Chemistry 3A

Introductory General Chemistry

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Math in Chem: Algebra Review

- The quantity a
- The inverse of the quantity: $\frac{1}{a} = {}^{1}/_{a}$
- The inverse of the inverse takes you back: $\frac{1}{\left(\frac{1}{a}\right)} = a$

$$\frac{\left(\frac{a+b}{c-d}\right)}{\left(\frac{e+f}{g-h}\right)} = \frac{(a+b)(g-h)}{(c-d)(e+f)}$$

- "Implied denominator of 1". It might help when solving chemistry problems

The number 2.4 = $\frac{2.4}{1}$

Quantities

Number	Unit	Dimension
1	mile	length (distance)
0.25	liters	volume
15	amperes	electric current

A (measured) **quantity** in science, in chemistry has a **number** and a **unit** associated with it

- The number is how many/much
- The unit is a scale of the measurement, the how many/much of what

Scientific Notation

A way of expressing numerical values

Format: *d.mmm* × 10^n

Part	*n.mmm*
Part Name	Significand (preferred), Coefficient, (Mantissa is obsolete term)
Part Property	Number greater than or equal to 1.0 and less than 10. This number properly express significant digits
Part	10^n
Part Name	Exponent
Part Property	Exponent of 10 where ***n*** is integer, negative, positive (note $10^0 = 1$)

Scientific Notation

decimal point moves to right

$1. = 10^0$

$10. = 10^1$

$100. = 10^2$

decimal point moves to left

$0.1 = 10^{-1}$

$0.01 = 10^{-2}$

$0.001 = 10^{-3}$

Scientific Notation

1. Is the number less than 10 and greater than 1?

   You don't really need scientific notation, because it will be
   [*d.mmm* × 10^0] and $10^0 = 1$, so → *d.mmm*

2. Otherwise take the number and express as *d.mmm*

3. If original number is greater than *d.mmm* you have to multiply by 10^1 ***n*** times to get to original number, so ***n*** will be positive (greater than zero): ***n*** × 1 = ***n*** (greater than zero)

4. If original number less than *d.mmm* you have to multiply by 10^{-1} ***n*** times to get to original number, so ***n*** will be positive (greater than zero): ***n*** × -1 = -***n*** (less than zero)

Scientific Notation

3. If original number is <u>*greater than*</u> *d.mmm* you have to multiply by 10^1 ***n*** times to get to original number, so ***n*** will be positive (greater than zero): ***n*** × 1 = +***n***

Your book: "if you moved decimal point to the left ***n*** places, then ***n*** is positive"

35 → 35. → 3.5 *moved to left 1 place*

3.5×10^1

23849 → 23849. → 2.3849 *moved to left 4 places*

2.3849×10^4

Scientific Notation

1. If original number *<u>less than</u>* *d.mmm* you have to multiply by 10^{-1} (or divide by 10) ***n*** times to get to original number, so ***n*** will be negative (less than zero): ***n*** × -1 = -***n***

Your book: "if you moved decimal point to the right ***n*** places, then ***n*** is negative"

0.0000035 → 3.5 *moved to right 6 places*

3.5×10^{-6}

0.023849 → 2.3849 *moved to right 2 places*

2.3849×10^{-2}

Scientific Notation

Patterns for memorizing

- *decimal point movement – number being changed – final exponent value*

- Left – Large – Positive
- Right – Small – Negative

Positive and negative for exponent, not significand!

34249 → 3.4249×10^4

-34249 → -3.4249×10^4

0.0034249 → 3.4249×10^{-3}

-0.0034249 → -3.4249×10^{-3}

Scientific Notation

Scientific notation is actually a *product* of two numbers: the significand and a power of 10!

$34249 = 3.4249 \times 10^4 = 3.4249 \times 10{,}000 = 34249$

$-34249 = -3.4249 \times 10^4 = -3.4249 \times 10{,}000 = -34249$

$0.0034249 = 3.4249 \times 10^{-3} = 3.4249 \times 0.001 = 0.0034249$

$-0.0034249 = -3.4249 \times 10^{-3} = -3.4249 \times 0.001 = -0.0034249$

Use this feature to confirm whether you converted a number to scientific notation properly!

