CHAPTER 1 | Matter and Energy: An Atomic Perspective

1.1. **Collect and Organize**

Figure P1.1(a) shows "molecules," each consisting of one red sphere and one blue sphere, and Figure P1.1(b) shows separate blue spheres and red spheres. For each figure we are to determine whether the substance(s) depicted is a solid, liquid, or gas and whether the figures show an element, a compound, a mixture of elements, or a mixture of compounds.

Analyze

An element is composed of all the same type of atom, and a compound is composed of two or more types of atoms. Solids have a definite volume and a highly ordered arrangement where the particles are close together. Liquids also have a definite volume but have a disordered arrangement of particles that are close together. Gases have disordered particles that fill the volume of the container and are far apart from each other.

Solve

(a) Because each particle in Figure P1.1(a) consists of one red sphere and one blue sphere, all the particles are the same—that is a compound. The particles fill the container and are disordered, so those particles are in the gas phase.
(b) Because it shows a mixture of red and blue spheres, Figure P1.1(b) depicts a mixture of blue elemental atoms and red elemental atoms. The blue spheres fill the container and are disordered, so those particles are in the gas phase. The red spheres have a definite volume and are ordered, so those particles are in the solid phase.

Think About It

Remember that both elements and compounds may be either pure or present in a mixture.

1.2. **Collect and Organize**

Figure P1.2(a) shows "atoms" of only red spheres, and Figure P1.2(b) has "molecules" consisting of two red spheres or two blue spheres. For each figure we are to determine whether the substance(s) depicted is solid, liquid, or gas and whether the figures show pure elements or compounds as pure substances or as a mixture.

Analyze

A pure substance (whether element or compound) is composed of all the same type of molecule or atom, not a mixture of two kinds. An element is composed of all the same type of atom, and a compound is composed of two or more types of atoms. Solids have a definite volume and a highly ordered arrangement where the particles are close together. Liquids also have a definite volume but have a disordered arrangement of particles that are close together. Gases have disordered particles that fill the volume of the container and are far apart from each other.

Solve

(a) Because all the atoms are of the same type, Figure P1.2(a) depicts a pure element. The particles take up a definite volume and are ordered, so that element is in the solid phase.
(b) Because it shows a mixture of blue diatomic molecules and red diatomic molecules, Figure P1.2(b) depicts a mixture of two elements. Both the blue and red diatomic particles fill the container's volume and are highly disordered; the mixture depicted is in the gas phase.

Think About It

Elements do not need to be present as single atoms. They may be diatomic, as in H_2 or Br_2, or even more highly associated, as in S_8 or P_4.

1.3. **Collect and Organize**

In this question we are to consider whether the reactants, as depicted, undergo a chemical reaction and/or a phase change.

Analyze
Chemical reactions involve the breaking and making of bonds in which atoms are combined differently in the products than in the reactants. When we consider a possible phase change, remember the following: Solids have a definite volume and a highly ordered arrangement where the particles are close together. Liquids also have a definite volume but have a disordered arrangement of particles that are close together. Gases have disordered particles that fill the volume of the container and are far apart from one another.

Solve
In Figure P1.3, two pure elements (red–red and blue–blue) in the gas phase recombine to form a compound (red–blue) in the solid phase (ordered array of molecules). Therefore, answer b describes the reaction shown.

Think About It
A phase change does not necessarily accompany a chemical reaction. We will learn later that the polarity of the product will determine whether a substance will be in the solid, liquid, or gaseous state at a given temperature.

1.4. **Collect and Organize**
In this question we are to consider whether the reactants, as depicted, undergo a chemical reaction (either recombination or decomposition) and/or a phase change.

Analyze
Chemical reactions involve the breaking and making of bonds in which atoms are combined differently in the products from how they are combined in the reactants. When we consider a possible phase change, remember the following: Solids have a definite volume and a highly ordered arrangement where the particles are close together. Liquids also have a definite volume but have a disordered arrangement of particles that are close together. Gases have disordered particles that fill the volume of the container and are far apart from one another.

Solve
In Figure P1.4 we see that no recombination of the diatomic molecules occurs. The pure element (red–red) condenses to a slightly disordered phase, whereas the other element (blue–blue) remains in the gas phase. Therefore, answer a describes the reaction pictured.

Think About It
Cooling of air in this fashion to different temperatures separates air's components.

1.5. **Collect and Organize**
Given a space-filling model of formic acid pictured in Figure P1.5, we are to write the molecular formula of formic acid.

Analyze
To determine the identity of the atoms in the space-filling model, we use the Atomic Color Palette (inside back cover of your textbook): black is carbon, red is oxygen, and white is hydrogen. To determine the formula, we need to count each type of atom in the structure.

Solve
The structure of formic acid includes two hydrogen atoms, two oxygen atoms, and one carbon atom. Therefore, its molecular formula is CH_2O_2.

Think About It
Writing the molecular formula as "2HC2O" is confusing and wrong. We indicate the number of atoms in a molecular formula with a subscript within the molecular formula, not with a coefficient. Also, you will find that it is a convention for organic molecular formulas to list C first, followed by H.

1.6. **Collect and Organize**
From the representations in Figure 1.6, we are to choose the one that contains the most atoms, contains the most elements, shows a solid solution, shows a homogeneous mixture, shows a pure compound, or shows a pure element.

Analyze

To categorize the representations, we need to apply the definitions of atom, element, solid solution, homogeneous mixture, pure compound, and pure element. An atom is the smallest particle constituent that makes up matter; an element is a substance composed of only one type of atom; a solid solution is a mixture of two elements in the solid state; a homogeneous mixture is a mixture of elements or compounds that has uniform composition and properties; a pure compound is a substance made of different elements in a specific ratio; a pure element is a substance made up of only one kind of atom with no other elements present in the substance.

Solve

(a) Of the representations, only [B], [F], [G], and [H] are molecules. Of those [B], glycine, contains 10 atoms; [F], ammonia, contains 4 atoms; [G], hydrogen peroxide, contains 4 atoms; and [H], propane, contains 11 atoms. Therefore, [H], propane, contains the most atoms.

