Petrucci's General Chemistry

PRINCIPLES AND MODERN APPLICATIONS

PETRUCCI HERRING MADURA BISSONNETTE

Matter: Its Properties and Measurement

1

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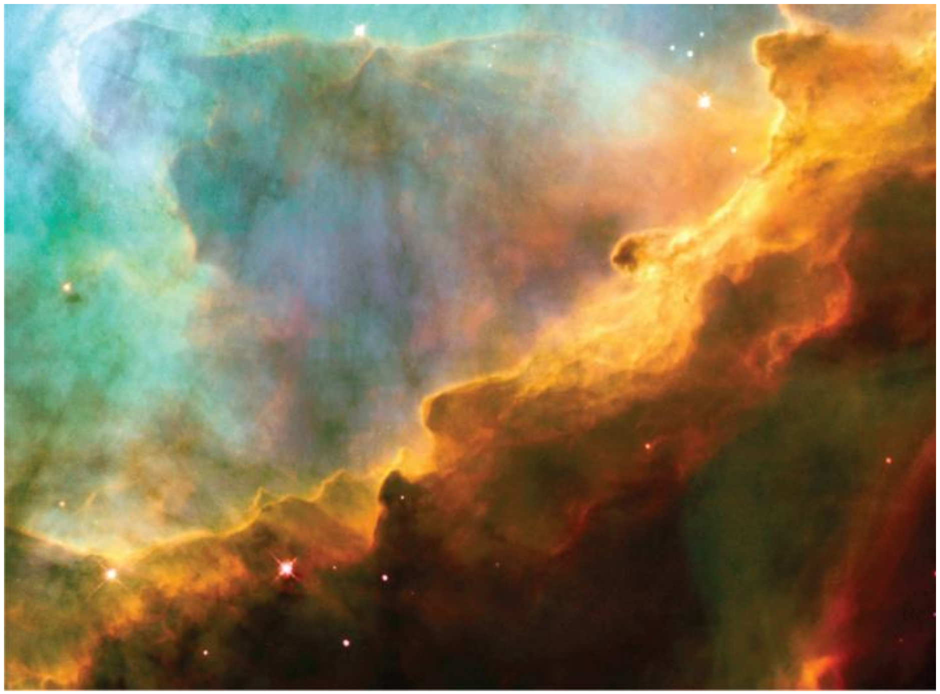


CONTENTS

1 -1 The Scientific Method

Louis Pasteur (1822-1895)

