

# Complete Solutions and Answers

for

## General Chemistry

by

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# Chapter Exercises

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NOTE: Full solutions to the computations in the chapter exercises shown below are also available in the *Solutions Manual to Accompany General Chemistry*. To procure a copy, visit [novaescienceandmath.com](http://novaescienceandmath.com).

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## Introduction Exercises

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### 1. Write five brief paragraphs summarizing the main ideas behind the titles of Sections I.1.1 through I.1.5.

Chemistry is all about electrons: Chemical reactions involve interactions between the electrons of atoms. The cloud-like regions where an atom's electrons are are called orbitals, and electrons reside in particular orbitals according to how much energy they have. The orbitals are grouped into energy groupings called shells. Atoms seek to gain, lose, or share electrons so that they have only full shells. Electronegativity also plays a role in electron position. Some atoms attract their electrons more strongly than others (higher electronegativity). This creates polar regions in molecules and leads to attractions and repulsions between molecules.

Chemistry is all about electrical forces: Some forces are stable, like the electrical attractions hold together the atoms in crystals. Others are less stable. Polarity in molecules creates attractions and repulsions between molecules, of which hydrogen bonding is the supremely important example. Hydrogen bonding in water is responsible for many of the unique properties of water.

Chemistry is all about minimizing energy: Two examples of energy minimization are a) a ball in a valley—the ball remains in the valley because its energy there is lower than it would be on the sides of the valley. If a tunnel opens up for the ball to move to another valley lower down, it goes there. b) when released, an inverted cone falls down on its side. This is a lower energy state for a cone than being inverted. In chemical reactions, atoms might be given an energy kick by a flame or other source of energy to get them out of their “energy valley”. Then the atoms are free to interact with each other. When they do, energy is released and the atoms combine together to form compounds where the atoms are in lower energy states. Entropy is a measure of the disorder in a system, and in natural processes, entropy always increases. Sometimes the goals of minimizing energy and maximizing entropy pull a system in opposite directions. Such processes go in the most favorable direction. Also mentioned is the fact that Einstein first proposed that the energy atoms possess is quantized.

Chemistry is all about whole-number ratios of atoms: In molecules and in crystals, atoms always combine together in consistent-whole number ratios. This is a powerful computational tool, and allows us to compute the amount of one compound that reacts with another compound.

Chemistry is all about modeling: Since chemistry involves atoms and electrons we cannot see, we must model chemical processes. This is the case in general with science: science is the process of developing mental models, and we call these models theories. The Cycle of Scientific Enterprise is a model of how scientific knowledge works. According to this model, theories are formed to account for known scientific facts in a unified explanatory framework. A scientific fact is statement supported by a lot of evidence that is correct so far as we know, but which can change. From theories, hypotheses are formed. A hypothesis is a specific prediction about what will happen in certain circumstances. Hypotheses are tested in experiments, and the outcome of an experiment (whether positive or negative) adds to the body of known scientific facts. If the hypothesis is confirmed, the theory it came from is strengthened. If disconfirmed, the theory is weakened.

### 2. Describe two examples, other than those in this Introduction, of a system of some kind spontaneously (without help) moving from a higher energy state to a lower energy state. (Hint: If energy is being released, it means the entities involved in the process are moving to a lower energy state.)

Examples include anything falling or going downhill, any chemical reaction in which light or heat is released, any mechanical system moving from a stretched or compressed state to a relaxed state.

### 3. Describe two examples, other than those in this Introduction, of a system that will move to a lower energy state if allowed to, but which needs an initial boost of energy to get started (like the ball in Figure I.5 being kicked and then having enough energy to get out of the valley).

Example answers:

1. Popping a balloon with a pin.
2. A cart that can roll downhill but which is stuck, and a small push gets it started.
3. Water that can drain from a container through a hole in the bottom, but the hole is plugged up. Applying a momentary higher pressure to the container can unplug the hole and allow the water to drain out.

**4. Describe two examples of processes in which entropy decreases. In each case, describe what source of energy and/or intelligence must be present for the decrease in entropy to occur. Here is an example to assist your thinking: an oxygen tank contains pressurized oxygen gas. The oxygen in this tank is more ordered than the oxygen in air because it has been separated from the air; there is a boundary (the tank) between the oxygen and the air. And if the valve on the tank is opened, the oxygen flows out into the air to increase the entropy (disorder). What we will never see: opening the tank valve and oxygen atoms from the atmosphere spontaneously flow into the tank. But the oxygen is put into the tank somehow, and the process that put it there decreases the entropy of that oxygen.**

Example answers:

1. A child stacking blocks. The child is supplying the energy and intelligence to position the blocks in the stack.
2. Building a house. The workers supply the intelligence and some of the energy. Other energy is supplied by various machines and vehicles.

**5. What is the ratio of nitrogen atoms to hydrogen atoms in ammonia molecules? What is the ratio of hydrogen atoms to carbon atoms in propane molecules?**

In ammonia the N:H ratio is 1:3. In propane, the H:C ratio is 8:3.

**6. Why are water molecules polar and what is the significance of this fact?**

They are polar because the electronegativity of oxygen is higher than that of hydrogen. The result is that water molecules are polar. This means they stick to each other and to other polar or electrically charged objects. This gives water many of its unique properties, such as the fact that it expands just before freezing so that ice floats.

**7. If oppositely charged objects attract, why can't a free electron and a free proton collide into one another and stick together because of their opposite charges?**

Energy is quantized, so an electron attached to a proton possesses a specific amount of energy and will go into an orbital for that specific amount of energy.

**8. A hydronium ion is a water molecule that has gained an extra proton. (A proton is identical to a hydrogen ion.) Hydronium ions form spontaneously in water, and are formed in greater quantities any time an acid is poured into water. What is the ratio of hydrogen atoms to oxygen atoms in hydronium ions?**

The H:O ratio is 3:1.

**9. What is hydrogen bonding?**

The example of hydrogen bonding discussed here is the attraction of the positive H ends of water molecules to the negative O region in the center of the molecule. This attraction makes water molecules stick together in the liquid state. It also makes water molecules arrange into hexagonal patterns when they enter the solid state.

**10. Distinguish between endothermic and exothermic processes.**

In an endothermic process, energy is absorbed. In an exothermic process energy is released. Fires and explosions are exothermic. Photosynthesis is an endothermic process where energy from the sun is absorbed to make the process occur.