(b) Of the representations, [B], [F], [G], and [H] are molecular representations of compounds. Of those [B], glycine, contains 4 elements (C, H, N, and O); [F], ammonia, contains 2 elements (N and H); [G], hydrogen peroxide, contains 2 elements (H and O); and [H], propane, contains 2 elements (C and H). Therefore, [B], glycine, contains the most elements.

(c) [A], brass is a solid solution composed of copper and zinc.

(d) [E] (dissolved NaCl in water) and [A] (a solid solution of copper and zinc) are homogeneous mixtures that have uniform composition and properties.

(e) The pure compounds in the list are: [B] (glycine), [F] (ammonia), [G] (hydrogen peroxide), and [H] (propane).

(f) The pure elements in the list are: [C] (helium), [D] (mercury), and [I] (platinum).

Think About It

Technically, by the broad definition, brass also is a homogeneous mixture. However, for mixtures of metals or other solids, we usually use the term "solid solution" to describe them. You might also hear the term "alloy" used for a solid solution of metal elements.

1.7. **Collect and Organize**

For this question we are asked to differentiate "hypothesis" from "scientific theory."

Analyze

These terms are part of the scientific method and result from different aspects of the process of observing and explaining a natural phenomenon.

Solve

A hypothesis is a tentative explanation of an observation or set of observations, whereas a scientific theory is a concise explanation of a natural phenomenon that has been extensively tested and explains why certain phenomena are always observed.

Think About It

Notice that a hypothesis might become a theory after much experimental testing.

1.8. **Collect, Organize, and Analyze**

In this question we consider how a hypothesis becomes a theory.

Solve

A theory is formed from a hypothesis when the hypothesis has been extensively tested with many observations and experiments. A theory is the best (current) possible explanation extensively supported by experimentation.

Think About It

A theory, tested over time, may be elevated to become a scientific law.

1.9. **Collect and Organize**

In this question we consider how Dalton's atomic theory supported his law of multiple proportions.

Analyze
Dalton's law of multiple proportions states that when two elements combine to make two (or more) compounds, the ratio of the masses of one of the elements, which combine with a given mass of the second element, is always a ratio of small whole numbers. His atomic theory states that matter in the form of elements and compounds is made up of small, indivisible units—atoms.

Solve
Dalton's atomic theory explained the small, whole-number mass ratios in his law of multiple proportions because the compounds contained small, whole-number ratios of atoms of different elements per molecule or formula unit.

Think About It
Dalton's theory is not strictly true–atoms are divisible into electrons, protons, and neutrons (and even further into subatomic quarks) and some compounds do not have whole-number ratios of atoms. For most matter and most compounds we encounter in chemistry, though, his theory is true.

1.10. **Collect and Organize**
In this question we are asked to explain why the existence of atoms in matter was considered a philosophy in ancient Greece but had become a theory in the early 1800s.

Analyze
A philosophy is a set of beliefs arrived at through rational thought and not tested by experiment. A theory is formed from a hypothesis when the hypothesis has been extensively tested with many observations and experiments. A theory is the best (current) possible explanation extensively supported by experimentation.

Solve
The philosophy of the atom became the atomic theory in the 1800s when much experimental evidence had accumulated pointing to the particulate nature of matter. That mounting evidence changed the belief into a tested best explanation for the nature of matter.

Think About It
Some materials do not conform to the law of definite or constant proportions that led to the atomic theory. An example is the nonstoichiometric compounds, in which the proportions of the elements composing the material can vary and the elements are not in strict whole-number proportions.

1.11. **Collect and Organize**
In this question we are asked to explain why scientists opposed Proust's law of definite proportions when he proposed it.

Analyze
The law of definite proportions states that the ratio of elements in a compound is always the same.

Solve
Proust's law needed to have corroborating evidence to fully support it. At the time, experiments to prepare a compound of tin with oxygen yielded various compositions. The compounds they prepared, later turned out to be mixtures of two compounds of tin oxide.

Think About It
Tin can form either tin(II) oxide, SnO, or tin(IV) oxide, SnO_2. What do you think the ratio of the elements would be for a 50–50 mixture of these two compounds? Of a 25–75 mixture?

1.12. **Collect and Organize**
For this question we are asked to describe a chemical reaction that illustrates Dalton's law of multiple proportions.

Analyze
Dalton's law of multiple proportions states that when two elements combine to make two (or more) compounds, the ratio of the masses of one of the elements, which combine with a given mass of the second element, is always a ratio of small whole numbers.

Solve
The law of multiple proportions can be illustrated for any combination of two elements that can give two compounds. One example is the reaction of carbon with oxygen to give either carbon monoxide, CO, or carbon dioxide, CO_2.

$$C(s) + \frac{1}{2}\, O_2(g) \rightarrow CO(g)$$
$$C(s) + O_2(g) \rightarrow CO_2(g)$$

Think About It
Other examples of this are: nitrogen reacting with oxygen to give NO, NO_2, N_2O, N_2O_5, and several others; and sulfur reacting with oxygen to give SO_2, SO_3, S_2O, S_2O_2, and several others.

1.13. **Collect and Organize**
We are to define *theory* as used in everyday conversation and differentiate it from its use in science.

Analyze
Theory in everyday conversation has a quite different meaning from its meaning in science.

Solve
Whereas *theory* in normal conversation means someone's idea or opinion that is open to speculation, a scientific theory is a concise and testable explanation of natural phenomena based on observation and experimentation that can accurately predict the results of experiments.

Think About It
Theory in normal conversation is more akin to a *hypothesis* or a *guess* that may or may not be testable

1.14. **Collect and Organize**
We consider in this question whether a theory can be proven.

Analyze
In science, a theory is the best (current) possible explanation extensively supported by experimentation and observations.

Solve
Theory is nearly equivalent to fact in science, without being the absolute truth. A theory is hard to prove absolutely but has many, many supporting experiments whose observations strongly support it.

Think About It
One experiment that is counter to the explanation for a phenomenon that the theory explains could disprove a theory, so theories may be toppled and replaced with new explanations and theories.

1.15. **Collect and Organize**
For the foods listed, we are to determine which are heterogeneous.