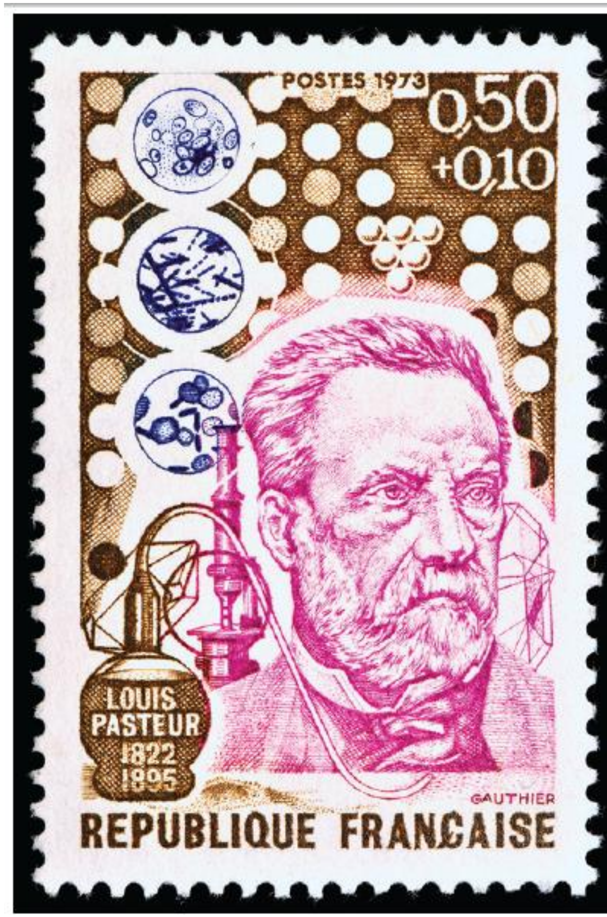
developer of germ theory

pasteurization of milk

rabies vaccination

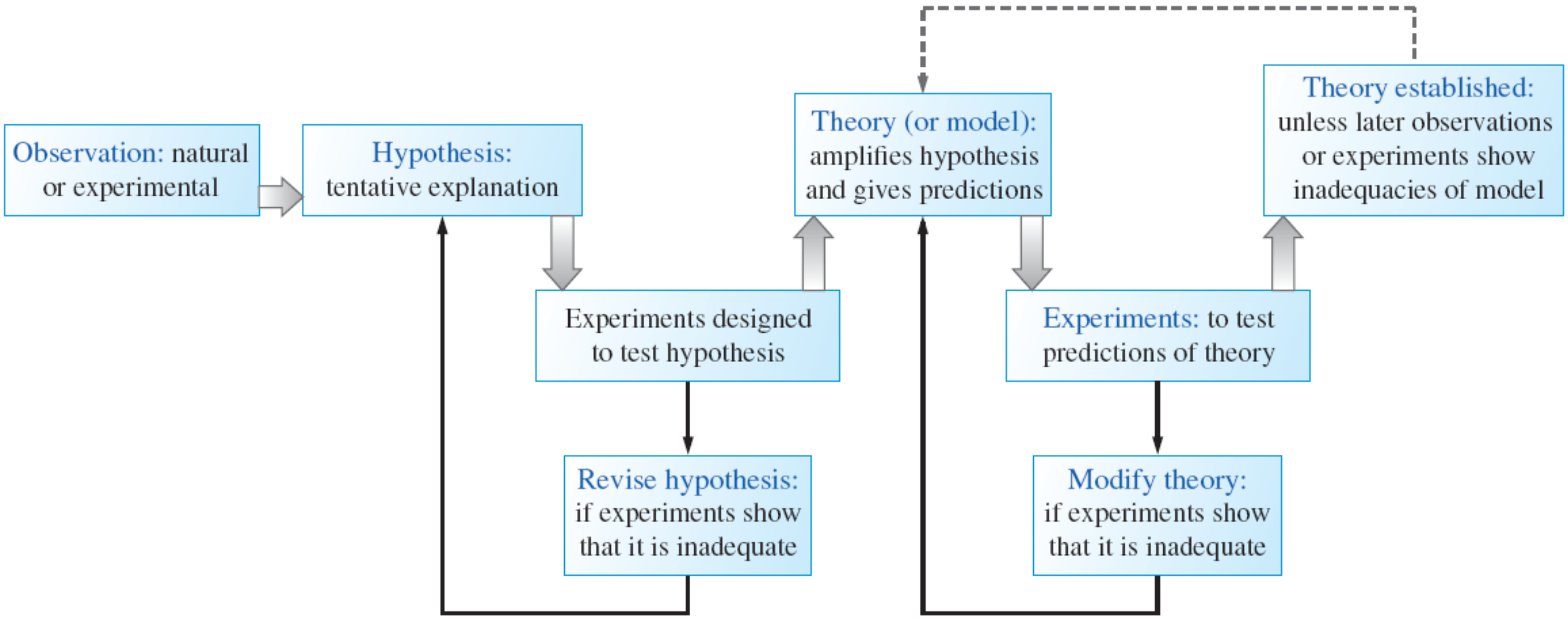
Called the greatest physician of all time by some.

He was a chemist by training and profession.



1 -1 The Scientific Method

A combination of observation, experimentation, and the formulation of laws, hypotheses, and theories.



1 -2 Properties of Matter

Matter: Occupies Space, has mass and inertia

Composition: Parts or components

ex. H_2O, 11.19% H and 88.81% O

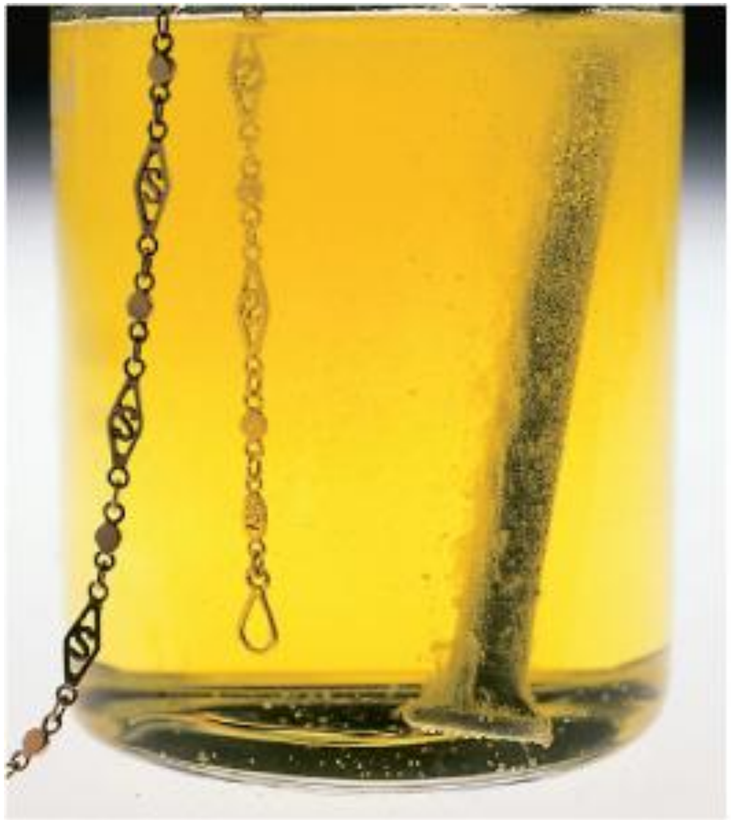
Properties: Distinguishing features

physical and chemical properties

Physical Property is one that a sample of matter displays without changing its composition.

Physical properties of sulfur and copper

Chemical Property is the ability (or inability) of a sample of matter to undergo a change in composition under stated conditions.