**11. In a previous course, you may have learned about the "gold foil experiment" conducted by Ernest Rutherford in 1909. (I describe this experiment in Chapter 2.) This experiment led Rutherford to propose that the positive charge in atoms is concentrated in a tiny nucleus in the center of the atom. Think about this experiment and explain why Rutherford had to depend on inference as he interpreted his experimental data.**

First, no one can see atoms or the charged particles in atoms. Any time we are trying to explain processes involving things we

cannot see or feel we must depend on inference. Second, at the time of this experiment very little was known about atoms. Rutherford had J.J. Thomson's atomic model in mind, in which the positive charge is distributed evenly throughout the atom. Rutherford's high-velocity alpha particles should have blown right through atoms of gold if the positive charge was structured this way. This didn't always happen, which forced Rutherford to come up with a new atomic theory based on inference from his data.

**12. Why doesn't oil dissolve in water?**

Water molecules are polar, oil molecules are not. Water molecules are attracted to each other and any nonpolar molecules around will simply get squeezed out of the way so that the oil and water separate.

**13. Distinguish between facts, theories, and hypotheses.**

A fact is a scientific statement supported by a lot of evidence that is correct so far as we know, but which can change if new data comes to light. A theory is a model of how the facts relate together. A theory explains the facts and allows new hypotheses to be formed which can be tested to produce new facts. Neither facts nor theories are truth claims; both are provisional and subject to change. A hypothesis is an informed prediction about what will happen in certain circumstances. All hypotheses are based on specific theories. It is hypotheses that are tested in experiments, and the results of the experiment either strengthen the theory (if the hypothesis is confirmed) or weaken the theory (if the hypothesis is not confirmed).

**14. Explain why it is scientifically inappropriate to say, "no theory is true until it is proven."**

Theories are not truth claims and are never regarded as "true," and we don't speak of them as true or false. They are models, and all models fall short of being complete descriptions of the thing they are modeling. Also, no theory is ever proven. Instead, theories get stronger if they produce successful hypotheses, i.e., those that are confirmed by experiment. So we speak of strong or weak theories. A strong theory is one that has produced many successful hypotheses and explains most or all of the known related facts.

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# Chapter 1 Exercises

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**1. Write a paragraph distinguishing between matter and mass.**

Matter consists of anything composed of atoms or parts of atoms. Mass is a variable used to quantify the amount of inertia (a property of matter) an object has.

**2. Distinguish between base units and derived units in the SI system of units and give three examples of each.**

The entire SI system of units is based on seven base units of measure—meter, kilogram, second, ampere, kelvin, candela, and mole. All other units of measure are derived from one or more of the base units. Examples of derived units are joule, newton, cubic meter, watt, and pascal.

**3. Describe the advantages the SI system has over the USCS system for scientific work.**

The SI system does not use random numbers such as 3, 12, and 5280. Also, there is only one major unit of measure for each kind of quantity. Instead of using several different units for measurements of different sizes, the SI system uses prefixes to scale up or down the unit used for the quantity in question.

**4. Why does the SI system use prefixes on the units of measure?**

Instead of using several different units for measurements of different sizes, the SI system uses prefixes to scale up or down the unit used for the quantity in question.

**5. Re-express the quantities in the following table using only a single numerical digit followed by an SI unit symbol, with a metric prefix if necessary. Example: 5 thousand liters = 5 kL****a. 8 pascals**

8 Pa

**b. 5 hundredths of a meter**

5 cm

**c. 3 million amperes**

3 MA

**d. 2 thousand meters**

2 km

**e. 4 thousandths of a second**

4 ms

**f. 6 thousand newtons**

6 kN

**g. 8 thousand grams**

8 kg

**h. 7 millionths of a liter**

7  $\mu$ L

**i. 1 thousandth of a joule**

1 mJ

**6. Re-write the quantities in the following table by writing out the unit names without symbols. Example: 5 km = 5 kilometers**

**a. 14 m<sup>3</sup>**

14 cubic meters

**b. 164.1 kg**

164.1 kilograms

**c. 250 MPa**

250 megapascals

**d. 16.533 ms**

16.533 milliseconds

**e. 160 kA**

160 kiloamps

**f. 19.55 cL**

19.55 centiliters

**g. 31.11 μJ**

31.11 microjoules

**h. 2300 K**

2300 kelvins

**i. 13.0 mmol**

13.0 millimoles

**7. Why must equations be used instead of conversion factors for most temperature unit conversions?**

Most temperature scales are not absolute scales. If they were, conversion factors could be used.

**8. Perform the USCS unit conversions required in the following table. (Note: The answers in the back of the book are given with the correct number of significant digits.)**

**a. 12.55 ft into yd**

$$12.55 \text{ ft} \cdot \frac{1 \text{ yd}}{3 \text{ ft}} = 4.183 \text{ yd}$$

**b. 0.44556 mi into ft**

$$0.44556 \text{ mi} \cdot \frac{5280 \text{ ft}}{1 \text{ mi}} = 2352.6 \text{ ft}$$

**c. 147.55 in into ft**

$$147.55 \text{ in} \cdot \frac{1 \text{ ft}}{12 \text{ in}} = 12.296 \text{ ft}$$

**d. 55.08 gal into ft<sup>3</sup>**

$$55.08 \text{ gal} \cdot \frac{1 \text{ ft}^3}{7.4805 \text{ gal}} = 7.363 \text{ ft}^3$$

**e. 934 ft<sup>3</sup> into in<sup>3</sup>**

$$934 \text{ ft}^3 \cdot \frac{12 \text{ in}}{1 \text{ ft}} \cdot \frac{12 \text{ in}}{1 \text{ ft}} \cdot \frac{12 \text{ in}}{1 \text{ ft}} = 1,610,000 \text{ in}^3$$

The result is rounded to 3 sig digs because the given information has only 3 sig digs.

**f. 739.22 ft<sup>3</sup>/s into gal/hr**

$$739.22 \frac{\text{ft}^3}{\text{s}} \cdot \frac{7.48052 \text{ gal}}{1 \text{ ft}^3} \cdot \frac{3600 \text{ s}}{1 \text{ hr}} = 19,907,000 \frac{\text{gal}}{\text{hr}}$$

The result is rounded to 5 sig digs because the given information has 5 sig digs.

**g. 12.4 yr into hr**

$$12.4 \text{ yr} \cdot \frac{365 \text{ dy}}{1 \text{ yr}} \cdot \frac{24 \text{ hr}}{1 \text{ dy}} = 109,000 \text{ hr}$$

The result is rounded to 3 sig digs because the given information has only 3 sig digs.