Practicing Scientific Notation

Let’s start with an “original” number

- one not in scientific notation
- This number will be (much) greater than 10

238,700

Two hundred thirty-eight thousand seven hundred

Practicing Scientific Notation

238,700

Our goal will be to get to a number between 1 and 10 since scientific notation requires it, and it should include the leftmost non-zero digit to the rightmost non-zero digit

This span of digits will be the significand

The significand should in the end be of *d.mmm…* form2.387

So we need to determine the exponent (power of 10)

Practicing Scientific Notation

1. Place the “implied” decimal point where it should be

238,700.

2. Move it in the direction of where it should end up

This is to the left to produce a 2.387 significand

23,870.

3. What is the relationship between 238,700 and 23,870? You have to multiply by 10!

That is $238{,}700 = 23{,}870 \times 10$

We also note that $10 = 10^1$

So $238{,}700 = 23{,}870 \times 10^1$

Let’s repeat the movement until we get to proper form

Practicing Scientific Notation

238,700. (the original number)

23,870. → $23,870 \times 10^1 = 238,700$

2,387. → $2,387 \times 10^2 = 238,700$

238.7 → $238.7 \times 10^3 = 238,700$

Note that we were dropping zeroes until we hit the non-zero number “7”, but the decimal point still moves

23.87 → $23.87 \times 10^4 = 238,700$

2.387 → $2.387 \times 10^5 = 238,700$

The decimal point was not moved to create the significand: we have a number less than 10, greater than 1. With each movement of decimal point, we created the power of 10. At every step, equal to original number

Practicing Scientific Notation

Let's try a number much less than 1

0.00003049 (the original number)

Following the rules/format, the significand should look like 3.049 in the end

0.0003049 / 10 = 0.00003049

$0.0003049 \times 10^{-1} = 0.00003049$

0.003049 / 100 = 0.00003049

$0.003049 \times 10^{-2} = 0.00003049$

0.03049 / 1000 = 0.00003049

$0.03049 \times 10^{-3} = 0.00003049$

0.3049 / 10000 = 0.00003049

$0.3049 \times 10^{-4} = 0.00003049$

3.049 / 100000 = 0.00003049

$3.049 \times 10^{-5} = 0.00003049$

Significant Digits

Significant digits indicate the precision, the confidence of a single measurement

Also called significant figures

Measurement /Value	Significant Digits	Explanation
1.7	2	All non-zero digits significant
1.732	4	
17.32704	7	Zeroes between non-zero digits are significant

Significant Digits

Measurement /Value	Significant Digits	Explanation
0.0045	2	leading zeroes after decimal point not significant
0.00450	3	trailing zeroes after decimal are significant
1200	2	
1200.	4	assertion of decimal point makes significant
0.000	0	no non-zero digits at all
1000.0	5	adding decimal point and any zeroes after it makes all digits significant
100	1	evaluated like the “1200” example above
1.200×10^{-3}	4	all digits in scientific notation should be significant

Significant Digits

Significant digits indicate the precision, the confidence of a single measurement

Preparative balance

- Measuring quantities usually 0.1 g (100 mg) or greater
- used to weigh masses for starting a chemistry experiment
- Precision example: 3.4 g sodium chloride (NaCl)

Analytical balance

- Measuring quantities usually down to 0.0001 g (0.1 mg or 100 µg) or greater
- used to weigh masses for determining yield of product at end of a chemistry experiment
- Precision example: 0.0241 g copper(II) sulfate pentahydrate

18 ≠ 18. ≠ 18.0 ≠ 18.00

- They are all mathematically equal to 18
- But they are not the same in terms of the precision or certainty of the value