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A chemical property of zinc and gold: reaction with hydrochloric acid

1 -3 Classification of Matter

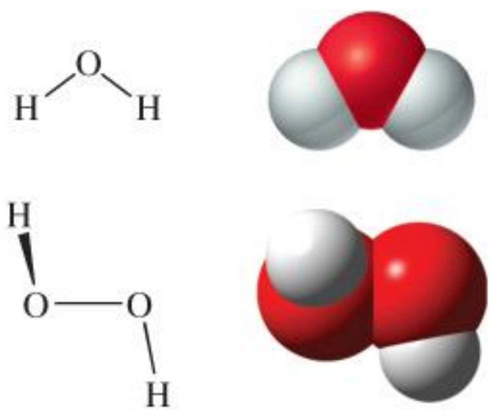
Matter is made of **atoms**.

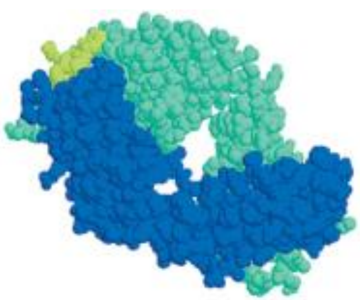
114 **elements**.

About 90% available from natural sources

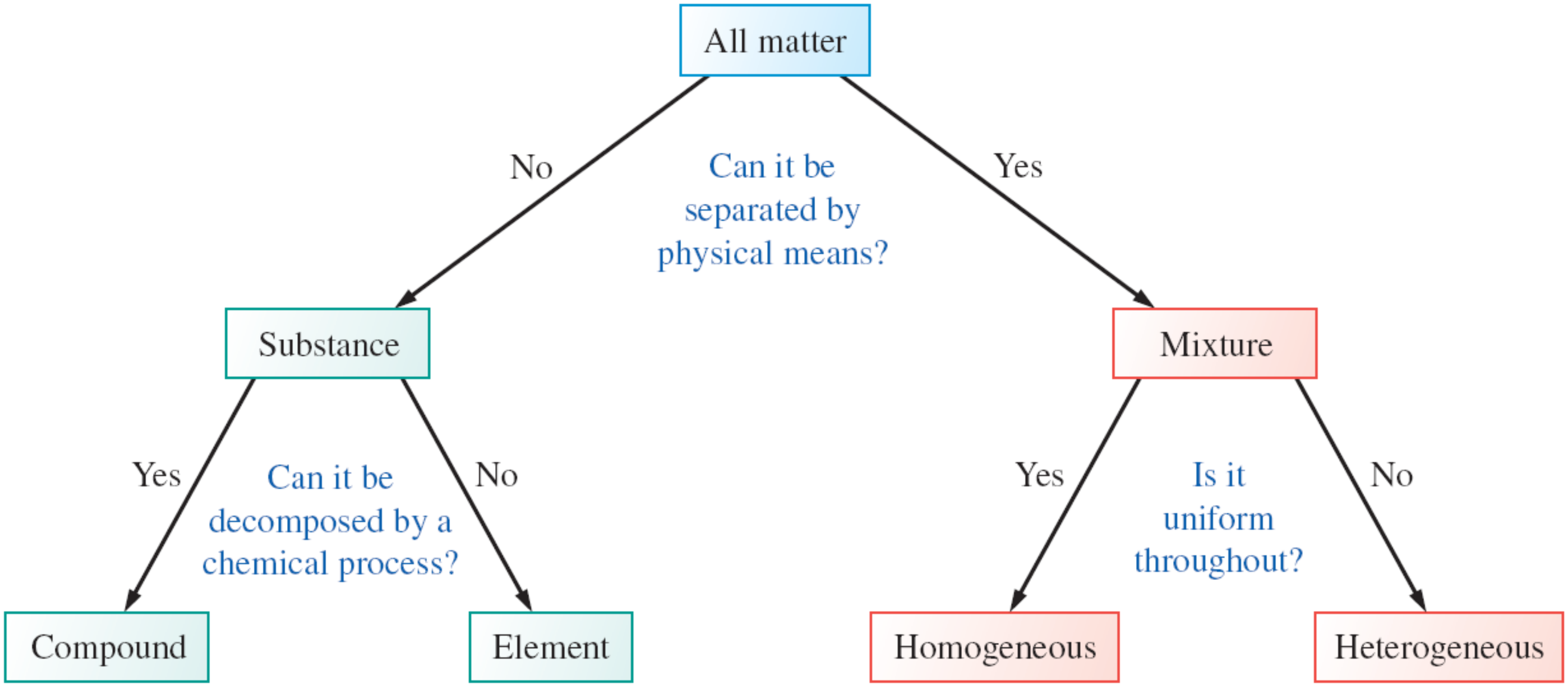
Compounds are comprised of two or more elements.

Molecules are the smallest units of compounds.