Analyze
A heterogeneous mixture has visible regions of different composition.

Solve
Clear regions of different composition are evident in a Snickers bar (b) and in an uncooked hamburger (d), but not in bottled water (a) or in grape juice (c).

Think About It
Bottled water contains homogeneous mixtures of small amounts of dissolved minerals such as salts of sodium, magnesium, and calcium that give water its flavor.

1.16. **Collect and Organize**
For the foods listed, we are to determine which are homogeneous.

Analyze
Homogeneous mixtures have the same composition throughout.

Solve
Freshly brewed coffee and vinegar (a, b) are homogeneous mixtures. A slice of white bread and a slice of ham (c, d) are heterogeneous mixtures.

Think About It
A slice of white bread is considered heterogeneous because its crust is different from the interior bread, and the bread contains gas bubbles that are clearly seen as tiny holes.

1.17. **Collect and Organize**
For the foods listed, we are to determine which are heterogeneous.

Analyze
A heterogeneous mixture has visible regions of different composition.

Solve
Clear regions of different composition are evident in orange juice (with pulp) (d) and tomato juice (e), but not in apple juice, cooking oil, or solid butter, or tomato juice (a–c).

Think About It
When butter melts, you notice milk solids and clear regions that are definitely discernible. Therefore, homogeneous solid butter becomes heterogeneous when heated.

1.18. **Collect and Organize**
For the substances listed, we are to determine which are homogeneous.

Analyze
Homogeneous mixtures have the same composition throughout.

Solve
Sweat, gasoline, and compressed air in a scuba tank (b, d, and e) are homogeneous. Nile River water (c) and a bronze sword from ancient Greece (because of surface oxidation) (a) are heterogeneous.

Think About It
Bronze is an alloy (a solid solution of one metal dissolved in another) of about 88% copper with other metal such as tin or zinc and is stronger than copper alone, allowing for its use in weaponry, sculptures, and vessels.

1.19. **Collect and Organize**
We are asked to consider whether distillation would be effective in removing suspended soil particles from water.

Analyze
In distillation, evaporation of a liquid and subsequent condensation of the vapor is used to separate substances of different volatilities.

Solve
Soil particles are not volatile, but water is; we can boil water, but not the soil. Therefore, yes, distillation can be used to remove soil particles from water. That is not a widely used process to purify water because boiling water is energy- and time-intensive. Filtration would be both cheaper and faster.

Think About It
In this distillation process we would collect pure water through condensation, and the soil particles would be left behind in the distillation flask.

1.20. **Collect and Organize**
Referring to Figure 1.9(b) in the textbook, we are to decide which compounds interact more strongly with the stationary phase on the basis of their relative positions in the chromatography experiment.

Analyze
In chromatography, a mixture of dissolved substances is placed on a solid stationary phase and a mobile phase (solvent) is used to separate the components. Substances that have more affinity for the stationary phase and less for the mobile phase move more slowly.

Solve
The colored compounds at the bottom interact more strongly with the stationary phase than ones at the top; they did not move as far up the stationary phase with the mobile phase.

Think About It
Figure 1.9(b) shows just one method of chromatography. Others include gas chromatography, ion exchange chromatography, and liquid chromatography, but they all operate on the same principle of the substances in the mixture having different affinities for the stationary and mobile phases.

1.21. **Collect and Organize**
For this question we are to list some chemical and physical properties of gold.

Analyze
A chemical property is seen when a substance undergoes a chemical reaction, thereby becoming a different substance. A physical property can be seen without any transformation of one substance into another.

Solve
One chemical property of gold is its resistance to corrosion (oxidation). Gold’s physical properties include its density, color, melting temperature, and electrical and thermal conductivity.

Think About It
Another metal that does not corrode (or rust) is platinum. Platinum and gold, along with palladium, are often called “noble metals.”

1.22. **Collect and Organize**
For this question we are to compare the physical properties of gold and silver.

Analyze
Physical properties include color, metallic luster, malleability, ductility, melting point, boiling point, density, electrical conductivity, and thermal conductivity.

Solve
Both gold and silver have metallic luster, are malleable, and conduct electricity. However, gold and silver have different densities, different melting temperatures, and different colors.

Think About It
The yellow color of pure gold, compared with most metals, which are silvery, is the result of relativistic effects in the atom.

1.23. **Collect and Organize**

We are asked in this question to name three properties to distinguish among table sugar, water, and oxygen.

Analyze

We can distinguish among substances by using either physical properties (such as color, melting point, and density) or chemical properties (such as chemical reactions, corrosion, and flammability).

Solve

We can distinguish among table sugar, water, and oxygen by examining their physical states (sugar is a solid, water is a liquid, and oxygen is a gas) and by their densities, melting points, and boiling points.

Think About It

These three substances are also very different at the atomic level. Oxygen is a pure element made up of diatomic molecules; water is a liquid compound made up of discrete molecules of hydrogen and oxygen (H_2O); and table sugar is a solid compound made up of carbon, hydrogen, and oxygen atoms.

1.24. **Collect and Organize**

We are asked in this question to name three properties to distinguish among table salt, sand, and copper.

Analyze

We can distinguish among substances by using either physical properties (such as color, melting point, and density) or chemical properties (such as chemical reactions, corrosion, and flammability).

Solve

We can distinguish among table salt, sand, and copper by examining their color (salt is composed of small cubic white crystals, sand is irregularly shaped and many-colored, and copper is a reddish metal). Salt will dissolve in water, whereas sand and copper will not. Copper conducts electricity, whereas solid table salt and sand do not. The densities of these substances also will differ.

Think About It

These three substances are also very different at the atomic level. Table salt is a crystalline ionic compound composed of sodium cations and chloride anions. Sand is a compound most commonly composed of silica, a compound of silicon and oxygen. Copper is a pure element and a metal.

1.25. **Collect and Organize**

From the list of properties of sodium, we are to determine which are physical and which are chemical properties.

Analyze

Physical properties are those that can be observed without transforming the substance into another substance. Chemical properties are observed only when one substance reacts with another and therefore is transformed into another substance.