18 ➔ 2 significant digits: ±1

18. ➔ also 2 significant digits: ±1

But the measuring device will show decimals

18.0 ➔ 3 significant digits: ±0.1

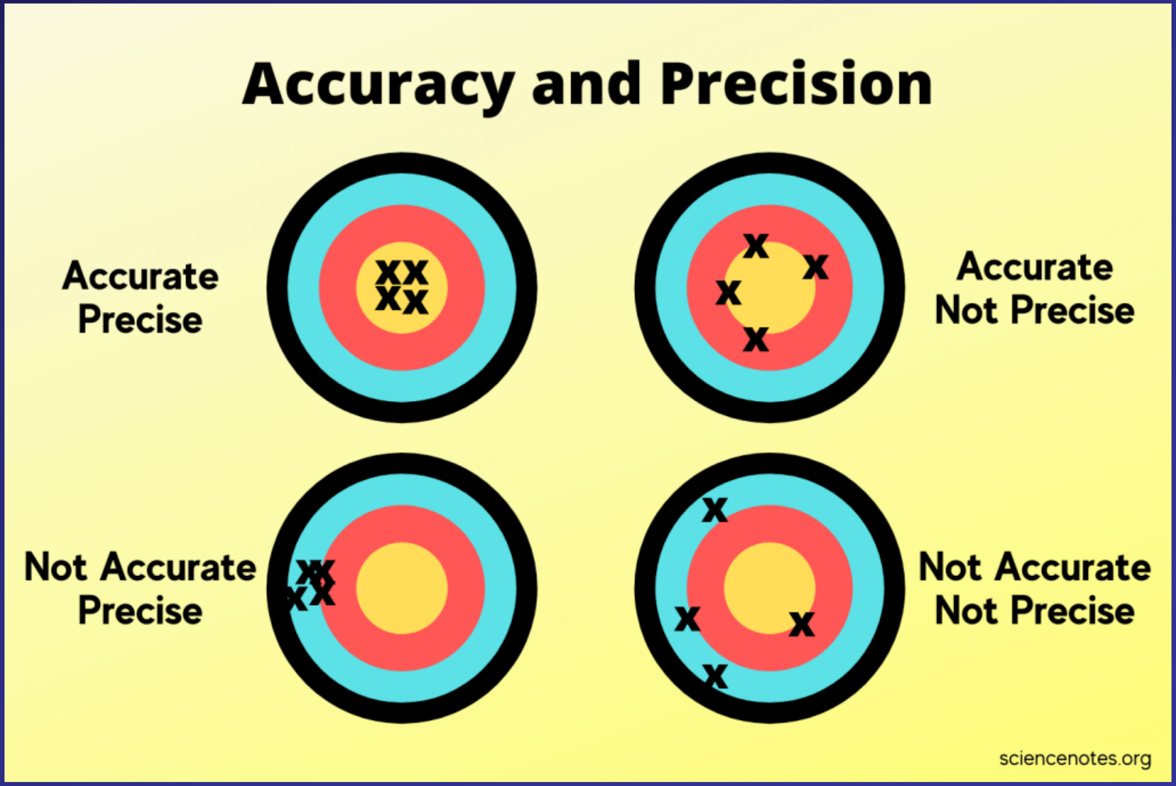
18.00 ➔ 4 significant digits: ±0.01

A Slight Tangent on “Precision”

Multiple Measurements

Precision – an indicator of how measurements repeat the value being measured

Accuracy – an indicator of how measurements get to the true value



Significant Digits in Scientific Notation

The rules on significant digits in numerical values always apply in scientific notation

$2.69 \times 10^{-5} = 0.0000269$ (3 significant digits)

$2.69000 \times 10^{-5} = 0.0000269000$ (6 significant digits)

$2.69 \times 10^{3} = 2690$ (3 significant digits)

You still have add the zero to get standard form of number as integer

$2.69000 \times 10^{3} = 2690.00$ (6 significant digits)

Doing Math with "Decimal Places"

Addition and Subtraction of Numbers with Different Decimal Places

Solve 12.11 + 18.0 + 1.013 =

				Result	
				Calculator's Display	Your Answer
Value	12.11	18.0	1.013	31.123	31.1
Decimal Places	2	1	3	3	1