Gamma globulin



A classification scheme for matter

1 -4 The Measurement of Matter: SI (Metric) Units

Table 1.1 SI Base Quantities

Physical Quantity	Unit	Symbol
Length	meter[a]	m
Mass	kilogram	kg
Time	second	s
Temperature	kelvin	K
Amount of substance	mole[b]	mol
Electric current[c]	ampere	A
Luminous intensity[d]	candela	cd

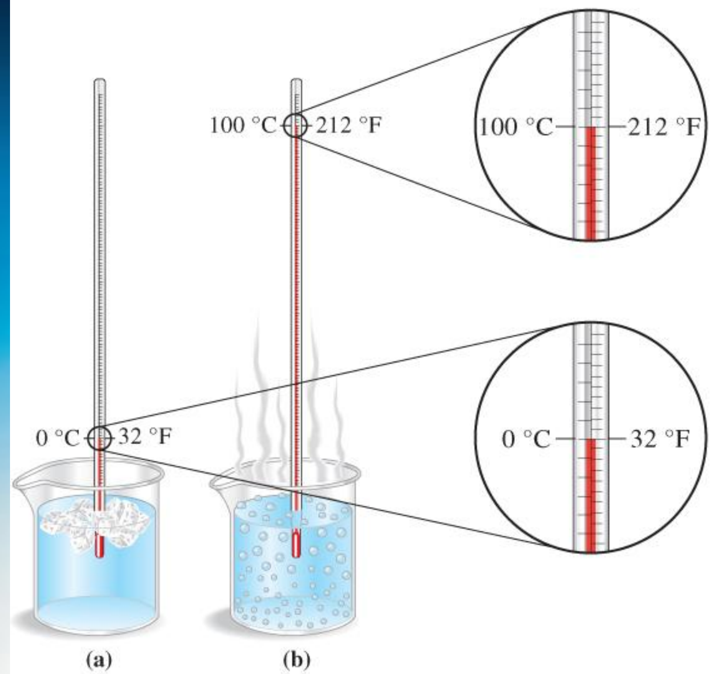
Table 1.2 SI Prefixes

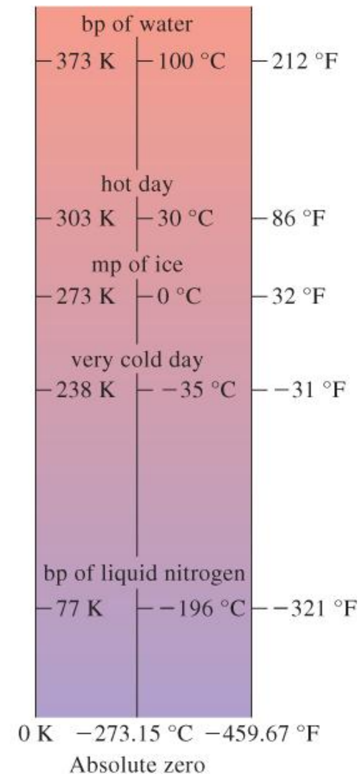
Multiple	Prefix
10^{18}	exa (E)
10^{15}	peta (P)
10^{12}	tera (T)
10^{9}	giga (G)
10^{6}	mega (M)
10^{3}	kilo (k)
10^{2}	hecto (h)
10^{1}	deka (da)
10^{-1}	deci (d)
10^{-2}	centi (c)
10^{-3}	milli (m)
10^{-6}	micro (μ)[a]
10^{-9}	nano (n)
10^{-12}	pico (p)
10^{-15}	femto (f)
10^{-18}	atto (a)
10^{-21}	zepto (z)
10^{-24}	yocto (y)

[a]The Greek letter μ (pronounced "mew").

Mass

Temperature





EXAMPLE 1-1 Converting Between Fahrenheit and Celsius Temperatures

The predicted high temperature for New Delhi, India, on a given day is 41°C. Is this temperature higher or lower than the predicted daytime high of 103°F for the same day in Phoenix, Arizona, reported by a newscaster?

Analyze

We are given a Celsius temperature and seek a comparison with a Fahrenheit temperature. To convert the given Celsius temperature to a Fahrenheit temperature, we use the equation given previously that expresses $t(°\mathrm{F})$ as a function of $t(°\mathrm{C})$.

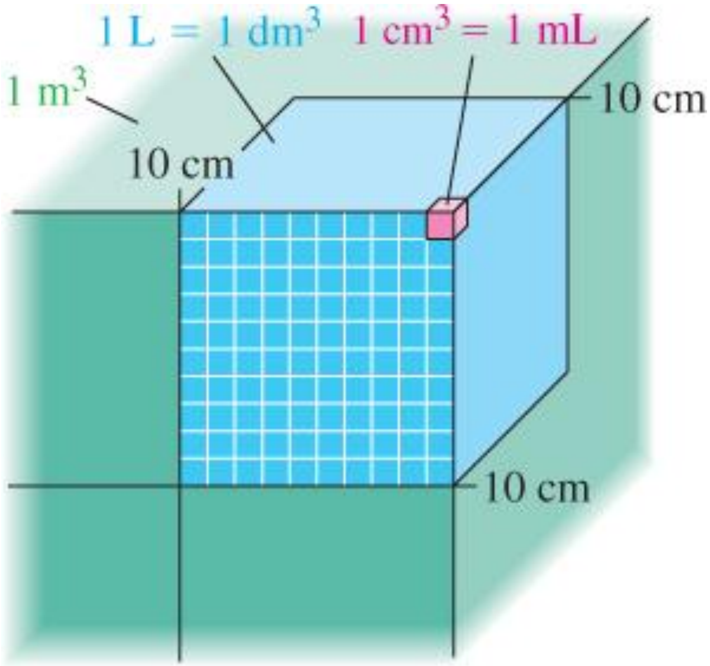
Solve

$$t(°\mathrm{F}) = \frac{9}{5}t(°\mathrm{C}) + 32 = \frac{9}{5}(41) + 32 = 106°\mathrm{F}$$

The predicted temperature for New Delhi, 106°F, is 3°F higher than for Phoenix, 103°F.