Solve

Density, melting point, thermal and electrical conductivity, and softness (a–d) are all physical properties, whereas tarnishing and reaction with water (e and f) are both chemical properties.

Think About It

Because the density of sodium is less than that of water, a piece of sodium will float on water as it reacts.

1.26. **Collect and Organize**

From the list of properties of hydrogen gas, we are to determine which are physical and which are chemical properties.

Analyze
Physical properties are those that can be observed without transforming the substance into another substance. Chemical properties are observed only when one substance reacts with another and therefore is transformed into another substance.

Solve
Density, boiling point, and electrical conductivity (a, c, and d) are all physical properties, whereas the reaction of hydrogen with oxygen (b) is a chemical property.

Think About It
Because the density of hydrogen gas is lower than that of any other gas, a lightweight balloon filled with hydrogen will float in air like the more familiar helium balloon.

1.27. **Collect and Organize**
We are to explain whether an extensive property can be used to identify a substance.

Analyze
An extensive property is one that, like mass, length, and volume, is determined by size or amount.

Solve
Extensive properties will change with the size of the sample and therefore cannot be used to identify a substance.

Think About It
We could, for example, have the same mass of feathers and lead, but their mass alone will not tell us which mass measurement belongs to which—the feathers or the lead.

1.28. **Collect and Organize**
Of the properties listed, we are to choose which are intensive properties.

Analyze
An intensive property does not depend on the size or amount of the sample.

Solve
Of the properties on the list, freezing point (a) and temperature (c) are intensive properties. Heat content (b) depends on sample size and is therefore an extensive property.

Think About It
Intensive properties are related to chemical interactions between atoms and molecules in the substance.

1.29. **Collect and Organize**
We are to explain whether the extinguishing of fires by carbon dioxide, CO_2, is a result of its chemical or physical properties (or both).

Analyze
Physical properties are those that can be observed without transforming the substance into another substance. Chemical properties are observed only when one substance reacts with another and therefore is transformed into another substance.

Solve
Carbon dioxide is a nonflammable gas (a chemical property; it does not burn) and it is denser than air (a physical property; it smothers the flames by excluding oxygen from the fuel). Therefore, CO_2's fire-extinguishing properties are due to both its physical and its chemical properties.

Think About It
Some metals, such as magnesium, will burn in carbon dioxide; you cannot extinguish those fires with a CO_2 fire extinguisher.

1.30. **Collect and Organize**

We are to explain whether the resistance of stainless steel to corrosion is a result of its chemical or physical properties.

Analyze

Physical properties are those that can be observed without transforming the substance into another substance. Chemical properties are observed only when one substance reacts with another and therefore is transformed into another substance.

Solve

Corrosion is the chemical reaction of a metal with a substance such as oxygen, and so the lower reactivity of stainless steel must then derive from its chemical properties.

Think About It

Stainless steel contains chromium, which forms a passive layer of chromium oxide on the surface to protect the iron in the steel from rusting.

1.31. **Collect and Organize**

We are asked to compare the arrangement of water molecules in water as a solid (ice) and water as a liquid.

Analyze

Figure A1.31 shows the arrangement of the water molecules in both those phases.

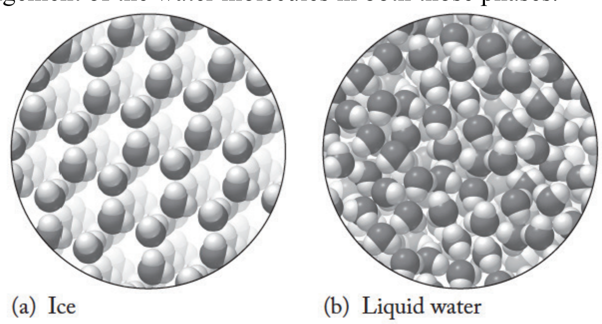


Figure A1.31

Solve

Water molecules in both the ice and liquid forms contain hydrogen bonds that link individual molecules together closely. In those arrangements, the hydrogen atoms in a water molecule point to an oxygen atom of a neighboring water molecule. The oxygen atom, in turn, points toward a hydrogen atom of a neighboring molecule. The hydrogen bonds in liquid water have no long-range structure and can move around each other, whereas in ice the molecules are arranged in a rigid hexagonal arrangement.

Think About It

The structure of ice is more open than the structure of liquid water. That is why, when water freezes, it expands.

1.32. **Collect and Organize**

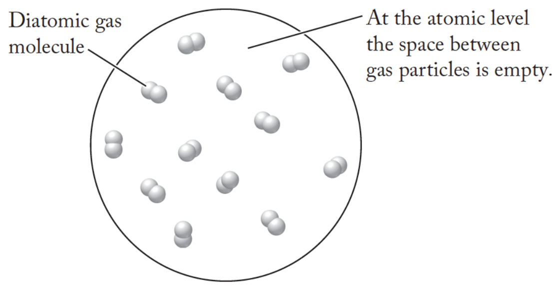
We are asked to describe what occupies the space between the molecules of a gas.

Analyze

A gas consists of particles (atoms or molecules) that are far apart from each other.

Solve

Nothing (no other atoms or molecules) exists in the space between particles in a gas.



Think About It
Because a gas consists of a lot of empty space, most gases are highly compressible.

1.33. **Collect and Organize**
We are to determine which phase (solid, liquid, or gas) has the greatest particle motion and which has the least.

Analyze
Gases have particles much separated from each other; these particles, therefore, have a wide range of movement. Particles in solids and liquids are close to one another, and therefore the particle motion in both phases is restricted. Solids hold their particles in rigid arrays.

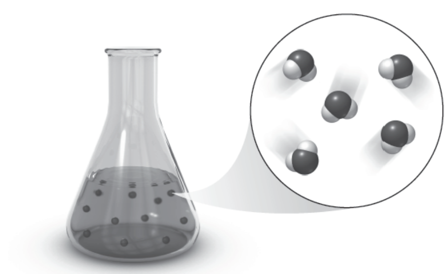
Solve
Because of their freedom of movement, gases have the greatest particle motion; because of the restriction of their solid lattice, solids have the least particle motion.

Think About It
Heating a solid or liquid can melt or vaporize a substance. During these phase changes with the addition of heat, particle motion increases.

