Scientific Notation and Significant Figures

CH 2000: Introduction to General Chemistry, Plymouth State University

SCIENTIFIC NOTATION

I. INTRODUCTION

In science, especially in chemistry, it is common to run into numbers that are extremely large or extremely small. For example:

- Mass of the Earth: 5973600000000000000000000 kg
- Mass of a single hydrogen atom: 0.00000000000000000000000000167353 kg

Obviously it is inconvenient to write such numbers and nearly impossible to communicate them, which is why s*cientific notation* was created. Every number written in scientific notation takes the form:

$$X.YYY.... \times 10^{z}$$

where "X" is a single digit number 1-9 (*note: X cannot be zero!*), "Y" is any number, containing as many digits as necessary, and "Z" is any whole number, including negatives and zero.

Example:

- Mass of the Earth: 5.9736×10^{24} kg
- Mass of a single hydrogen atom: 1.67353×10^{-27} kg

II. CONVERTING SCIENTIFIC NOTATION TO REGULAR NOTATION

Notice that a number written in scientific notation is in fact a mathematical expression, wherein two numbers are multiplied together while the second number is a ten with an exponent. To convert a scientific notation number into a regular decimal number, you just do the math.

Conveniently, when 10 is raised to an exponent, the resulting number is found by starting with "1" and then shifting the decimal to the right (if the exponent is positive) or to the left (if the exponent is negative) by the indicated number of places.

Example:

1) $10^{2} = 100$ 2) $10^{-2} = 0.01$ 3) $10^{0} = 1$

Looking back at the scientific notation, we can now multiply the first (left) number by the "10" number to convert to a regular decimal. Notice that this really has the affect of just moving the decimal in the first (left) number by the number indicated in the exponent of the "10" number.

Example

1) $4.8 \times 10^{2} = 480$ 2) $8 \times 10^{-2} = 0.08$ 3) $3.14 \times 10^{0} = 3.14$

Of course there is no need to use scientific notation for the number in Example 3 above (3.14), but that is how to do it, if circumstances require scientific notation.

Practice (*answers are at the end of the worksheet*)
Convert each of the numbers from scientific notation to regular notation:

1. 2.28×10^{2}
2. 1.043×10^{4}
3. -6.634×10^{5}
4. 4×10^{-4}
5. 8.12×10^{-3}
6. 1.0×10^{-1}
7. 4.030×10^{-5}
8. -7.854×10^{-2}
9. 3.333×10^{12}
10. 7.234×10^{-12}

Notes:

- For numbers written in regular notation that are *smaller* than one (1), you MUST start the number with a zero in the one's place, e.g., 0.1
- For numbers written in regular notation that are *smaller* than one (1), the number of zeros between the decimal and the first non-zero digit is equal to *one less than the 10's exponent*.
- Any trailing zeros in the scientific notation number must also appear in the regular notation.

III. CONVERTING REGULAR NOTATION TO SCIENTIFIC NOTATION

It is probably more common that you will need to convert a regular digit number into scientific notation. To do so, you need to:

1. Count the number of places you will need to move the decimal (either right or left) so the resulting number has only one digit to the left of the decimal.
2. Write the number in scientific notation, with one non-zero digit left of the decimal and the exponent of the "10" as found in step 1 (negative is original number is less than one, positive if it is greater than one).

Example:

1) $2011 = 2.011 \times 10^{3}$ 2) $0.00405 = 4.05 \times 10^{-3}$

Practice:
Convert each of the following numbers from regular notation to scientific notation:

11. 5280
12. 1776
13. -182.8
14. 8564000000
15. 0.0034
16. 0.2134
17. -0.000005
18. 0.30006

IV. USING A CALCULATOR WITH SCIENTIFIC NOTATION

Except for the most basic ones, most calculators have functions for using scientific notation built in. However, there are several different ways calculators may do this, so you should become familiar with your own (and you are required to have one for General Chemistry!). You need to learn to do two things:

1. Switch your calculator between displaying scientific and regular notation
2. Enter numbers in scientific notation

Switching your calculator between displaying scientific and regular notation

Take a moment to figure out how to switch your calculator between the two notations. One common way calculators do this is through the use of a "Mode" button or menu. Note that "regular notation" mode may be called "normal" or "floating."

Entering numbers in scientific notation

Typically numbers are entered in scientific notation by entering the left number followed by an "exponent" key, which may look like "E," "EE," "Exp," or "10^". Some calculators may require you to enter literally "× 10^Z", but you should NOT do this if you have an exponent key, as it may cause you to get a number that is off by a factor of 10!