Assess

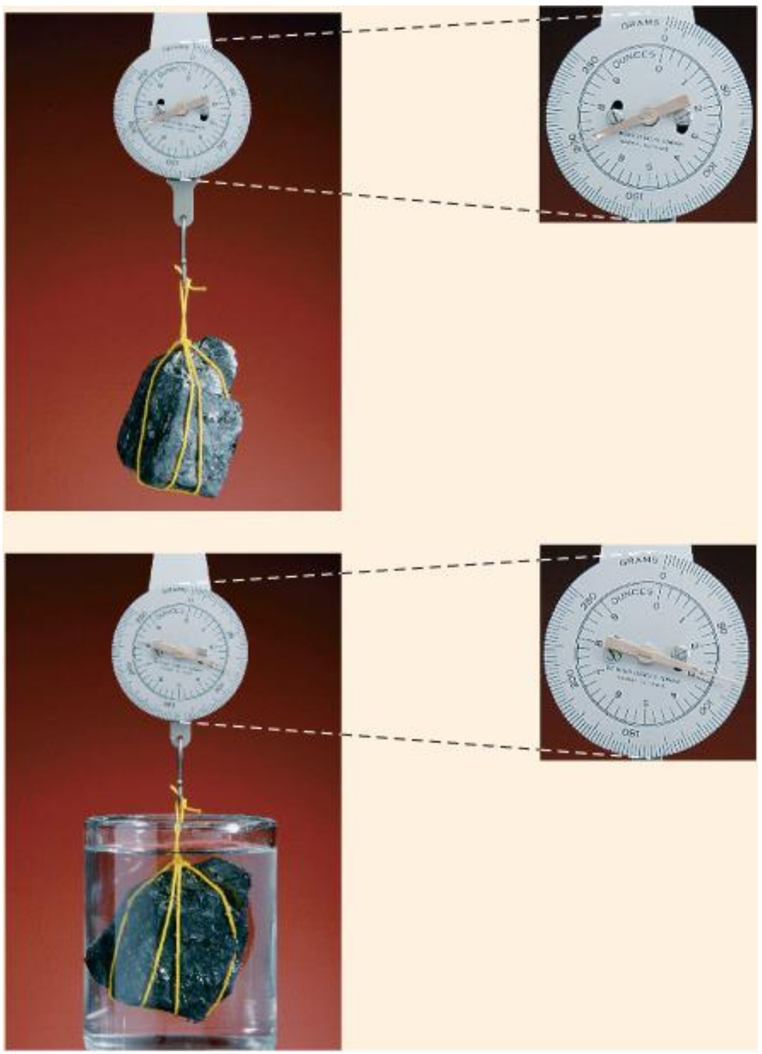
For temperatures at which $t(°\mathrm{C}) > -40°\mathrm{C}$, the Fahrenheit temperature is greater than the Celsius temperature. If the Celsius temperature is lower than −40°C, then $t(°\mathrm{F})$ is lower than (more negative than) $t(°\mathrm{C})$ (Fig. 1-8). Concept Assessment 1-3 asks you to think further about the relationship between $t(°\mathrm{C})$ and $t(°\mathrm{F})$.



Volume

Derived Units

Velocity		m s^{-1}
Volume	m^3	1000 L
	L	1000 cm^3 1 dm^3
Force	N	kg m s^{-2}
Pressure	Pa	kg m^{-1} s^{-2}
Energy	J	kg m^2 s^{-2}



EXAMPLE 1-3 **Determining the Density of an Irregularly Shaped Solid**

A chunk of coal is weighed twice while suspended from a spring scale (see Figure 1-10). When the coal is suspended in air, the scale registers 156 g; when the coal is suspended underwater at 20°C, the scale registers 59 g. What is the density of the coal? The density of water at 20°C is 0.9982 g cm^{-3}.