**h. 51,083 in into mi**

$$51,083 \text{ in} \cdot \frac{1 \text{ ft}}{12 \text{ in}} \cdot \frac{1 \text{ mi}}{5280 \text{ ft}} = 0.80623 \text{ mi}$$

**i. 14,560.77 gal/hr into qt/s**

$$14,560.77 \frac{\text{gal}}{\text{hr}} \cdot \frac{4 \text{ qt}}{1 \text{ gal}} \cdot \frac{1 \text{ hr}}{3600 \text{ s}} = 16.17863 \frac{\text{qt}}{\text{s}}$$

**j. 15.90 mi/dy into in/hr**

$$15.90 \frac{\text{mi}}{\text{dy}} \cdot \frac{5280 \text{ ft}}{1 \text{ mi}} \cdot \frac{12 \text{ in}}{1 \text{ ft}} \cdot \frac{1 \text{ dy}}{24 \text{ hr}} = 41,980 \frac{\text{in}}{\text{hr}}$$

**9. Perform the SI/metric unit conversions required in the following table.****a. 35.4 mm into m**

$$35.4 \text{ mm} \cdot \frac{1 \text{ m}}{1000 \text{ mm}} = 0.0354 \text{ m}$$

**b. 76.991 mL into μL**

$$76.991 \text{ mL} \cdot \frac{1 \text{ L}}{1000 \text{ mL}} \cdot \frac{10^6 \mu\text{L}}{1 \text{ L}} = 76,991 \mu\text{L}$$

**c. 34.44 cm<sup>3</sup> into L**

$$34.44 \text{ cm}^3 \cdot \frac{1 \text{ mL}}{1 \text{ cm}^3} \cdot \frac{1 \text{ L}}{1000 \text{ mL}} = 0.03444 \text{ L}$$

**d. 6.33 g/cm<sup>2</sup> into kg/m<sup>2</sup>**

$$6.33 \frac{\text{g}}{\text{cm}^2} \cdot \frac{1 \text{ kg}}{1000 \text{ g}} \cdot \frac{100 \text{ cm}}{1 \text{ m}} \cdot \frac{100 \text{ cm}}{1 \text{ m}} = 63.3 \frac{\text{kg}}{\text{m}^2}$$

**e. 9.35 m/s<sup>2</sup> into mm/ms<sup>2</sup>**

$$9.35 \frac{\text{m}}{\text{s}^2} \cdot \frac{1000 \text{ mm}}{1 \text{ m}} \cdot \frac{1 \text{ s}}{1000 \text{ ms}} \cdot \frac{1 \text{ s}}{1000 \text{ ms}} = 0.00935 \frac{\text{mm}}{\text{ms}^2}$$

**f. 542.2 mJ/s into J/s**

$$542.2 \frac{\text{mJ}}{\text{s}} \cdot \frac{1 \text{ J}}{1000 \text{ mJ}} = 0.5422 \frac{\text{J}}{\text{s}}$$

**g. 56.6 μs into ms**

$$56.6 \mu\text{s} \cdot \frac{1 \text{ s}}{10^6 \mu\text{s}} \cdot \frac{10^3 \text{ ms}}{1 \text{ s}} = 0.0566 \text{ ms}$$

**h. 44.19 mL into cm<sup>3</sup>**

$$44.19 \text{ mL} \cdot \frac{1 \text{ cm}^3}{1 \text{ mL}} = 44.19 \text{ cm}^3$$

**i. 532 nm into μm**

$$532 \text{ nm} \cdot \frac{1 \text{ m}}{10^9 \text{ nm}} \cdot \frac{10^6 \mu\text{m}}{1 \text{ m}} = 0.532 \mu\text{m}$$

**j. 96,963,000 mL/ms into m<sup>3</sup>/s**

$$96,963,000 \frac{\text{mL}}{\text{ms}} \cdot \frac{1 \text{ L}}{1000 \text{ mL}} \cdot \frac{1 \text{ m}^3}{1000 \text{ L}} \cdot \frac{1000 \text{ ms}}{1 \text{ s}} = 96,963 \frac{\text{m}^3}{\text{s}}$$

**k. 295.6 cL into μL**

$$295.6 \text{ cL} \cdot \frac{1 \text{ L}}{100 \text{ cL}} \cdot \frac{10^6 \mu\text{L}}{1 \text{ L}} = 2,956,000 \mu\text{L}$$

**l. 0.007873 m<sup>3</sup> into mL**

$$0.007873 \text{ m}^3 \cdot \frac{100 \text{ cm}}{1 \text{ m}} \cdot \frac{100 \text{ cm}}{1 \text{ m}} \cdot \frac{100 \text{ cm}}{1 \text{ m}} \cdot \frac{1 \text{ mL}}{1 \text{ cm}^3} = 7873 \text{ mL}$$

**m. 8,750 mm<sup>2</sup> into m<sup>2</sup>**

$$8750 \text{ mm}^2 \cdot \frac{1 \text{ m}}{1000 \text{ mm}} \cdot \frac{1 \text{ m}}{1000 \text{ mm}} = 0.00875 \text{ m}^2$$

**n. 87.1 cm/s<sup>2</sup> into m/s<sup>2</sup>**

$$87.1 \frac{\text{cm}}{\text{s}^2} \cdot \frac{1 \text{ m}}{100 \text{ cm}} = 0.871 \frac{\text{m}}{\text{s}^2}$$

**o. 15.75 kg/m<sup>3</sup> into g/cm<sup>3</sup>**

$$15.75 \frac{\text{kg}}{\text{m}^3} \cdot \frac{1000 \text{ g}}{1 \text{ kg}} \cdot \frac{1 \text{ m}}{100 \text{ cm}} \cdot \frac{1 \text{ m}}{100 \text{ cm}} \cdot \frac{1 \text{ m}}{100 \text{ cm}} = 0.01575 \frac{\text{g}}{\text{cm}^3}$$

**p. 0.875 km into m**

$$0.875 \text{ km} \cdot \frac{1000 \text{ m}}{1 \text{ km}} = 875 \text{ m}$$

**q. 16,056 MPa into kPa**

$$16,056 \text{ MPa} \cdot \frac{10^6 \text{ Pa}}{1 \text{ MPa}} \cdot \frac{1 \text{ kPa}}{10^3 \text{ Pa}} = 16,056,000 \text{ kPa}$$

**r. 7,845  $\mu\text{A}$  into mA**

$$7845 \mu\text{A} \cdot \frac{1 \text{ A}}{10^6 \mu\text{A}} \cdot \frac{1000 \text{ mA}}{1 \text{ A}} = 7.845 \text{ mA}$$

**10. Reproduce the following table on your own paper and fill in the empty cells.****a. 431.1 $^{\circ}\text{F}$** 

$$T_C = \frac{5}{9}(T_F - 32) = \frac{5}{9}(431.1 - 32) = 221.7^{\circ}\text{C}$$

The 32 is exact, so it does not limit the sig digs resulting from the subtraction. The 5/9 is also exact, so the result has 4 sig digs, just like the given value.

$$T_K = T_C + 273.15 = 221.7 + 273.15 = 494.9 \text{ K}$$

By the addition rule, the result is limited to one decimal.