Practice

With your calculator in regular mode, enter the following numbers, hit the "Enter" or "=" key and ensure your calculator displays the correct number:

19. 2.14×10^{-3}
20. 5.1×10^{6}
21. 6.701×10^{-6}
22. -9.555×10^{5}

SIGNIFICANT FIGURES

I. INTRODUCTION

The use of significant figures is necessary and important when reporting numbers in science, because it communicates the precision to which you are certain about your answer. Believe it or not, significant figures are not a new concept to you, and they do have application in real life! For example, let's say you are buying something at a store, and you ask a clerk "how much is this?" You might receive one of the following answers:

- "About $100"
- "$98 and change"
- "$98.76"

All of these answers may be correct, and depending on the circumstance, any of them may be appropriate. For example, if the clerk is guessing based on experience but does not know for sure, the first answer is the best. On the other hand, if the clerk does not know but gives the third answer, he is lying. Furthermore, you will be very annoyed when you get to the counter and discover it costs $105.25!

In chemistry, significant figures are particularly important, because every instrument is limited in how precisely it can measure, and more precise instruments are more expensive. If a chemist reports a number with more significant figures than his instrument can measure, he is lying about how good his instrument is. On the other hand, if a chemist reports fewer numbers than her instrument can do, she has wasted her money!

II. DETERMINING SIGNIFICANT FIGURES OF A NUMBER

There are a few rules to follow when determining how many significant figures a number contains:

1. All non-zero digits are significant
2. All zero's between any significant digits are significant
3. All zero's on the left of non-zero digits are not significant
4. All zero's on the right of non-zero digits are significant if they are also right of the decimal
5. In scientific notation, all the digits of the first (left) number are significant

Example

Number	Significant Figures	Number	Significant Figures
54	2	0.0345	3
123.4	4	0.405	3
101	3	13.20	4
303.03	5	3.0000	5
0.005	1	10.0	3
50	1	0.00305600	6
24000	2	8.70×10^{-9}	3

Practice

How many significant figures are in each of the following numbers?

23. 2002
24. 8723094
25. 0.000945
26. 25.300
27. 0.34
28. 0.04980
29. 990099.00
30. 3.887×10^{-3}

III. USING SCIENTIFIC NOTATION TO COMMUNICATE SIGNIFICANT FIGURES

As indicated by Rule 5 above, one good use of scientific notation is in the communication of significant digits. That is, one always knows the significant figures of a number in scientific notation, even if the same number in regular notation would have an ambiguous number of them.

Example

In regular notation, the number 500 would technically have one significant figure. However, it may be that it was measures on an instrument that can go to two or three significant figures. Or you may want to write it in such a way that there is no ambiguity about it only having one significant figure. Here is where scientific notation can help:

- One significant figure: 5×10^2
- Two significant figures: 5.0×10^2
- Three significant figures: 5.00×10^2

Practice

Write the following numbers in scientific notation, so they have the number of significant figures indicated:

31. 0.563 (3 sig figs)
32. 747 (3 sig figs)
33. 6400 (4 sig figs)
34. 12000 (3 sig figs)
35. 28890 (4 sig figs)
36. 0.004 (2 sig figs)

IV. MATH WITH SIGNIFICANT FIGURES

In the process of doing mathematical operations, you will often be combining two or more numbers together that have different significant figures. There are a few rules you need to know in order to ensure your answer has the correct number of significant figures:

1. When adding or subtracting, line up the decimals of the number. The significant figures in the final answer by the number where the significant figures on the right side end first.
2. When multiplying or dividing, the significant figures in the final answer are equal to the least number of significant figures in any of the numbers.

Example

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1.   53.3              2.   210
   +  2.43                - 33.3
     55.7                 180  (1.8 × 10^2)
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3. $36.7 \times 1.2 \times 6342 = 270000$ (2.7×10^5)
4. $9.83 \div 23.56 = 0.417$

Practice

Do the arithmetic below and report your answers to the proper number of significant figures. Use scientific notation if your answer would be ambiguous without it:

37. 45 + 100.5
38. 945000 - 65345
39. 0.098 + 12.3456
40. 26.7 + 78.98
41. 24.89 + 25.111
42. $(9.109 \times 10^{-6}) + (1.6726 \times 10^{-2})$
43. 96.78×1.2
44. 0.0224×345.3
45. $(5.00 \times 10^{2}) \times 5.544$
46. $654000 \div 1111$

<u>ANSWERS TO **PRACTICE** QUESTIONS</u>

1. 228
2. 10430
3. -663400
4. 0.0004
5. 0.00812
6. 0.10
7. 0.00004030
8. -0.07854
9. 333000000000
10. 0.000000000007234
11. 5.280×10^3
12. 1.776×10^3
13. -1.828×10^2
14. 8.564×10^9
15. 3.4×10^{-3}
16. 2.134×10^{-1}
17. -5×10^{-6}
18. 3.0006×10^{-1}
19. 0.00214
20. 5100000
21. 0.000006701
22. -955500
23. 4
24. 7
25. 3
26. 5
27. 2
28. 4
29. 8
30. 4
31. 5.63×10^3
32. 7.47×10^2
33. 6.400×10^3
34. 1.20×10^4
35. 2.889×10^4
36. 4.0×10^{-3}
37. 145
38. 8.80×10^5
39. 12.444
40. 105.7
41. 50.00
42. 0.016735 or 1.6735×10^{-2}
43. 1200 or 1.2×10^3
44. 7.73
45. 2770 or 2.77×10^3
46. 589