

Scientific Methods: Scientific Notation

Scientific notation is the way that scientists handle very large or very small numbers, such as the size or age of the Universe, or the size of the national debt. For example, instead of writing 1,500,000,000,000, or 1.5 trillion, we write 1.5×10^{12} . There are two parts to this number: 1.5 (digits term) and 10^{12} (exponential term). Here are some examples of scientific notation used in astronomy (and a few just for comparison!).

THE CHART OF REALLY BIG NUMBERS

$1,000,000,000,000,000,000,000,000,000 = 1 \times 10^{30}$	We don't even have a word for this. It's the mass of the Sun in kilograms.
$100,000,000,000,000,000,000,000 = 1 \times 10^{23}$	One hundred trillion billion: The approximate number of stars in the Universe
$40,100,000,000,000 = 4.01 \times 10^{13}$	40.1 Trillion: the distance (in km) to the nearest star, Proxima Centauri.
$1,600,000,000,000 = 5.7 \times 10^{12}$	5.7 Trillion: the number of dollars in the U.S. national debt, circa 2000.
$200,000,000,000 = 2 \times 10^{11}$	Two Hundred Billion: Approximate number of stars in the Milky Way Galaxy.
$15,000,000,000 = 1.5 \times 10^{10}$	15 Billion: Approximate age of the Universe (in years).
$6,000,000,000 = 6 \times 10^9$	Six Billion: Approximate number of people on the planet, circa 2000.
$1,000,000,000 = 1 \times 10^9$	One Billion: The number of Earth-sized planets that would fit into the Sun; Also the speed of light in km/hr
$100,000,000 = 1 \times 10^8$	One hundred million: the radius of the Sun in meters.
$78,300,000 = 78.3 \times 10^6$	78.3 million: the minimum distance from the Earth to Mars.
$384,400 = 3.844 \times 10^5$	Three hundred eighty four thousand, four hundred: the distance to the moon from Earth (in km)
$40,000 = 4 \times 10^4$	Forty thousand: the distance around the Earth at the equator (in km).
$4,000 = 4 \times 10^3$	Four thousand: The circumference of Pluto (in km).

As you can see, the exponent of 10 is the number of places the decimal point must be shifted to give the number in long form. A **positive** exponent shows that the decimal point is shifted that number of places to the right. A **negative** exponent shows that the decimal point is shifted that number of places to the left. (None of these appear above, because they would be really SMALL numbers...but you get the idea!)

The number of digits reported indicates the number of significant figures. This can help you figure out when the zeroes are important, and when they are just "place-holders".

$$4.660 \times 10^7 = 46,600,000$$

This number has 4 significant figures. The first zero is the only one that is significant, the rest are only place-holders. As another example,

$$5.3 \times 10^{-4} = 0.00053$$

This number has 2 significant figures. LEADING zeroes are always place-holders.

How to do calculations:

On your scientific calculator:

Make sure that the number in scientific notation is put into your calculator correctly.

Read the directions for your particular calculator. For most scientific calculators:

1. Punch the number (the digits part) into your calculator.
2. Push the EE or EXP button. Do **NOT** use the x (times) button!!
3. Enter the exponent number. Use the +/- button to change its sign.
4. That's all. Now you are free to continue as normal. Usually your calculator will return numbers in scientific notation if they are input in scientific notation. Otherwise you have to count the places from the decimal point...

To check yourself, multiply 5×10^{10} by 6×10^{-4} on your calculator. Your answer should be 3×10^7 (your calculator may say "3E7", which is the same thing).

If you don't have a scientific calculator, you will need to know the following rules for combining numbers expressed in scientific notation:

Addition and Subtraction:

- All numbers are converted to the same power of 10, and the digit terms are added or subtracted.
- Example: $(4.215 \times 10^{-2}) + (3.2 \times 10^{-4}) = (4.215 \times 10^{-2}) + (0.032 \times 10^{-2}) = 4.247 \times 10^{-2}$
- Example: $(8.97 \times 10^4) - (2.62 \times 10^3) = (8.97 \times 10^4) - (0.262 \times 10^4) = 8.71 \times 10^4$

Multiplication:

- The digit terms are multiplied in the normal way and the exponents are added. The end result is formatted so that there is only one nonzero digit to the left of the decimal.
- Example: $(3.4 \times 10^6)(4.2 \times 10^3) = (3.4)(4.2) \times 10^{(6+3)} = 14.28 \times 10^9 = 1.4 \times 10^{10}$
(to 2 significant figures)
- Example: $(6.73 \times 10^{-5})(2.91 \times 10^2) = (6.73)(2.91) \times 10^{(-5+2)} = 19.58 \times 10^{-3} = 1.96 \times 10^{-2}$
(to 3 significant figures)

Division:

- The digit terms are divided in the normal way and the exponents are subtracted. The quotient is changed (if necessary) so that there is only one nonzero digit to the left of the decimal.
- Example: $(6.4 \times 10^6)/(8.9 \times 10^2) = (6.4)/(8.9) \times 10^{(6-2)} = 0.719 \times 10^4 = 7.2 \times 10^3$
(to 2 significant figures)
- Example: $(3.2 \times 10^3)/(5.7 \times 10^{-2}) = (3.2)/(5.7) \times 10^{3-(-2)} = 0.561 \times 10^5 = 5.6 \times 10^4$
(to 2 significant figures)

Powers of Exponentials:

- The digit term is raised to the indicated power and the exponent is multiplied by the number that indicates the power.
- Example: $(2.4 \times 10^4)^3 = (2.4)^3 \times 10^{(4 \times 3)} = 13.824 \times 10^{12} = 1.4 \times 10^{12}$
(to 2 significant figures)
- Example: $(6.53 \times 10^{-3})^2 = (6.53)^2 \times 10^{(-3) \times 2} = 42.64 \times 10^{-6} = 4.26 \times 10^{-5}$
(to 3 significant figures)

Roots of Exponentials:

- Change the exponent if necessary so that the number is divisible by the root. Remember that taking the square root is the same as raising the number to the one-half power.
- Example:

$$\sqrt{3.6 \times 10^5} = \sqrt{36 \times 10^4} = \sqrt{36} \times \sqrt{10^4} = 6.0 \times 10^2$$

- Example:

$$\sqrt[3]{7.3 \times 10^{-8}} = \sqrt[3]{73 \times 10^{-9}} = \sqrt[3]{73} \times \sqrt[3]{10^{-9}} = 4.2 \times 10^{-3}$$

QUIZ:

- Question 1** Write in scientific notation: 0.000467 and 32000000
- Question 2** Express 5.43×10^{-3} as a number.
- Question 3** $(4.5 \times 10^{-14}) \times (5.2 \times 10^3) = ?$
- Question 4** $(6.1 \times 10^5)/(1.2 \times 10^{-3}) = ?$
- Question 5** $(3.74 \times 10^{-3})^4 = ?$
- Question 6** The fifth root of $7.20 \times 10^{22} = ?$

Answers: (1) 4.67×10^{-4} ; 3.2×10^7 (2) 0.00543 (3) 2.3×10^{-10} (2 significant figures) (4) 5.1×10^8 (2 significant figures) (5) 1.96×10^{-10} (3 significant figures) (6) 3.73×10^4 (3 significant figures)



This page adapted from a math review for chemistry students at Texas A & M University.