Analyze

We need the ratio of mass to volume of the chunk of coal. The mass of the coal is easily obtained; it is what registers on the scale when the coal is suspended in air: 156 g. But what is the volume of this chunk of coal? The key to this calculation is the weight measurement under water. The coal weighs less than 156 g when submerged in water because the water exerts a buoyant force on the coal. The buoyant force is the difference

(continued)

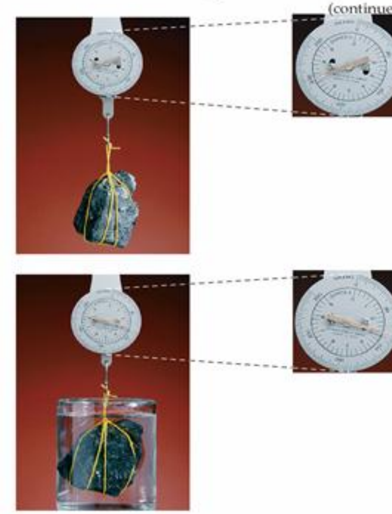


Figure 1-10 **Measuring the volume of an irregularly shaped solid**
When submerged in a liquid, an irregularly shaped solid displaces a volume of liquid equal to its own volume. The necessary data can be obtained by two mass measurements of the type illustrated here; the required calculations are like those in Example 1-3.
Kristen Brockmann/Fundamental Photographs

between the two weight measurements: 156 g − 59 g = 97 g. Recall the statement on page 42 that a submerged solid displaces a volume of water equal to its own volume. We don't know this volume of water directly, but we can use the mass of displaced water, 97 g, and its density, 0.9982 g/cm^3, to calculate the volume of displaced water. The volume of the coal is equal to the volume of displaced water.

Solve

The mass of the chunk of coal is 156 g. If we use m_{water} to denote the mass of displaced water, then the volume of the displaced water is calculated as follows:

$$V = \frac{m_{water}}{d} = \frac{156\ g - 59\ g}{0.9982\ g/cm^3} = 97\ cm^3$$

The volume of the chunk of coal is the same as the volume of displaced water. Therefore, the density of the coal is

$$d = \frac{156\ g}{97\ cm^3} = 1.6\ g/cm^3$$

Assess

To determine the density of an object, we might think it is necessary to make measurements of both the mass and volume of the object. Example 1-3 shows that a volume measurement is not necessary. The steps in our calculation can be combined to give the following expression:

(density of object)/(density of water) = (weight in water)/(weight in air − weight in water).

Measuring Volume of an Irregular Object

1 -6 Uncertainties in Scientific Measurements

Systematic errors

Thermometer constantly 2ºC too low (Built-in).

Random errors

Limitation in reading a scale (Experimenter's skill).

Precision

Reproducibility of a measurement.

Accuracy

How close to the real value.