Solve 100.29 – 2.343 – 72.9 =

				Result	
				Calculator's Display	Your Answer
Value	100.29	2.343	72.9	25.047	25.1
Decimal Places	2	3	1	3	1

Solve 1000.23 – 87.532 + 200.49 – 50.439 =

					Result	
					Calculator's Display	Your Answer
Value	1000.23	87.532	200.49	50.439	1062.749	1062.75
Decimal Places	2	3	2	3	3	2

Doing Math with Sig Digits

Multiplication and Division of Numbers with Different Significant Digits

Solve 4.56 x 1.4 =

			Result	
			Calculator's Display	Your Answer
Value	4.56	1.4	6.384	6.4
Sig Digits	3	2	-	1

Solve 834.4 ÷ 34.92 x 2.104 =

				Result	
				Calculator's Display	Your Answer
Value	834.4	34.92	2.104	50.27427262	50.27
Sig Digits	4	4	4	-	4

Solve 2340.09 ÷ 24.190 =

			Result	
			Calculator's Display	Your Answer
Value	2340.09	24.190	50.27427262	50.27
Sig Digits	6	5	-	4

Doing Calculations: NO INTERMEDIATE ROUNDING!!!

Simple example

Calculate the cost of carpeting a 4.8 m x 3.2 m floor where the carpeting costs \$42 per square meter

You do the calculation in steps:

1. The area: $4.8\ \text{m} \times 3.2\ \text{m} = 15.36\ \text{m}^2$ (value on calculator display)
2. Finishing off

   rounding no decimal: $15\ \text{m}^2 \times (\$42 / \text{m}^2) =$ **\$630.00**

   rounding to one decimal: $15.4\ \text{m}^2 \times (\$42 / \text{m}^2) =$ **\$646.80**

   no rounding: $15.36\ \text{m}^2 \times (\$42 / \text{m}^2) =$ **\$645.12**
3. No need for intermediate result determination in nearly all cases
4. $4.8\ \text{m} \times 3.2\ \text{m} \times (\$42 / \text{m}^2) =$ **\$645.12**

In business accounting & chemistry, do the rounding at the end of the calculation. To significant digits

Doing Chem Math

- Addition and Subtraction
  - look at the DECIMAL PLACES!
- Multiplication and Division
  - look at the SIGNIFICANT DIGITS!

The Book

1. Do the Multiplication and Division first
2. Then do Addition and Subtraction operations

If you do intermediate rounding—I wouldn’t!—then if you follow the book, this is acceptable

PEMDAS

PEMDAS -- (P)arentheses, (E)xponents, (MD) Multiplication/Division, (AS) Addition/Subtraction

5 + 6 x 2 - 8 / 4

- P and E: none
- MD: 5 + 12 - 2
- AS: 15

14^2 + 633 / 3 - 14 x 8

- P: none
- E: 196 + 633 / 3 - 14 x 8 (did 14^2)
- MD: 196 + 211 - 112
- AS: 295

PEMDAS

PEMDAS -- (P)arentheses, (E)xponents, (MD) Multiplication/Division, (AS) Addition/Subtraction

$(22.17 + 100.24) \times (443.4 + 349.3) / 4^3$

- P: $122.41 \times 792.7 / 4^3$
- E: $122.41 \times 792.7 / 64$ (64 is not a MEASUREMENT!)
- MD: 1516.162609
- AS: 1516.162609 ==> **1516**

PEMDAS

PEMDAS -- (P)arentheses, (E)xponents, (MD) Multiplication/Division, (AS) Addition/Subtraction

100.13 – 23.433 / ((443.4 + 349.3) / 2^4)

- P: 100.13 – 23.433 / (792.7 / 2^4) →
  100.13 – 23.433 / (792.7 / 16) →
  100.13 – 23.433 / 49.54375
- E: evaluated within parentheses!
- MD: 100.13 - 0.47297590513
- AS: 99.6570240949 ==> **99.66**