1.34. **Collect and Organize**
We are to identify the chemical nature of the gas inside the bubbles in boiling water.

Analyze
Heating a substance increases the molecules' motion. If enough heat is added, the molecules may undergo a phase change.

Solve
In boiling water, the liquid water is undergoing a phase change to water vapor. The bubbles are composed of gaseous water.



Think About It
The energy required to boil water is not enough energy to break the H—O bonds in water. Therefore, the bubbles do not contain hydrogen and oxygen gas from the decomposition of water.

1.35. **Collect and Organize**

We are asked to identify the process that results in snow disappearing, but not melting, on a sunny but cold winter day.

Analyze

The cold air temperature does not allow the snow to melt, but the sunny day does add warmth to the solid snow.

Solve

The snow, instead of melting, sublimes: going directly from the solid ice crystals in snow to water vapor.

Think About It

A more familiar example of sublimation is that of "dry ice," which is solid CO_2 and at ambient temperature and pressure sublimes, rather than melts, to give a "fog" for stage shows.

1.36. **Collect and Organize**

Considering the processes of water condensing, depositing, evaporating, and subliming, we are to identify which process releases the most energy and which process absorbs the most energy.

Analyze

Figure A1.36 shows these processes and their relative energy transformations. Up arrows show absorption of energy, and down arrows show release of energy for the processes.

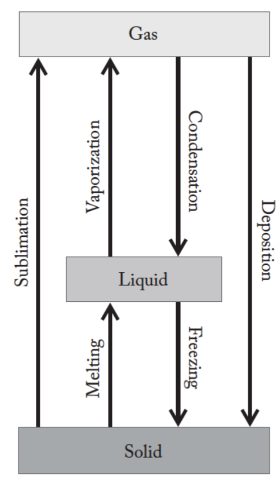


Figure A1.36

Solve

(a) Deposition, the formation of a solid from a gas, releases the most energy.
(b) Sublimation, the formation of a gas from a solid, absorbs the most energy.

Think About It

Sublimation and deposition are opposite processes. The amount of energy absorbed in the sublimation of a quantity of water will be equal to the amount of energy released when that same quantity of water is deposited.

1.37. **Collect and Organize**

We are asked whether energy and work are related.

Analyze

In this context, energy is defined as the capacity to do work. Work is defined as moving an object with a force over some distance. Energy also is thought to be a fundamental component of the universe. The Big Bang theory postulates that all matter originated from a burst of energy, and Albert Einstein proposed that $m = E/c^2$ (mass equals energy divided by the speed of light squared).

Solve
Energy is the ability to do work and must be expended to do work.

Think About It
A system with high energy has the potential to do a lot of work.

1.38. **Collect and Organize**
We are asked to explain how potential and kinetic energy differ. Both are forms of energy, and therefore they both have the potential to do work.

Analyze
Potential energy (PE) is the energy an object has because of its position. Kinetic energy (KE) is the energy of an object due to its motion.

Solve
Consider the following equations:

$$\text{PE} = mgh$$

$$\text{KE} = \frac{1}{2}mu^2$$

Gravitational potential energy is stored energy, which depends on an object's position (h) and mass (m), whereas kinetic energy is energy of motion, which depends on an object's mass (m) and speed (u). The constant g is the acceleration, due to gravity, of a free-falling object near the surface of the earth.

Think About It
When an object falls, potential energy is converted into kinetic energy.

1.39. **Collect and Organize**
From three statements about heat, we are asked to choose those that are true.

Analyze
Heat is defined as the transfer of energy between objects or regions of different temperature and the energy flows from high thermal energy to low thermal energy. Heat is an extrinsic property; the amount of heat in a substance depends on the quantity of the substance and it is measured by taking the temperature.

Solve
All these statements (a, b, and c) are true.

Think About It
Later in this course we will be able to quantify the heat in a substance or the heat released or absorbed by a physical change or a chemical reaction.

1.40. **Collect and Organize**
For the process of speaking on a cell phone, we are asked to describe three energy transfers that take place.

Analyze
Many kinds of energy exist: potential energy of chemical bonds, thermal energy, kinetic energy, electrical energy, light energy, and sound energy.

Solve
Your answers may vary for this question. As examples, some forms of energy transfer that occur during the cell phone conversation include the following: thermal energy from the warm phone is transferred to your hand, sound energy is transferred into electrical energy as you speak and vice versa when your friend hears your words, electrical energy is converted into microwave energy to carry the signal, chemical energy of the battery is transferred into electrical energy to power the phone, and electrical energy is transferred into light energy to light up the display.

Think About It

Cell phone manufacturers make extensive use of the special properties of several modern materials, including lithium–ion batteries, semiconductors, special alloys, and "gorilla glass."

1.41. **Collect and Organize**

We are asked to compare the kinetic energy of a subcompact car (1400 kg) with that of a dump truck (18,000 kg) when they are traveling at the same speed.

Analyze

We can compare the kinetic energies by using the equation

$$KE = \frac{1}{2}mu^2$$

Solve

For the subcompact car:

$$KE = \frac{1}{2}(1400 \text{ kg})u_1^2$$

For the dump truck:

$$KE = \frac{1}{2}(18{,}000 \text{ kg})u_2^2$$

Because $u_1 = u_2$, we can replace u_1 in the first expression with u_2. The ratio of the kinetic energies is

$$\frac{KE_2}{KE_1} = \frac{\frac{1}{2}(18{,}000 \text{ kg})u_2^2}{\frac{1}{2}(1400 \text{ kg})u_2^2} = \frac{18{,}000 \text{ kg}}{1400 \text{ kg}} = 13$$

When traveling at the same speed, the dump truck has 13 times more kinetic energy than the subcompact car.

Think About It

The same dump truck has more kinetic energy when traveling faster because kinetic energy depends on the velocity of an object as well as its mass.

1.42. **Collect and Organize**

We are asked to compare the kinetic energy of a baseball traveling at 92 mph with the kinetic energy when it travels at 78 mph.