ACCULAB
sartorius group
VICON
10.5 g
ON/OFF
ZERO
CAL
F
ENTER
PRINT

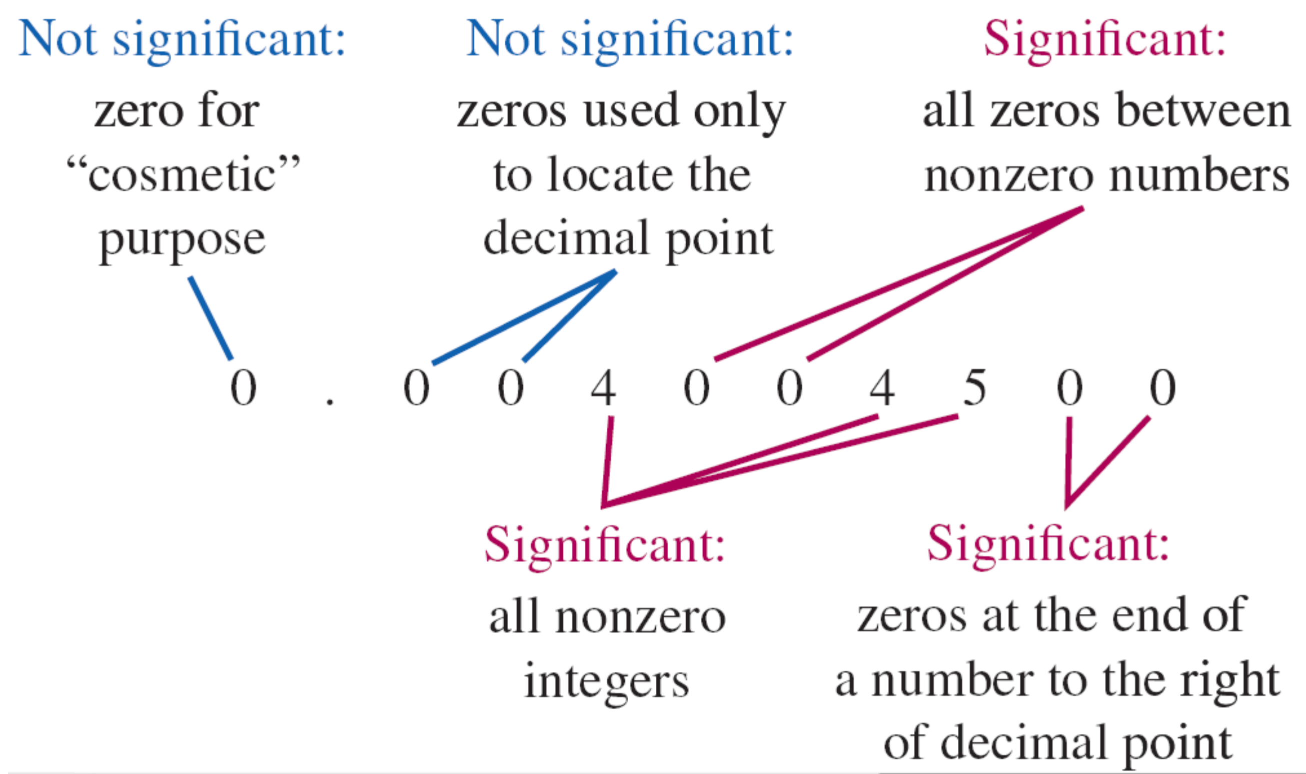

Denver Instrument
M-220
10.4978
GRAM

1 -7 Significant Figures

- All nonzero digits are significant.
- Zeros are also significant, but with two important exceptions for quantities less than one. Any zeros (1) preceding the decimal point, or (2) following the decimal point and preceding the first nonzero digit, are not significant.
- The case of terminal zeros that precede the decimal point in quantities greater than one is ambiguous.

Determining the number of significant figures in a quantity

1 -7 Significant Figures



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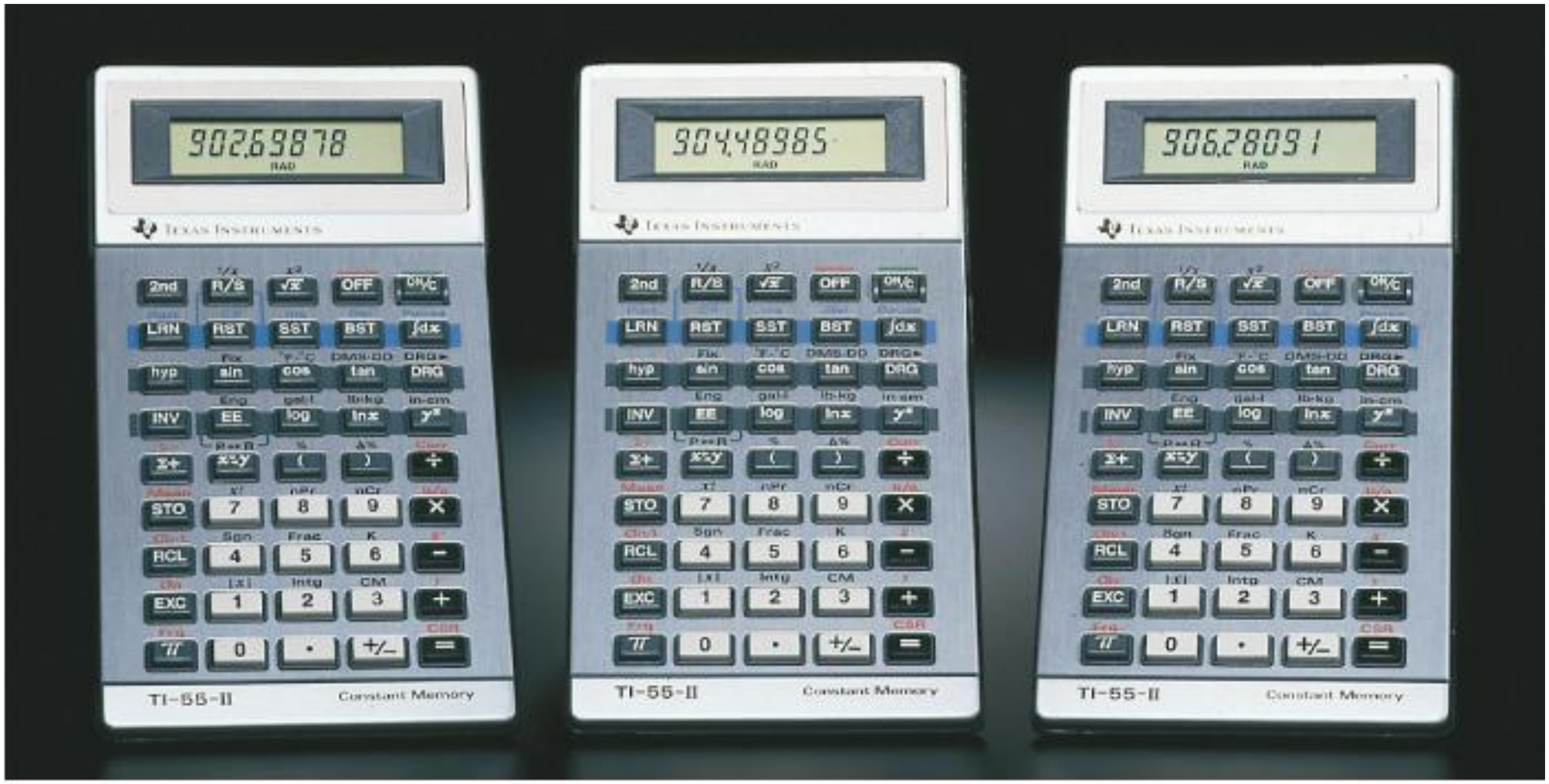
Determining the number of significant figures in a quantity

The calculators show the effect of the change in a low precision number (N) in a calculation $14.79 \times 12.11 \times N$

N = 5.04 5.05 5.06



▲ Figure 1-12

Significant figure rule in multiplication

EXAMPLE 1-5 Applying Significant Figure Rules: Multiplication/Division

Express the result of the following calculation with the correct number of significant figures.

$$\frac{0.225 \times 0.0035}{2.16 \times 10^{-2}} = ?$$

Analyze

By inspecting the three quantities, we see that the least precisely known quantity, 0.0035, has *two* significant figures. Our result must also contain only *two* significant figures.