"Conversion Factors"

Calculations in chemistry frequently require converting between the units of a quantity

- Volume: fluid ounces to milliliter ("fl oz" to "ml")
- Temperature: Celsius to Kelvin ("°C" to "K")
- Pressure: torr to atmosphere ("torr" to "atm"

Conversions not just about measurement systems but also include scales which are powers of 10

- 1 liter (L) = 1000 milliliters = 1000 mL

  not 1000 ml! use SI unit lettering case
- 1 kilogram (kg) = 1000 grams (g)

Conversion Nomenclature

Prefix	Meaning	Example
Multiple of 10 (greater than 1)		
kilo- (k)	10^3 = 1000	2 kilograms (kg) = 2000 grams
mega- (M)	10^6 = 1,000,000	3.7 megajoules (MJ) = 3,700,000 J
giga- (G)	10^9 = 1,000,000,000	10 gigahertz (GHz) = 10,000,000,000 Hz
Submultiples of 10 (fractions of 1)		
deci- (d)	10^{-1} = 1/10	1 deciliter (dL, dl) = 0.1 L
centi- (c)	10^{-2} = 1/100	2.54 centimeter (cm) = 0.0254 m
milli- (m)	10^{-3} = 1/1000	14 millibar (mbar) = 0.014 bar
micro- (u/μ)	10^{-6} = 1/1000000	259 microliters (μl, ul, μL, uL) = 0.000259 L
nano- (n)	10^{-9} = 1/1000000000	34 nanograms (ng) = 0.000000034 g
pico- (p)	10^{-12} = 1/1000000000000	250 picoliters (pL) = 0.00000000025 L
femto- (f)	10^{-15} =1/ 1000000000000000	4.3 femtomoles (fmol) = 0.0000000000000043 mol

***units** in green are often used in chemistry*

Conversion Practice

A room measures 16 ft x 20 ft in area. What is it in square meters (m^2)

A conversion problem is going to be an equation usually involving a mathematical product (the multiplication of quantities), and these quantities will include your given quantities and <u>conversion factors</u>

$$16 \text{ ft} \times 12 \text{ ft} \times \ldots\ldots = \ ? \ m^2$$

Conversion Practice

A room measures 16 ft x 20 ft in area. What is it in square meters (m^2)

I remember

- 12 inches = 1 foot
- 2.54 cm = 1 inch
- 100 cm = 1 meter

These are actually conversion factors !

We have to get enough conversion factors to go from units on the left to the result with unit on right of equation!

$$16 \text{ ft} \times 12 \text{ ft} \times \ldots\ldots = \ ? \ m^2$$

Conversion Practice

A room measures 16 ft x 20 ft in area. What is it in square meters (m^2)

- 12 inches = 1 foot
- 2.54 cm = 1 inch
- 100 cm = 1 meter

We know we have to multiply 16 ft x 12 ft to get an area → that will give us a value in square feet (ft^2)

$$16\ \text{ft} \times 12\ \text{ft} \times \ldots\ldots = \ ?\ \text{m}^2$$

Conversion Practice

A room measures 16 ft x 20 ft in area. What is it in square meters (m^2)

- 12 inches = 1 foot
- 2.54 cm = 1 inch
- 100 cm = 1 meter

So we need a conversion factor that is in ft^2

12 in = 1 ft ➔ $(12 \text{ in})^2 = (1 \text{ ft})^2$

I am not going to evaluate it right now: I will add it to the equation

$$\frac{16 \text{ ft}}{1} \times \frac{12 \text{ ft}}{1} \times \frac{(12 \text{ in})^2}{(1 \text{ ft})^2} \times \ldots = ? \;\; \text{m}^2$$

Conversion Practice

$$\frac{16\ \text{ft}}{1} \times \frac{12\ \text{ft}}{1} \times \frac{(12\ \text{in})^2}{(1\ \text{ft})^2} \times \ \ldots = ?\ \ \text{m}^2$$