**b. -56.1 $^{\circ}\text{C}$** 

$$T_F = \frac{9}{5}T_C + 32 = \frac{9}{5}(-56.1) + 32 = -69.0^{\circ}\text{F}$$

$$T_K = T_C + 273.15 = -56.1 + 273.15 = 217.1 \text{ K}$$

**c. 16.0 K**

$$T_K = T_C + 273.15 \rightarrow T_C = T_K - 273.15 = 16.0 - 273.15 = -257.2^{\circ}\text{C}$$

The given value limits the result to one decimal place because of the addition rule.

$$T_F = \frac{9}{5}T_C + 32 = \frac{9}{5}(-257.2) + 32 = -431.0^{\circ}\text{F}$$

**d. 0.0 $^{\circ}\text{F}$  (exact)**

$$T_C = \frac{5}{9}(T_F - 32) = \frac{5}{9}(0.0 - 32) = -17.7\bar{7}^{\circ}\text{C}$$

Since the given value is exact and the conversion is exact, the result is also exact, indicated by the repeating decimal (the bar over the 7). This result can be written with as many decimals as you please.

$$T_K = T_C + 273.15 = -17.7\bar{7} + 273.15 = 255.323 \text{ K (exact)}$$

Since both values are exact, the addition rule places no limit on the precision indicated in the result. The only way to indicate that this result is exact is to say so. No amount of zeros added to the end of the value will indicate that the value is exact.

**e.  $-77.0^\circ\text{C}$**

$$T_K = T_C + 273.15 = -77.0 + 273.15 = 196.2 \text{ K}$$

$$T_F = \frac{9}{5}T_C + 32 = \frac{9}{5}(-77.0) + 32 = -107^\circ\text{F}$$

The result is limited to 3 sig digs because the given value has 3 sig digs.

**f.  $4,002 \text{ K}$**

$$T_K = T_C + 273.15 \rightarrow T_C = T_K - 273.15 = 4002 - 273.15 = 3729^\circ\text{C}$$

$$T_F = \frac{9}{5}T_C + 32 = \frac{9}{5}(3729) + 32 = 6744^\circ\text{F}$$

**g.  $-32.0^\circ\text{F}$**

$$T_C = \frac{5}{9}(T_F - 32) = \frac{5}{9}(-32.0 - 32) = -35.6^\circ\text{C}$$

$$T_K = T_C + 273.15 = -35.6 + 273.15 = 237.6 \text{ K}$$

**h.  $65.25^\circ\text{C}$**

$$T_K = T_C + 273.15 = 65.25 + 273.15 = 338.40 \text{ K}$$

$$T_F = \frac{9}{5}T_C + 32 = \frac{9}{5}(65.25) + 32 = 149.5^\circ\text{F}$$

**i.  $1,958^\circ\text{C}$**

$$T_K = T_C + 273.15 = 1958 + 273.15 = 2231 \text{ K}$$

$$T_F = \frac{9}{5}T_C + 32 = \frac{9}{5}(1958) + 32 = 3556^\circ\text{F}$$

**j.  $998.0 \text{ K}$**

$$T_K = T_C + 273.15 \rightarrow T_C = T_K - 273.15 = 998.0 - 273.15 = 724.8^\circ\text{C}$$

$$T_F = \frac{9}{5}T_C + 32 = \frac{9}{5}(724.8) + 32 = 1337^\circ\text{F}$$

### 11. Distinguish between accuracy and precision.

Accuracy relates to error—the greater the accuracy, the lower the error. Error is the difference between a measurement of a quantity and the quantity's true value. Accuracy can be increased by eliminating the sources of error. Precision is the amount of fine-ness or resolution in a measurement, and is determined by the instrument used to take the measurement. To increase precision, a more precise measurement instrument must be used. The precision in a measurement is indicated by the number of significant digits in the measurement.

**12. Describe the measurements you would obtain from an instrument that was very precise but not very accurate.**

You would have lots of digits and/or decimal places in the order, but the more precise digits would be meaningless. For example, in a measurement such as 44.1234, if the accuracy was off by 5% there would be an error of around 2.2. Thus, the actual value could be anywhere from about 41.9 to 46.3 and all the decimal places in the measurement have no value.

**13. Which is more important on the speedometer of a car—accuracy or precision?**

No one needs to know their speed to a precision of greater than the nearest 1 mile per hour, so precision isn't really that important. However, accuracy is important because if your speedometer was off by a few percent you could be driving faster than you knew. This could lead to unsafe driving or speeding violations.

**14. Explain why accuracy is important on a heart rate monitor but precision is not.**

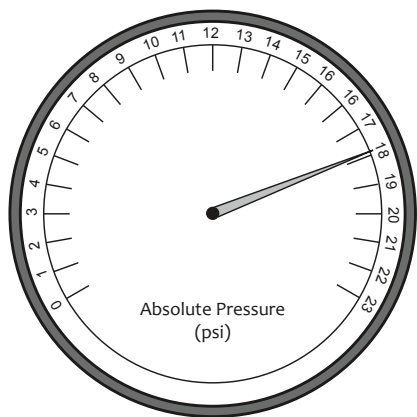
This is similar to the previous question. The precision of a heart rate does not need to be greater than about 1 beat per minute, but accurate readings are important for medical personnel to monitor patients' condition.

