thus,

$(23 \text{ x } 10^{-3}) + (3.1 \text{ x } 10^{-3}) = (23 + 3.1) \text{ x } 10^{-3} = 26.1 \text{ x } 10^{-3}$ *or 0.0261*

13

Example 2

$(2.3 \text{ x } 10^{2}) + (3.1 \text{ x } 10^{3}) = ?$

$(0.23 \text{ x } 10^{3}) + (3.1 \text{ x } 10^{3})$

$3.33 \text{ x } 10^{3}$ *or 3,330*

Substraction

$(N \text{ x } 10^{y}) - (M \text{ x } 10^{y}) = (N + M) \text{ x } 10^{y}$

Example 1

$(4.2 \text{ x } 10^{4}) - (2.7 \text{ x } 10^{2}) = ?$

$2.7 \text{ x } 10^{2} = 0.027 \text{ x } 10^{4}$

$4.2 - 0.027 = 4.173$

$4.173 \text{ x } 10^{4}$

Example 2

$(4.2 \text{ x } 10^{-4}) - (2.7 \text{ x } 10^{-2}) = ?$

$270 \text{ x } 10^{-4} - 4.2 \text{ x } 10^{-4} = 265.8 \text{ x } 10^{-4}$ veya $2.658 \text{ x } 10^{-2}$ or 0.02658

Units. International units have special prefixes to indicate orders of magnitude, so that scientific notation is not always necessary.

milli = 10^{-3}
micro = 10^{-6}
nano = 10^{-9}
pico = 10^{-12}
fempto = 10^{-15}
atto = 10^{-18}

- How many milli, micro, nano, pico, femto, attograms in 1 g ?

1000 milligram (mg) = 1,000,000 microgram (µg), 1,000,000,000 nanogram (ng) = … etc.
In scientific notation,
1x 10^3 mg = 1 x 10^6 µg = 1 x 10^9 ng = … etc.

Dimensional Analysis in Problem Solving

Most of the problems that you have to solve in the lab relate to the preparation of specific solutions. We can solve maybe 95% of practical problems in the lab using **dimensional analysis**. Learn how to use both of these, and apply them correctly. This is a very useful, very easy technique and use it to solve problems (do not use cross multiplication!!!).

Dimensional Analysis is a problem-solving method that uses the fact that any number or expression can be multiplied by one without changing its value.

Unit factors may be made from any two terms that describe the same or equivalent "amounts" of what we are interested in. To solve problems with dimensional analysis:

- look at what you have
- where you want to be
- what you need to know to get there
- set up the necessary conversion factors to get you there.

Example: You have 6.02 x 10^{23} quarters of a Turkish Lira vertically arranged one after another and you want to walk from one end to the other. How long (say, in years) would it take? (Take the width of a quarter as 1 mm).

- look at what you have
  6.02 x 10^{23} quarters of a Turkish Lira each 1 mm thick
- where you want to be
  I want to know how many years it will take to go from one end to the next
- what you need to know to get there
  I need to somehow change the length (mm) to time (years)
- set up the necessary conversion factors to get you there

…….. ……. ……. ……… = years

6.02 x 10^{23} quarters = 6.02 x 10^{23} mm

6.02 x 10^{23} mm x 1m /1000mm x 1 km/1000m= 6.02 x 10^{17} km

Here I need some creativity to somehow change km to years…I know that, the speed of light is 300,000km/second

Thus, if I traveled with light speed;

$6.02\ 10^{17}$ km x second/300,000km x minute/60seconds x hour/60minutes x day/24hours x year/365days = **63,630 years**

Answer: Even If I travel with the light speed (which is not possible!!!) it would take me 63,630 (that is sixty three thousand and six hundred and thirty) years to go from one end to the other.

As you may noticed, with unit (dimensional) analysis method and I solved the problem in single line without using extensive cross-multiplications.

Example: How many mm in a km?

What you want to find out is the # millimeters = 1 kilometer.

Start with the original question , and then arrange the conversion factors so that the units cancel approppriately:

$1\ \text{km} \times \frac{1000\ \text{m}}{\text{km}} \times \frac{1000\ \text{mm}}{\text{m}}$ = 1,000,000 mm (or 1×10^{6} mm in scientific notation)

Once you cancel out the units, you will be left with meters, and then just crank the math.

Practice problems

1. Give the whole number or fraction that corresponds to these exponential expressions.

a. 4^{3} b. 3^{-3} c. 3^{-2} d. 10^{4} e. 10^{-5}

15

2. Express the following whole numbers using exponents:

a. 4 b. 64 c. 1000 d. 10,000 e. 0,0001

3. Convert the following numbers to scientific notation.

a. 100.0 b. 3.545 c. 5,564.000 d. 1,000,000 e. 0.00032

4. Convert the following numbers to standard notation.

a. 2.3×10^{4} b. 0.23×10^{4} c. 2×10^{-3} d. 1000×10^{3} e. 0.00896×10^{-7}

5. Fill in the blanks so that the numbers on both sides of the = sign are equal.

solved example: $3.43 \times 10^{4} = 0.343 \times 10^{5}$

a. $3.43 \times 10^{-5} = 0.343 \times 10^{?} = 343 \times 10^{?}$

b. $3 \times 10^{-3} = ? \times 10^{-2} = ? \times 10^{2} = 0.003 \times 10^{?}$

c. $2000 \times 10^{3} = 2.000 \times 10^{?}$

d. $32 \times 10^{-8} = 0.32 \times 10^{?}$

e. $0.006 \times 10^{1} = ? \times 10^{-1}$

6. Fill in the following conversions.

    a. 1 mm = ………… m = …………. = cm ……….. = ……….. nm = ………… µm = ………. °A

    b. 1 g ………… mg = …………. = ng ……….. = ……….. µm

    c. 1 L = ………… ml = …………. = dl ……….. = ……….. nl = ………… µl = ………. cm^3

7. Solve the following with/without your calculator.

    a. $(1.2 \times 10^{-4}) / (3 \times 10^{3}) =$
    b. $1.4 \times 10^{5} + 7 \times 10^{7} =$
    c. $(4 \times 10^{1}) \times (9 \times 10^{5}) =$
    d. $4.7 \times 10^{-2} - 5.8 \times 10^{3} =$
    e. $(4 \times 10^{6})(2 \times 10^{3}) / (8 \times 10^{-4})(2 \times 10^{3}) =$

Recommended keywords

- Scientific notation
- Conversions of weights and measures
- Dimensional (unit) Analysis in Problem Solving