Analyze

We can compare the kinetic energies by using the equation

$$KE = \frac{1}{2}mu^2$$

Kinetic energy is usually expressed in joules ($1 \text{ J} = 1 \text{ kg} \cdot \text{m/s}^2$), and so by strict standards we should convert the speed in miles per hour to meters per second. However, the question asks us to express the comparison as a percentage. In that case the result, whether we convert or not, will be the same. We can save a step, then, by using the miles-per-hour values for the speeds of the baseball and comparing their associated kinetic energies as a ratio.

Solve

For the 78 mph baseball:

$$KE = \frac{1}{2}m_1(78 \text{ mph})^2$$

For the 92 mph baseball:

$$KE = \frac{1}{2}m_2(92 \text{ mph})^2$$

Because $m_1 = m_2$, the ratio of the kinetic energies is

$$\frac{KE_2}{KE_1} = \frac{\frac{1}{2}m_2(92 \text{ mph})^2}{\frac{1}{2}m_1(78 \text{ mph})^2} = \frac{(92 \text{ mph})^2}{(78 \text{ mph})^2} \times 100 = 140\% \text{ (answer to two significant digits)}$$

The baseball has 140% more kinetic energy as a fastball at 92 mph than as a changeup pitch at 78 mph.

Think About It
If a larger ball, such as a softball, were thrown at the same speed as the baseball, it would have more kinetic energy because of its larger mass.

1.43. **Collect and Organize**
We are to compare SI units with U.S. customary units.

Analyze
SI units are based on a decimal system to describe basic units of mass, length, temperature, energy, and so on. U.S. customary units vary.

Solve
SI units, which were based on the original metric system, can be easily converted into a larger or smaller unit by multiplying or dividing by multiples of 10. U.S. customary units are more complicated to manipulate. For example, to convert miles to feet you have to know that 1 mile is 5280 feet, and to convert gallons to quarts you have to know that 4 quarts is in 1 gallon.

Think About It
Once you can visualize a meter, a gram, and a liter, using the SI system is quite convenient.

1.44. **Collect, Organize, and Analyze**
In this question we are to suggest two reasons why SI units are not more widely used in the United States.

Solve
U.S. customary units instead of SI units are used everywhere in the United States because many of our manufacturing facilities have been built to make parts in inches or to bottle liquids in gallons. And for people used to buying and measuring in the U.S. customary units, converting their thinking to visualize a kilometer instead of a mile or a liter instead of a quart has been difficult.

Think About It
The only widespread everyday use of an SI unit in the United States is the soda bottle, which comes in 2 L sizes.

1.45. **Collect and Organize**
For this question we are to think about why scientists might prefer the Celsius scale over the Fahrenheit scale.

Analyze
The Celsius scale is based on a 100-degree range between the freezing point and boiling point of water, whereas the Fahrenheit scale is based on the 100-degree range between the freezing point of a concentrated salt solution and the average internal human body temperature.

Solve
Scientists might prefer the Celsius scale because it is based on the phase changes (freezing and boiling) for a pure common solvent (water).

Think About It
Because the difference in the freezing and boiling point of water on the Fahrenheit scale is 180 degrees compared with 100 degrees for the Celsius scale, one degree Fahrenheit is smaller than one degree Celsius. Notice in Figure A1.45 that a 10˚C range is much larger than a 10°F range.

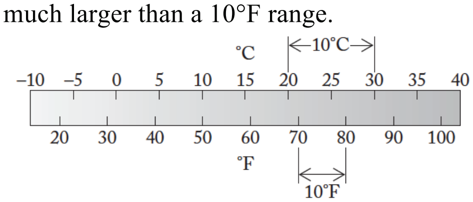


Figure A1.45

1.46. **Collect and Organize**

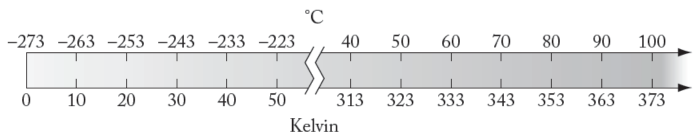
For this question we are to compare the Celsius and Kelvin scales.

Analyze

The Celsius scale is based on a 100-degree range between the freezing point (0˚C) and boiling point (100˚C) of water, whereas the Kelvin scale is based on the lowest temperature possible and is not tied to the physical property of any one substance.

Solve

The Celsius and Kelvin scales differ in that their zero points are 273.15 degrees different, with 0 K = –273.15˚C. The size of a Kelvin, however, is the same as the size of 1˚C.



Think About It

Neither the Celsius nor the Fahrenheit scale sets a lower limit on temperature, but the Kelvin scale does at absolute zero.

1.47. **Collect and Organize**

In this question we are to define the *absolute* temperature scale.

Analyze

The Kelvin scale is the absolute temperature scale, and its lowest temperature is 0 K.

Solve

The absolute temperature scale (Kelvin scale) has no negative temperatures, and its zero value is placed at the lowest possible temperature.

Think About It

Because the Kelvin scale has no negative temperatures, it will often be used in equations when using a negative temperature (in Celsius) would result in a nonsensical answer.

1.48. **Collect and Organize**

This question asks whether a temperature in Celsius would ever equal the temperature in Fahrenheit. We have to use the conversion equation between Celsius and Fahrenheit degrees.

Analyze

The equation converting between the temperatures is given as

$$^\circ\text{C} = \frac{5}{9}\left(^\circ\text{F} - 32\right)$$

To find the temperature at which these temperature scales meet, ˚C = ˚F in the above equation; substituting ˚C for ˚F gives

$$^\circ\text{C} = \frac{5}{9}\left(^\circ\text{C} - 32\right)$$

Solve

Rearranging this equation and solving for ˚C gives

$$^{\circ}\text{C} = \frac{5}{9}\left(^{\circ}\text{C} - 32\right)$$

$$\frac{9}{5}\left(^{\circ}\text{C}\right) = \left(^{\circ}\text{C} - 32\right)$$

$$\frac{9}{5}\left(^{\circ}\text{C}\right) - {}^{\circ}\text{C} = -32$$

$$\frac{4}{5}\left(^{\circ}\text{C}\right) = -32$$

$$^{\circ}\text{C} = -40\,^{\circ}\text{C} = -40\,^{\circ}\text{F}$$

Think About It

Because the intervals between degrees on the Celsius scale are larger than the degrees on the Fahrenheit scale, the two scales will eventually meet at one temperature. This solution shows that those temperature scales meet at –40°.