**15. Sometimes we want high accuracy in a measurement, but are not too concerned about high precision. Sometimes we want both high accuracy and high precision. Explain why no one wants low accuracy and high precision.**

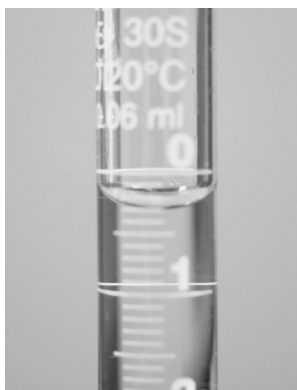
This is discussed in question 12. Having lots of digits and/or decimal places is of no value if the measurement is not accurate to begin with.

**16. On the package of a digital stopwatch I once purchased was the phrase: "1/100th second accuracy." The stopwatch readings in seconds contained two decimal places, but the values the stopwatch actually displayed were spaced 0.03 seconds apart. Thus, it could read 12.31 s, 12.34 s, 12.37 s, etc. Comment on the accuracy and precision of this stopwatch with respect to the claim on the package.**

What is probably meant is that the watch is precise to 1/100th of a second, which means the stopwatch shows seconds, tenths of seconds, and hundredths of seconds. In this case, the term the package uses is incorrect. It could actually be a statement about the accuracy, in which case decimals more precise than a hundredth of a second would be unreliable. But since possible readings are spaced 0.03 s apart, the accuracy is not to the nearest 1/100 of a second. If the time was 12.325 would be displayed as 12.34 and would have an error of 0.015 s, which is more than 0.01 s.

**17. Using the correct number of significant digits and the correct units of measure, record the measurements represented by the following instruments.**

(a)



(b)

(c) **01320**  
gallons

(d) **010**  
wind speed  
(mph)

Note: The last digit in measurements (a) and (b) must be estimated, and thus could vary by 1 or 2 from the answers given here. However, measurements should have the same number of digits as the answers shown.

a. 17.9 psi

b. 0.28 mL

c.  $1.320 \times 10^3$  gal

d.  $1.0 \times 10^1$  mph

18. Using the correct number of significant digits, compute the percent difference for the experimental results in each of the following cases:

a. A scientist measures the masses of three compounds resulting from a certain chemical reaction. Her measurements are 0.234 g, 1.678 g, and 4.446 g. Her calculations predict that the reaction results in masses of 0.239 g, 1.688 g, and 4.678 g, respectively. Determine the percent difference for each of the three compounds.

$$\frac{|0.239 \text{ g} - 0.234 \text{ g}|}{0.239 \text{ g}} \times 100\% = \frac{0.005}{0.239} \times 100\% = 2\%$$

$$\frac{|1.688 \text{ g} - 1.678 \text{ g}|}{1.688 \text{ g}} \times 100\% = \frac{0.010}{1.688} \times 100\% = 0.59\%$$

$$\frac{|4.678 \text{ g} - 4.446 \text{ g}|}{4.678 \text{ g}} \times 100\% = \frac{0.232}{4.678} \times 100\% = 4.96\%$$

b. A student measures the density of aluminum and finds it to be  $2.81 \text{ g/cm}^3$ . The accepted density value for this alloy is  $2.72 \text{ g/cm}^3$ .

$$\frac{\left| 2.72 \frac{\text{g}}{\text{cm}^3} - 2.81 \frac{\text{g}}{\text{cm}^3} \right|}{2.72 \frac{\text{g}}{\text{cm}^3}} \times 100\% = \frac{0.09}{2.72} \times 100\% = 3\%$$

c. According to the Periodic Table of the Elements, the atomic mass of carbon is  $12.011 \text{ g/mol}$ . A calculation from experimental data results in a figure of  $12.0117 \text{ g/mol}$ .

$$\frac{\left| 12.011 \frac{\text{g}}{\text{mol}} - 12.0117 \frac{\text{g}}{\text{mol}} \right|}{12.011 \frac{\text{g}}{\text{mol}}} \times 100\% = \frac{0.001}{12.011} \times 100\% = 0.008\%$$

d. The predicted yields for the products of certain chemical reaction are 23.4 kg of compound A and 2.21 kg of compound B. Careful measurements of the masses of the compounds produced indicate masses of 21.610 kg for compound A and 1.995 kg of compound B.

$$\frac{|23.4 \text{ kg} - 21.610 \text{ kg}|}{23.4 \text{ kg}} \times 100\% = \frac{1.8}{23.4} \times 100\% = 7.7\%$$

$$\frac{|2.21 \text{ kg} - 1.995 \text{ kg}|}{2.21 \text{ kg}} \times 100\% = \frac{0.22}{2.21} \times 100\% = 10\%$$

To express the second result with the required 2 sig digs, we must write it as  $1.0 \times 10^1 \%$ .

19. Perform each of the unit conversions indicated in the table below. Express each result using the correct number of significant digits. Where possible and appropriate, express your result in both standard notation and scientific notation. (Note: By possible, I refer to the fact that sometimes a result can only be expressed with the correct number of significant digits if it is written in scientific notation, such as a value of 100 with two or three significant digits. By appropriate, I refer to the fact that it is silly to write a value with a very large number of zeros. Such values should always be expressed in scientific notation. It is also silly to use scientific notation to express a value such as 3 or 4.1. Such values should only

be expressed in standard notation.)

a. 1,737 km (radius of the earth's moon) into ft

$$1737 \text{ km} \cdot \frac{1000 \text{ m}}{1 \text{ km}} \cdot \frac{1 \text{ ft}}{0.3048 \text{ m}} = 5,699,000 \text{ ft} = 5.699 \times 10^6 \text{ ft}$$

$$(\text{Or: } 1737 \text{ km} \cdot \frac{1000 \text{ m}}{1 \text{ km}} \cdot \frac{1 \text{ mi}}{1609 \text{ m}} \cdot \frac{5280 \text{ ft}}{1 \text{ mi}} = 5.700 \times 10^6 \text{ ft})$$

b. 2.20 g (mass of a single peanut m&m) into kg

$$2.20 \text{ g} \cdot \frac{1 \text{ kg}}{1000 \text{ g}} = 0.00220 \text{ kg} = 2.20 \times 10^{-3} \text{ kg}$$

c. 591 mL (volume of a typical water bottle) into  $\mu\text{L}$

$$591 \text{ mL} \cdot \frac{1 \text{ L}}{1000 \text{ mL}} \cdot \frac{10^6 \mu\text{L}}{1 \text{ L}} = 591,000 \mu\text{L} = 5.91 \times 10^5 \mu\text{L}$$