I added the conversion factor in a way that when "ft x ft" is evaluated, it equals "ft^2"

If we evaluate that expression right now and stop, we drop the units to get just the numbers, and we get an answer of $16 \times 12 \times 12^2 = 27468$

The $ft \times ft / ft^2$ should "cancel": two "ft" in the numerator, "ft^2" in the denominator "in^2" is left in the numerator, so that would be the intermediate result: "27,468 in^2"

Conversion Practice

$$\frac{16\ \mathrm{ft}}{1} \times \frac{12\ \mathrm{ft}}{1} \times \frac{(12\ \mathrm{in})^2}{(1\ \mathrm{ft})^2} \times \frac{(2.54\ \mathrm{cm})^2}{(1\ \mathrm{in})^2} \times \frac{(1\ \mathrm{m})^2}{(100\ \mathrm{cm})^2} = ?\ \ \mathrm{m}^2$$

Note that we had to use the squared version of these linear conversions to get cancellation of the units in the quantities, but this is to demonstrate what you may sometimes need to keep track of. The book discusses this too.

When you have ensured all the units cancel, remove them from the equation, and evaluate the expression on the left

$$\frac{16}{1} \times \frac{12}{1} \times \frac{(12)^2}{(1)^2} \times \frac{(2.54)^2}{(1)^2} \times \frac{1^2}{100^2} = 17.8\ \mathrm{m}^2$$

Conversion Practice

- Now I suppose you could look up in a table that $1\ \text{ft}^2 = 0.092903\ \text{m}^2$

$$\frac{16\ \text{ft}}{1} \times \frac{12\ \text{ft}}{1} \times \frac{0.092903\ \text{m}^2}{1\ \text{ft}^2} = 17.8\ \ \text{m}^2$$

Just keep in mind what the conversion factor is and how you use it to cancel units properly in evaluating the product. Ensure that the resulting final unit is what it should be.

Density

How much mass is in a given volume

The math definition:

$$density = \frac{mass}{volume}$$

$$\rho = \frac{m}{V}$$

Greek letter *rho* (ρ) is symbol for density

Densities of Natural Substances

Table 1.4.1: Densities of Common Substances	
Substance	**Density at 25°C (g/cm3)**
blood	1.035
body fat	0.918
whole milk	1.030
corn oil	0.922
mayonnaise	0.910
honey	1.420

Problem Solving Process Using Density

The problem/question (from your book)

A mercury thermometer for measuring a patient's temperature contains 0.750 g of mercury.

What is the volume of this mass of mercury?

The most important thing you will ever do is to spend the time and effort to fully understand the question, and identify the key elements of it

Look for what is asked for: <u>volume</u> of mercury

Look for what is given: a <u>mass</u> (7.50 g) of mercury

Problem Solving Process Using Density

What is missing from the information given in the problem/question?

Usually the information not given are constants of nature and (numerical) properties of matter and energy like atomic weights.
In this case, it is a <u>density</u>.

The density of a substance is a property that allows you to relate its mass to its volume *and vice versa*

The density of water is 1 g/mL (at 0°C) and is a <u>property</u> of water

The density of mercury is 13.6 g/mL

Problem Solving Process Using Density

For this equation about density, this is all just algebra below which you already know

$$\rho = \frac{m}{V} \rightarrow V \times \rho = m \rightarrow V = \frac{m}{\rho} = \frac{1}{\rho} \times m$$

In the last manipulation, we have an expression that tells us what the volume is equal to: the inverse of the density multiplied by the mass, or “mass over density”

Problem Solving Process Using Density

$$\frac{1}{\rho} \times m = V$$

We now just enter the values to solve:

$$\frac{1}{13.6\ \mathrm{g}/\mathrm{mL}} \times 7.50\ \mathrm{g} = \frac{1\ \mathrm{mL}}{13.6\ \mathrm{g}} \times 7.50\ \mathrm{g} = 0.55\ \mathrm{mL}$$