Solve

When we carry out the calculation above by using an electronic calculator, the result is displayed as 0.0364583. In our analysis of this problem, we determined that the result must be rounded off to two significant figures, and so the result is properly expressed as 0.036 or as 3.6×10^{-2}.

Assess

To check for any possible calculation error, we can estimate the correct answer through a quick mental calculation by using exponential numbers. The answer should be $(2 \times 10^{-1})(4 \times 10^{-3})/(2 \times 10^{-2}) \approx 4 \times 10^{-2}$, and it is. Expressing numbers in exponential notation can often help us quickly estimate what the result of a calculation should be.

PRACTICE EXAMPLE A: Perform the following calculation, and express the result with the appropriate number of significant figures.

$$\frac{62.356}{0.000456 \times 6.422 \times 10^{3}} = ?$$

PRACTICE EXAMPLE B: Perform the following calculation, and express the result with the appropriate number of significant figures.

$$\frac{8.21 \times 10^{4} \times 1.3 \times 10^{-3}}{0.00236 \times 4.071 \times 10^{-2}} = ?$$

EXAMPLE 1-6 Applying Significant Figure Rules: Addition/Subtraction

Express the result of the following calculation with the correct number of significant figures.

$$(2.06 \times 10^2) + (1.32 \times 10^4) - (1.26 \times 10^3) = ?$$

Analyze

If the calculation is performed with an electronic calculator, the quantities can be entered just as they are written, and the answer obtained can be adjusted to the correct number of significant figures. To determine the correct number of significant figures, identify the largest quantity, and then write the other quantities with the same power of ten as appears in the largest quantity. The answer can have no more digits beyond the decimal point than the quantity having the smallest number of such digits.

Solve

The largest quantity is 1.32×10^4 and thus, we write the other two quantities as 0.0206×10^4 and 0.126×10^4. The result of the required calculation must be rounded off to two decimal places.

$$\begin{aligned}(2.06 \times 10^2) &+ (1.32 \times 10^4) - (1.26 \times 10^3)\\ &= (0.0206 \times 10^4) + (1.32 \times 10^4) - (0.126 \times 10^4)\\ &= (0.0206 + 1.32 - 0.126) \times 10^4\\ &= 1.2146 \times 10^4\\ &= 1.21 \times 10^4\end{aligned}$$

Assess

If you refer back to the margin note on page 48, you will see that there is another way to approach this problem. To determine the absolute error in the least precisely known quantity, we write the three quantities as $(2.06 \pm 0.01) \times 10^2$, $(1.32 \pm 0.01) \times 10^4$ and $(1.26 \pm 0.01) \times 10^3$. We conclude that 1.32×10^4 has the largest absolute error ($\pm 0.01 \times 10^4$) and so, the absolute error in the result of the calculation above is also $\pm 0.01 \times 10^4$. Thus, 1.2146×10^4 is rounded to 1.21×10^4.

PRACTICE EXAMPLE A: Express the result of the following calculation with the appropriate number of significant figures.

$$0.236 + 128.55 - 102.1 = ?$$

PRACTICE EXAMPLE B: Perform the following calculation, and express the result with the appropriate number of significant figures.

$$\frac{(1.302 \times 10^3) + 952.7}{(1.57 \times 10^2) - 12.22} = ?$$

Both Multiplication/Division and Addition/Subtraction with Significant Figures

When doing different kinds of operations with measurements with significant figures, do whatever is in parentheses first, evaluate the significant figures in the intermediate answer, then do the remaining steps

$$3.489 \times (5.67 - 2.3) =$$

2 dp   1 dp

$$3.489 \times 3.\underline{3}7 = 12$$

4 sf   1 dp & 2 sf   2 sf

Rounding

When rounding to the correct number of significant figures, if the number after the place of the last significant figure is

0 to 4, round down

- drop all digits after the last sig. fig. and leave the last sig. fig. alone
- add insignificant zeros to keep the value if necessary

5 to 9, round up

- drop all digits after the last sig. fig. and increase the last sig. fig. by one
- add insignificant zeros to keep the value if necessary

To avoid accumulating extra error from rounding, round only at the end, keeping track of the last sig. fig. for intermediate calculations

Rounding

Rounding to 2 significant figures

2.34 rounds to 2.3

2.37 rounds to 2.4

2.349865 rounds to 2.3

- 0.0234 rounds to 0.023 or 2.3×10^{-2}
- 0.0237 rounds to 0.024 or 2.4×10^{-2}
- 0.02349865 rounds to 0.023 or 2.3×10^{-2}

- 234 rounds to 230 or 2.3×10^{2}
- 237 rounds to 240 or 2.4×10^{2}
- 234.9865 rounds to 230 or 2.3×10^{2}