d.  $7 \times 10^8 \text{ m}$  (radius of the sun) into mi

$$7 \times 10^8 \text{ m} \cdot \frac{1 \text{ mi}}{1609 \text{ m}} = 400,000 \text{ mi} = 4 \times 10^5 \text{ mi}$$

e.  $1.616 \times 10^{-35} \text{ m}$  (Planck length, a fundamentally small length) into ft

$$1.616 \times 10^{-35} \text{ m} \cdot \frac{1 \text{ ft}}{0.3048 \text{ m}} = 5.302 \times 10^{-35} \text{ ft}$$

f.  $750 \text{ cm}^3$  (size of the engine in my old motorcycle) into  $\text{m}^3$

$$750 \text{ cm}^3 \cdot \frac{1 \text{ m}}{100 \text{ cm}} \cdot \frac{1 \text{ m}}{100 \text{ cm}} \cdot \frac{1 \text{ m}}{100 \text{ cm}} = 0.00075 \text{ m}^3 = 7.5 \times 10^{-4} \text{ m}^3$$

g.  $2.9979 \times 10^8 \text{ m/s}$  (speed of light in a vacuum) into mi/hr

$$2.9979 \times 10^8 \frac{\text{m}}{\text{s}} \cdot \frac{1 \text{ ft}}{0.3048 \text{ m}} \cdot \frac{1 \text{ mi}}{5280 \text{ ft}} \cdot \frac{3600 \text{ s}}{1 \text{ hr}} = 6.7061 \times 10^8 \frac{\text{mi}}{\text{hr}}$$

By using the exact factor  $0.3048 \text{ m} = 1 \text{ ft}$  instead of the approximate factor  $1609 \text{ m} = 1 \text{ mi}$  we preserve the 5 sig digs in our result.

h. 168 hr (one week) into s

$$168 \text{ hr} \cdot \frac{3600 \text{ s}}{1 \text{ hr}} = 605,000 \text{ s} = 6.05 \times 10^5 \text{ s}$$

If the problem had said exactly one week, we would calculate  $604,800 \text{ s}$ . But we were given a number of hours with 3 sig digs, so that is what we have in the result.

i.  $5,570 \text{ kg/m}^3$  (average density of the earth) into  $\text{g/cm}^3$

$$5570 \frac{\text{kg}}{\text{m}^3} \cdot \frac{1000 \text{ g}}{1 \text{ kg}} \cdot \frac{1 \text{ m}}{100 \text{ cm}} \cdot \frac{1 \text{ m}}{100 \text{ cm}} \cdot \frac{1 \text{ m}}{100 \text{ cm}} = 5.57 \frac{\text{g}}{\text{cm}^3}$$

j. 45 gps (gal/sec, flow rate of Mississippi River at the source) into  $\text{m}^3/\text{min}$

$$45 \frac{\text{gal}}{\text{s}} \cdot \frac{3.785 \text{ L}}{1 \text{ gal}} \cdot \frac{1 \text{ m}^3}{1000 \text{ L}} \cdot \frac{60 \text{ s}}{1 \text{ min}} = 10 \frac{\text{m}^3}{\text{min}}$$

To express this result with the required 2 sig digs, we must write it as  $1.0 \times 10^1 \text{ m}^3/\text{min}$ .

k. 600,000  $\text{ft}^3/\text{s}$  (flow rate of Mississippi River at New Orleans) into L/hr

$$600,000 \frac{\text{ft}^3}{\text{s}} \cdot \frac{12 \text{ in}}{1 \text{ ft}} \cdot \frac{12 \text{ in}}{1 \text{ ft}} \cdot \frac{12 \text{ in}}{1 \text{ ft}} \cdot \frac{2.54 \text{ cm}}{1 \text{ in}} \cdot \frac{2.54 \text{ cm}}{1 \text{ in}} \cdot \frac{2.54 \text{ cm}}{1 \text{ in}} \cdot \frac{1 \text{ L}}{1000 \text{ cm}^3} \cdot \frac{3600 \text{ s}}{1 \text{ hr}} = 6 \times 10^{10} \frac{\text{L}}{\text{hr}}$$

**l. 5,200 mL (volume of blood in a typical man's body) into m<sup>3</sup>**

$$5200 \text{ mL} \cdot \frac{1 \text{ cm}^3}{1 \text{ mL}} \cdot \frac{1 \text{ m}}{100 \text{ cm}} \cdot \frac{1 \text{ m}}{100 \text{ cm}} \cdot \frac{1 \text{ m}}{100 \text{ cm}} = 0.0052 \text{ m}^3 = 5.2 \times 10^{-3} \text{ m}^3$$

**m. 5.65 × 10<sup>2</sup> mm<sup>2</sup> (area of a postage stamp) into in<sup>2</sup>**

$$5.65 \times 10^2 \text{ mm}^2 \cdot \frac{1 \text{ m}}{1000 \text{ mm}} \cdot \frac{1 \text{ m}}{1000 \text{ mm}} \cdot \frac{100 \text{ cm}}{1 \text{ m}} \cdot \frac{100 \text{ cm}}{1 \text{ m}} \cdot \frac{1 \text{ in}}{2.54 \text{ cm}} \cdot \frac{1 \text{ in}}{2.54 \text{ cm}} = 0.876 \text{ in}^2$$

**n. 32.16 ft/s<sup>2</sup> (acceleration of gravity, or one "g") into m/s<sup>2</sup>**

$$32.16 \frac{\text{ft}}{\text{s}^2} \cdot \frac{0.3048 \text{ m}}{1 \text{ ft}} = 9.802 \frac{\text{m}}{\text{s}^2}$$

**o. 10.6 μm (wavelength of light from a CO<sub>2</sub> laser) into in**

$$10.6 \mu\text{m} \cdot \frac{1 \text{ m}}{10^6 \mu\text{m}} \cdot \frac{100 \text{ cm}}{1 \text{ m}} \cdot \frac{1 \text{ in}}{2.54 \text{ cm}} = 0.000417 \text{ in} = 4.17 \times 10^{-4} \text{ in}$$

**p. 1.1056 g/mL (density of heavy water) into kg/m<sup>3</sup>**

$$1.1056 \frac{\text{g}}{\text{mL}} \cdot \frac{1 \text{ kg}}{10^3 \text{ g}} \cdot \frac{1 \text{ mL}}{1 \text{ cm}^3} \cdot \frac{100 \text{ cm}}{1 \text{ m}} \cdot \frac{100 \text{ cm}}{1 \text{ m}} \cdot \frac{100 \text{ cm}}{1 \text{ m}} = 1105.6 \frac{\text{kg}}{\text{m}^3} = 1.1056 \times 10^3 \frac{\text{kg}}{\text{m}^3}$$