Could be expressed as 5.5×10^{-1} mL

Or converting to microliters (µL)

$$0.55\ \mathrm{mL} \times \frac{1000\ \mu\mathrm{l}}{1\ \mathrm{mL}} = 550\ \mu\mathrm{L}$$

Temperature

- A measure of the average kinetic energy of particles in a substance
- Not energy itself, but an indicator or measure of energy

Measuring Temperature

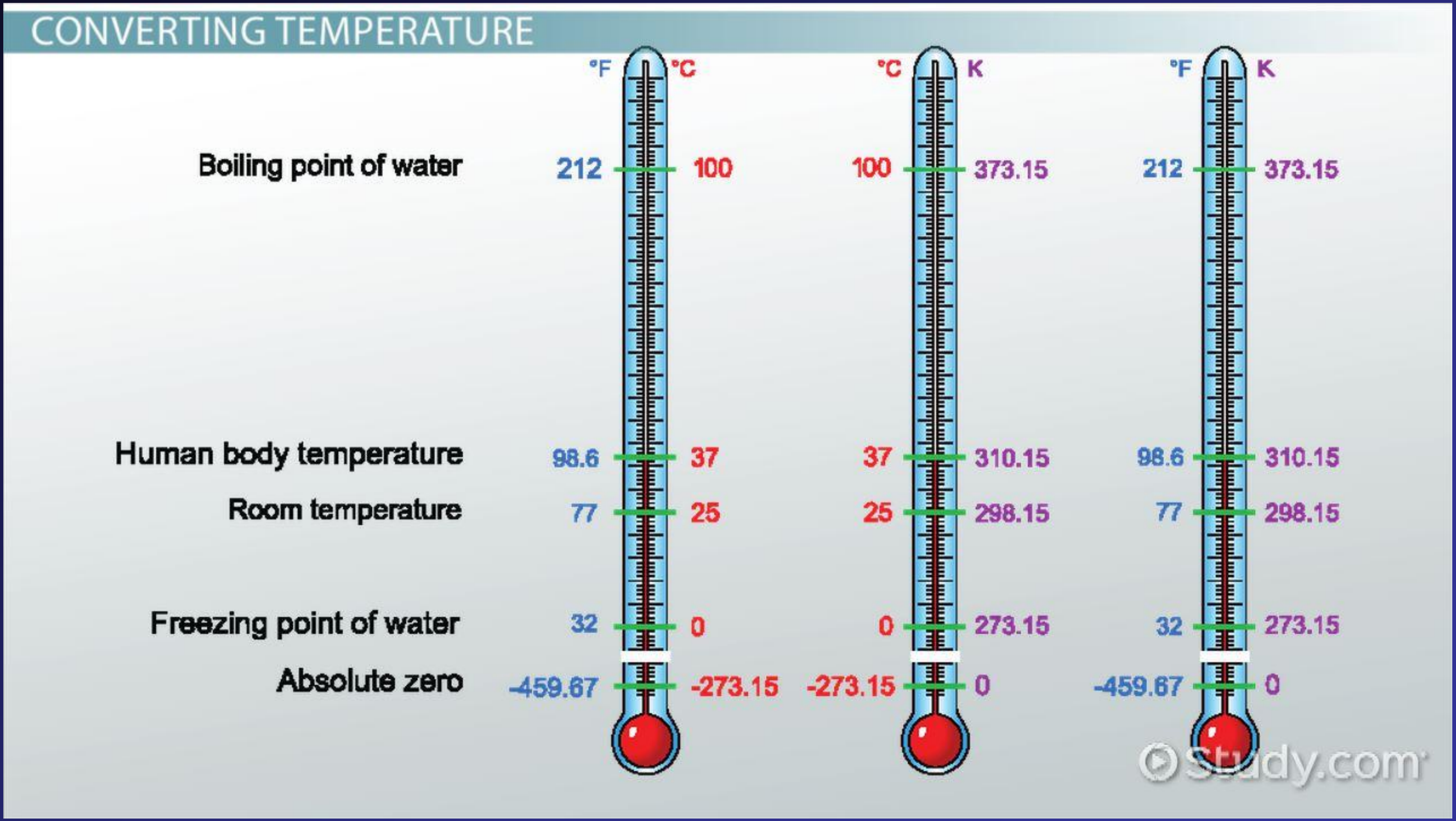


image from Study.com

Temperature Scales

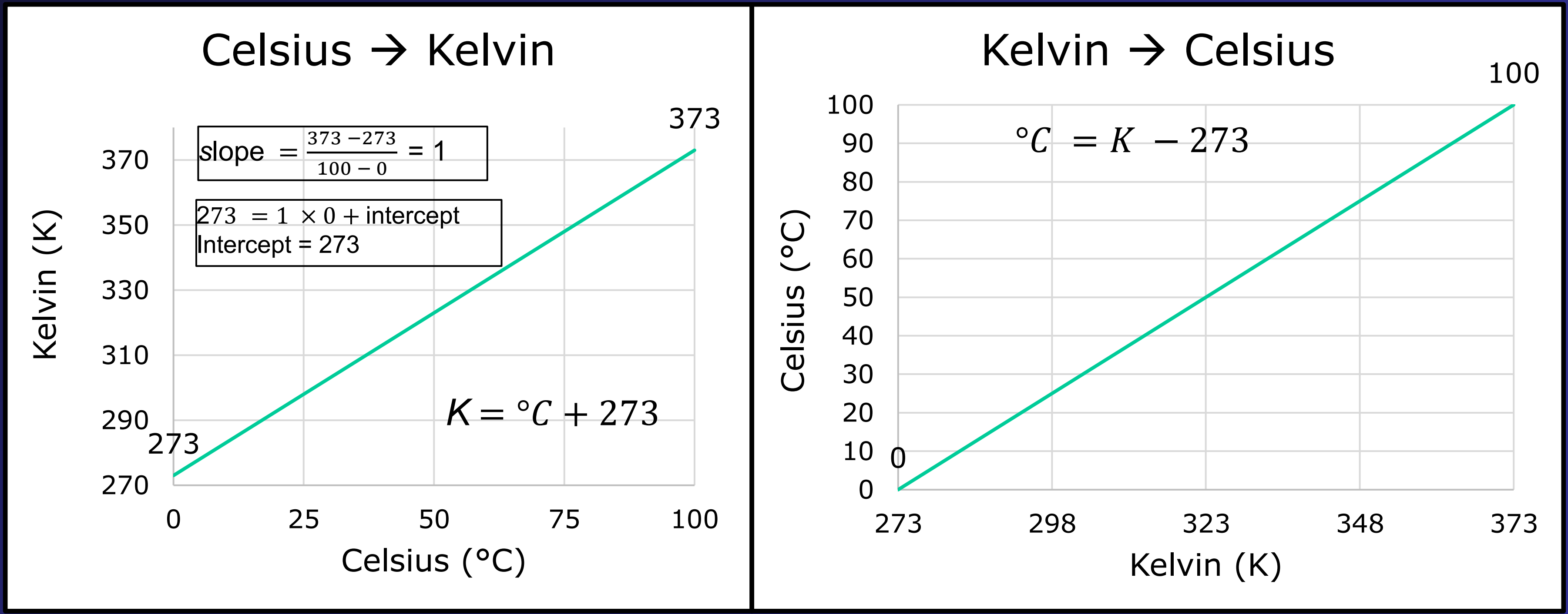
Three scales (measurement types) are used to get a value of temperature

Scale	Water Property	
	freezing point	boiling point
Fahrenheit	32° F	212° F
Celsius (centigrade)	0° C	100° C
Kelvin	273 K	373 K

Thermometers usually involve expansion or contraction of calibrated sealed tube of mercury (Hg) or dyed-alcohol

Converting Temperature

Conversions apply basic algebraic principles of sloped lines



Converting Temperature

Fahrenheit not used in chemistry, but be prepared to convert