1.49. **Collect and Organize**

For this problem we need to convert the distance of the Olympic mile (1500 m) in meters to miles and then to feet. Then we need to compare that distance with an actual mile by using a ratio and then converting that to a percentage.

Analyze

To convert the distance, we can use the following conversions:

$$\frac{1\text{ km}}{1000\text{ m}},\ \frac{0.6214\text{ mi}}{1\text{ km}},\text{ and }\frac{5280\text{ ft}}{1\text{ mi}}$$

To determine the percentage the Olympic mile distance is compared with the actual mile, we will use

$$\%\text{ distance} = \frac{\text{Olympic mile distance in feet}}{5280\text{ ft}} \times 100$$

Solve

$$1500\text{ m} \times \frac{1\text{ km}}{1000\text{ m}} \times \frac{0.6214\text{ mi}}{1\text{ km}} = 0.9321\text{ mi}$$

$$\%\text{ distance} = \frac{0.9321\text{ mi}}{1\text{ mi}} \times 100 = 93.2\%$$

Think About It

This calculation shows that the Olympic mile is just a little bit shorter than the conventional mile.

1.50. **Collect and Organize**

To find how much gas is needed, we need only convert the miles traveled (389 mi) into the gallons that would be used by using the known value of the gas mileage for the SUV (18 mi/gal).

Analyze

The number of gallons used in the trip can be computed by

$$\text{number of gallons used} = \text{number of miles traveled} \times \frac{1\text{ gallon}}{\text{number of miles}}$$

Solve

$$\text{number of gallons used} = 389\text{ mi} \times \frac{1\text{ gal}}{18\text{ mi}} = 22\text{ gal}$$

Think About It
This answer is a reasonable value. For a quick estimate you can round the trip to 400 miles and the gas mileage to 20 miles per gallon. A quick mental computation gives this to be about 20 gallons. The above answer is, therefore, in the correct range.

1.51. **Collect and Organize**
This problem asks for a simple conversion of length: from meters to miles.

Analyze
The conversions that we need include meters to kilometers and kilometers to miles:

$$\frac{1\text{ km}}{1000\text{ m}} \text{ and } \frac{0.6214\text{ mi}}{1\text{ km}}$$

Solve

$$4.0\times10^{3}\text{ m}\times\frac{1\text{ km}}{1000\text{ m}}\times\frac{0.6214\text{ mi}}{1\text{ km}}=2.5\text{ mi}$$

Think About It
The answer is reasonable because 4000 m would be a little over 2 mi when estimated. For a natural piece of silk to be that long, though, is surprising.

1.52. **Collect and Organize**
This problem asks us to convert the speed of light in meters per second to kilometers per hour. We have to convert both distance and time into other units. We have to convert from meters (a short unit of distance) to kilometers (a longer unit of distance) and from seconds (a short unit of time) to an hour (a longer unit of time). We could convert these units in several ways; the most direct would be from meters to kilometers and from seconds to minutes to hours. We will need, therefore, the following equivalencies:

$$1000\text{ m} = 1\text{ km}$$
$$60\text{ s} = 1\text{ min}$$
$$60\text{ min} = 1\text{ hr}$$

Analyze
The conversion of units for this problem can be expressed as ratios. Because we are converting from meters to kilometers, the following ratio for unit conversions is appropriate:

$$\frac{1\text{ km}}{1000\text{ m}}$$

To convert seconds to hours, the following conversion ratios are appropriate:

$$\frac{1\text{ min}}{60\text{ s}} \text{ and } \frac{1\text{ hr}}{60\text{ min}}$$

Solve

$$\frac{2.998\times10^{8}\text{ m}}{\text{s}}\times\frac{1\text{ km}}{1000\text{ m}}\times\frac{60\text{ s}}{1\text{ min}}\times\frac{60\text{ min}}{1\text{ hr}}=1.079\times10^{9}\text{ km/hr}$$

Think About It
The speed of light in kilometers per hour is nearly the same order of magnitude as the speed in meters per second. This makes sense in that to convert from meters to kilometers we divided by 1000 and to convert from seconds to hours we multiplied by 3.6×10^3. The two conversions, therefore, nearly offset each other.

1.53. **Collect and Organize**
To determine the Calories burned by the wheelchair marathoner in a race, we can first find the number of hours the race will be for the marathoner at the pace of 13.1 miles per hour. We can then calculate the Calories burned from that value and the rate at which the marathoner burns Calories.

Analyze

The time for the marathoner to complete the race will be given by

$$\text{time to complete the marathon} = \frac{\text{distance of the marathon}}{\text{pace of the marathoner}}$$

The Calories burned will be computed by

$$\text{Calories burned} = \frac{\text{Calories burned}}{\text{hr}} \times \text{length of the marathon race}$$

Solve

$$\text{time to complete the marathon} = \frac{26.2\ \text{mi}}{13.1\ \text{mi/hr}} = 2.00\ \text{hr}$$

$$\text{Calories burned} = \frac{665\ \text{Cal}}{\text{hr}} \times 2.00\ \text{hr} = 1330\ \text{Cal}$$

Think About It

We could solve this problem without touching a calculator. Because the marathoner takes 2.00 hr to complete the race, the Calories she burns are simply twice the number of Calories she burns in 1 hr.

1.54. **Collect and Organize**

To compute the runner's speed we have to use the definition *speed* = *distance*/*time*. In the marathon runner's case we are given distance in miles and time in hours plus additional minutes. The first calculation of speed, therefore, in miles per hour will not require any unit conversion. However, we will use that result to compute the runner's speed in meters per second, using conversions for miles to meters and hours to seconds.

Analyze

The equation to compute speed is given by

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

Because the time is given as 3 hr 35 min, we will have to convert the 35 min into a part of an hour by using the fact that 1 hr = 60 min. We can then divide the marathon distance by this time in hours to get the speed in miles per hour.