**q. 13.6 g/cm<sup>3</sup> (density of liquid mercury metal) into mg/m<sup>3</sup>**

$$13.6 \frac{\text{g}}{\text{cm}^3} \cdot \frac{1000 \text{ mg}}{1 \text{ g}} \cdot \frac{100 \text{ cm}}{1 \text{ m}} \cdot \frac{100 \text{ cm}}{1 \text{ m}} \cdot \frac{100 \text{ cm}}{1 \text{ m}} = 1.36 \times 10^{10} \frac{\text{mg}}{\text{m}^3}$$

**r. 93,000,000 mi (distance from earth to the sun) into cm**

$$93,000,000 \text{ mi} \cdot \frac{1609 \text{ m}}{1 \text{ mi}} \cdot \frac{100 \text{ cm}}{1 \text{ m}} = 1.5 \times 10^{13} \text{ cm}$$

**s. 65 mph (typical highway speed limit) into m/s**

$$65 \frac{\text{mi}}{\text{hr}} \cdot \frac{1609 \text{ m}}{1 \text{ mi}} \cdot \frac{1 \text{ hr}}{3600 \text{ s}} = 29 \frac{\text{m}}{\text{s}}$$

**t. 633 nm (wavelength of light from a red laser) into in**

$$633 \text{ nm} \cdot \frac{1 \text{ m}}{10^9 \text{ nm}} \cdot \frac{100 \text{ cm}}{1 \text{ m}} \cdot \frac{1 \text{ in}}{2.54 \text{ cm}} = 0.0000249 \text{ in} = 2.49 \times 10^{-5} \text{ in}$$

**u. 5.015% of the speed of light (see item g, or Table A.2) into mph**

First convert the speed of light to mi/hr:

$$2.9979 \times 10^8 \frac{\text{m}}{\text{s}} \cdot \frac{1 \text{ mi}}{1609 \text{ m}} \cdot \frac{3600 \text{ s}}{1 \text{ hr}} = 6.708 \times 10^8 \frac{\text{mi}}{\text{hr}}$$

Now calculate the proportion indicated by the percentage:

$$6.708 \times 10^8 \frac{\text{mi}}{\text{hr}} \cdot 0.05015 = 3.364 \times 10^6 \frac{\text{mi}}{\text{hr}} = 33,640,000 \frac{\text{mi}}{\text{hr}}$$

**v. 6.01 kJ/mol (molar heat of fusion of water) into J/mol**

$$6.01 \frac{\text{kJ}}{\text{mol}} \cdot \frac{1000 \text{ J}}{1 \text{ kJ}} = 6010 \frac{\text{J}}{\text{mol}} = 6.01 \times 10^3 \frac{\text{J}}{\text{mol}}$$

**w. 32.1 bar (pressure in saltwater at 318 m, free diving record depth) into psi**

$$32.1 \text{ bar} \cdot \frac{100,000 \text{ Pa}}{1 \text{ bar}} \cdot \frac{1 \text{ psi}}{6895 \text{ Pa}} = 466 \text{ psi} = 4.66 \times 10^2 \text{ psi}$$

x. **0.116 nm (radius of a sodium atom) into cm**

$$0.116 \text{ nm} \cdot \frac{1 \text{ m}}{10^9 \text{ nm}} \cdot \frac{100 \text{ cm}}{1 \text{ m}} = 1.16 \times 10^{-8} \text{ cm}$$

y.  **$6.54 \times 10^{-24} \text{ cm}^3$  (volume of a sodium atom) into  $\text{in}^3$**

$$6.54 \times 10^{-24} \text{ cm}^3 \cdot \frac{1 \text{ in}}{2.54 \text{ cm}} \cdot \frac{1 \text{ in}}{2.54 \text{ cm}} \cdot \frac{1 \text{ in}}{2.54 \text{ cm}} = 3.99 \times 10^{-25} \text{ in}^3$$

z. **0.385 J/(g·K) (specific heat capacity of copper) into J/(mg·K)**

$$0.385 \frac{\text{J}}{\text{g} \cdot \text{K}} \cdot \frac{1 \text{ g}}{1000 \text{ mg}} = 0.000385 \frac{\text{J}}{\text{mg} \cdot \text{K}} = 3.85 \times 10^{-4} \frac{\text{J}}{\text{mg} \cdot \text{K}}$$

aa. **370 mL (volume of a soft drink can) into  $\text{ft}^3$**

$$370 \text{ mL} \cdot \frac{1 \text{ cm}^3}{1 \text{ mL}} \cdot \frac{1 \text{ in}}{2.54 \text{ cm}} \cdot \frac{1 \text{ in}}{2.54 \text{ cm}} \cdot \frac{1 \text{ in}}{2.54 \text{ cm}} \cdot \frac{1 \text{ ft}}{12 \text{ in}} \cdot \frac{1 \text{ ft}}{12 \text{ in}} \cdot \frac{1 \text{ ft}}{12 \text{ in}} = 0.013 \text{ ft}^3 = 1.3 \times 10^{-2} \text{ ft}^3$$

ab. **268,581  $\text{mi}^2$  (land area of Texas) into  $\text{mm}^2$**

$$268,581 \text{ mi}^2 \cdot \frac{5280 \text{ ft}}{1 \text{ mi}} \cdot \frac{5280 \text{ ft}}{1 \text{ mi}} \cdot \frac{0.3048 \text{ m}}{1 \text{ ft}} \cdot \frac{0.3048 \text{ m}}{1 \text{ ft}} \cdot \frac{1000 \text{ mm}}{1 \text{ m}} \cdot \frac{1000 \text{ mm}}{1 \text{ m}} = 6.95622 \times 10^{17} \text{ mm}^2$$

ac. **50,200  $\text{mi}^2/\text{yr}$  (current rate of global deforestation) into  $\text{ft}^2/\text{s}$**

$$50,200 \frac{\text{mi}^2}{\text{yr}} \cdot \frac{5280 \text{ ft}}{1 \text{ mi}} \cdot \frac{5280 \text{ ft}}{1 \text{ mi}} \cdot \frac{1 \text{ yr}}{365 \text{ dy}} \cdot \frac{1 \text{ dy}}{24 \text{ hr}} \cdot \frac{1 \text{ hr}}{3600 \text{ s}} = 44,400 \frac{\text{ft}^2}{\text{s}} = 4.44 \times 10^4 \frac{\text{ft}^2}{\text{s}}$$

## Chapter 2 Exercises

### 1. Write paragraphs describing the experiments performed by J.J. Thomson, Robert Millikan, and Ernest Rutherford.

Thomson placed electrodes from a high-voltage electrical source inside a sealed-glass vacuum tube. This apparatus can generate a cathode ray from the negative electrode, called the cathode, to the positive one, called the anode. The anode inside Thomson's vacuum tube had a hole in it for some of the electrons to escape through, which created a beam of cathode rays heading toward the other end of the tube. Thomson placed the electrodes of another voltage source inside the tube, above and below the cathode ray, and discovered that the beam of electrons deflected when this voltage was turned on. He also placed magnetic coils on the sides of the tube and discovered that the electrons also deflected as they passed through the magnetic field produced by the coils. The deflection of the beam toward the positive electrode led Thomson to theorize that the beam was composed of negatively charged particles. By trying out many different arrangements of cathode ray tubes, Thomson confirmed that the ray was negatively charged. Then using the scale on the end of the tube to measure the deflection angle, he was able to determine the charge-to-mass ratio of the individual electrons he had discovered.

Inside a heavy metal drum about the size of a 5-gallon bucket, Millikan placed a pair of horizontal metal plates connected to an adjustable high-voltage source. The upper plate had a hole in the center and was connected to the positive voltage, the lower plate to the negative. He used an atomizer spray pump to spray in a fine mist of watchmaker's oil above the positive plate. Some of the oil droplets would fall through the hole in the upper plate and move into the region between the plates. Connected through the side of the drum between the two plates was a telescope eyepiece and lamp so that Millikan could see the oil droplets between the plates. The process of squirting in the oil droplets with the atomizer sprayer caused some of the droplets to acquire a charge of static electricity. This means the droplets had excess electrons on them and carried a net negative charge. They picked up these extra electrons by friction as the droplets squirted through the rubber sprayer tube. As Millikan looked at an oil droplet through the eyepiece and adjusted the voltage between the plates, he could make the charged oil droplet hover when the voltage was just right. Millikan took into account the weight of the droplets and the viscosity of the air as the droplets fell and was able to determine that every droplet had a charge on it that was a multiple of  $1.6 \times 10^{-19}$  C. From this he deduced that this must be the charge on a single electron.

Rutherford created a beam of  $\alpha$ -particles by placing some radioactive material (radium bromide) inside a lead box with a hole in one end. The  $\alpha$ -particles from the decaying radium atoms streamed out the hole at very high speed. Rutherford aimed the  $\alpha$ -particles at an extremely thin sheet of gold foil only a few hundred atoms thick. Surrounding the gold foil was a ring-shaped screen coated with a material that glows when hit by  $\alpha$ -particles. Rutherford could then determine where the  $\alpha$ -particles went after encountering the gold foil. When Rutherford began taking data, he had Thomson's plum pudding model in mind and was expecting results consistent with that atomic model. In the plum pudding model, the atom's positive charge is spread throughout the atom and the negative electrons are embedded in the positive material. Rutherford expected the massive and positively charged  $\alpha$ -particles to blow right through the gold foil. What Rutherford found was astonishing. Most of the  $\alpha$ -particles passed straight through the foil and struck the screen on the other side, just as Rutherford expected. However, occasionally an  $\alpha$ -particle (one particle out of every several thousand) deflected with a small angle. And sometimes the deflected particles bounced almost straight back. From thus Rutherford theorized that the positive charge in the atom is all concentrated in a tiny nucleus and that most of the atom is empty space.

### 2. Describe the main points or features in the atomic models proposed by John Dalton, J.J. Thomson, and Ernest Rutherford.

Dalton's 1803 model contained the following five points:

1. All substances are composed of tiny, indivisible substances called atoms.
2. All atoms of the same substance are identical.
3. Atoms of different elements have different weights.
4. Atoms combine in whole-number ratios to form compounds.
5. Atoms are neither created nor destroyed in chemical reactions.

In 1897, Thomson theorized that electrons came from inside atoms. He developed a new atomic model that envisions atoms as tiny clouds of massless, positive charge sprinkled with thousands of the negatively charged electrons. Thomson's model is usually called the plum pudding model.

Rutherford's 1911 model contained the following points:

1. The positive charge in atoms is concentrated in a tiny region in the center of the atom, which Rutherford called the nucleus.
2. Atoms are mostly empty space.
3. The electrons, which contain the atoms' negative charge, are outside the nucleus.

**3. Explain why Ernest Rutherford found the reflection of alpha particles off gold foil so astonishing.**

At the time of this experiment, very little was known about atoms. Rutherford had J.J. Thomson's atomic model in mind, in which the positive charge is distributed evenly throughout the atom. Rutherford's high-velocity alpha particles should have blown right through atoms of gold if the positive charge was structured this way, but sometimes one of the particles would bounce almost straight back. Rutherford said this was like firing an artillery shell at a piece of tissue and having it bounce back.

**4. Write paragraphs distinguishing between these pairs of terms:**

**a. compounds and elements**

There are 118 elements, distinguished from one another by the number of protons in the nucleus. Compounds are formed when atoms of two or more elements are chemically bonded together.

**b. mixtures and compounds**

Mixtures are formed when two or more different substances are combined without a chemical reaction occurring. If a chemical reaction does occur, then compounds are formed. The components of mixtures may be separated by physical means. The elements in compounds can only be separated by chemical means, that is, by a chemical reaction.

**c. heterogeneous mixtures and homogeneous mixtures**

Homogeneous mixtures are solutions—one substance is dissolved in another. These mixtures have a uniform composition all the way down to the level of individual atoms or molecules. These individual particles are too small to be seen with any microscope. Heterogeneous mixtures contain larger lumps of material. These lumps are visible either with the eye or with a microscope.

**d. suspensions and colloids**

In a suspension, larger particles are temporarily suspended in a fluid medium (liquid or gas), but the particles will settle out eventually. A colloid is formed when substances in two different physical states are combined.

**5. Classify each of the following as element, compound, homogeneous mixture, or heterogeneous mixture.**

**a. water**

compound

**b. cesium chloride**

compound

**c. pond water**

heterogeneous mixture

**d. methane**

compound

**e. a soft drink**

homogeneous mixture