To convert this speed to meters per second, we can use the following conversions:

$$\frac{1\ \text{km}}{1000\ \text{m}} \text{ and } \frac{0.6214\ \text{mi}}{1\ \text{km}}$$

$$\frac{1\ \text{min}}{60\ \text{s}} \text{ and } \frac{1\ \text{hr}}{60\ \text{min}}$$

Solve

First, the number of hours for the runner to complete the marathon is

$$3\ \text{hr} + \left(35\ \text{min} \times \frac{1\ \text{hr}}{60\ \text{min}}\right) = 3.58\ \text{hr}$$

(a) The speed in miles per hour is

$$\text{speed} = \frac{26.2\ \text{mi}}{3.58\ \text{hr}} = 7.31\ \text{mi/hr}$$

(b) Converting this speed to meters per second gives

$$\frac{7.31\ \text{mi}}{\text{hr}} \times \frac{1\ \text{km}}{0.6214\ \text{mi}} \times \frac{1000\ \text{m}}{1\ \text{km}} \times \frac{1\ \text{hr}}{60\ \text{min}} \times \frac{1\ \text{min}}{60\ \text{s}} = 3.27\ \text{m/s}$$

Think About It

Both values seem reasonable. A walking pace is about 3 mi/hr, so running could be imagined to be twice that fast. Also, a fast runner can easily run at 3 m/s.

1.55. **Collect and Organize**

A light-year is the distance light travels in 1 year. To determine the distance of 4.3 light-years in kilometers, we will first have to convert 4.3 years into seconds and then use the speed of light to determine the distance the light travels over that time.

Analyze

We can find the length of time of 4.3 years in seconds by using the following conversions:

$$\frac{1\ \text{yr}}{365.25\ \text{d}},\ \frac{1\ \text{d}}{24\ \text{hr}},\ \frac{1\ \text{hr}}{60\ \text{min}},\ \text{and}\ \frac{1\ \text{min}}{60\ \text{s}}$$

We can find the distance of 4.3 light-years in meters from the speed of light:

distance of 4.3 light-years = speed of light (in meters/second) × 4.3 yr (in seconds)

We can convert this value into kilometers by using

$$\frac{1\ \text{km}}{1000\ \text{m}}$$

Solve

$$4.3\ \text{yr} \times \frac{365.25\ \text{d}}{1\ \text{yr}} \times \frac{24\ \text{hr}}{1\ \text{d}} \times \frac{60\ \text{min}}{1\ \text{hr}} \times \frac{60\ \text{s}}{1\ \text{min}} = 1.36 \times 10^{8}\ \text{s}$$

$$\text{distance to Proxima Centauri} = (1.36 \times 10^{8}\ \text{s}) \times \frac{2.998 \times 10^{8}\ \text{m}}{\text{s}} \times \frac{1\ \text{km}}{1000\ \text{m}} = 4.1 \times 10^{13}\ \text{km}$$

Think About It

This is a very large distance since light travels so fast. The light-year, being such a large distance, is an ideal unit for expressing astronomical distances.

1.56. **Collect and Organize**

By calculating the horsepower for the Tesla Roadster, we can compare its power with that of the Porsche Boxster Spyder.

Analyze

We can convert the kilowatt power given for the Roadster (215 kW) into horsepower by using the conversion factor given: 1 horsepower = 745.7 W.

Solve

The horsepower for the Roadster is

$$215\ \text{kW} \times \frac{1000\ \text{W}}{1\ \text{kW}} \times \frac{1\ \text{horsepower}}{745.7\ \text{W}} = 288\ \text{horsepower}$$

The Boxster Spyder, at 320 horsepower, is more powerful than the Roadster, at 288 horsepower.

Think About It

Still, that the all-electric Roadster has such a high power in comparison with a gasoline-powered sports car is impressive.

1.57. **Collect and Organize**

To solve this problem, we need to know the volume of water in liters that is to be removed from the swimming pool. Using that volume and the rate at which the water can be siphoned, we can find how long removing the water will take.

Analyze

The volume of water to be removed in cubic meters can be found from

length of pool (in meters) × width of pool (in meters) × depth of water to be removed (in meters)

This volume will have to be converted to liters through the conversion

$$\frac{1\ \text{L}}{1 \times 10^{-3}\ \text{m}^3}$$

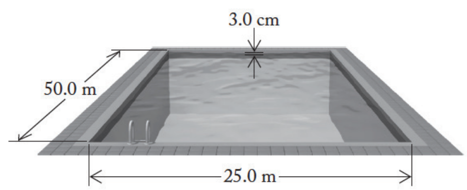
The time to siphon the water is determined by the rate at which the siphon pump operates:

$$\text{time to siphon the water} = \frac{\text{volume of water to be siphoned in liters}}{\text{rate at which the water can be siphoned in liters per second}}$$

Solve

The volume of the water to be siphoned out of the pool is

$$50.0\ \text{m} \times 25.0\ \text{m} \times \left(3.0\ \text{cm} \times \frac{1\ \text{m}}{100\ \text{cm}}\right) = 37.5\ \text{m}^3$$



Converting this into liters,

$$37.5\ \text{m}^3 \times \frac{1\ \text{L}}{1\times10^{-3}\ \text{m}^3} = 3.75\times10^4\ \text{L}$$

The amount of time to siphon this water is

$$\text{time to siphon the water} = \frac{3.75\times10^4\ \text{L}}{5.2\ \text{L/s}} = 7210\ \text{s}$$

$$7210\ \text{s} \times \frac{1\ \text{min}}{60\ \text{s}} = 120\ \text{min, or } 2.0\ \text{hr}$$

Think About It

This may be a surprisingly long time to siphon only 3.0 cm of water from the pool, but the total volume to be siphoned is quite large because of the pool's size.

1.58. **Collect and Organize**

To compare the prices of the soft drinks, we will have to convert to a common unit of volume, either ounces or liters.

Analyze

We can use the following conversions to convert ounces to quarts to liters for the soft drink priced at \$1.00 for 24 oz:

$$\frac{1\ \text{qt}}{32\ \text{oz}} \quad \text{and} \quad \frac{0.9464\ \text{L}}{1\ \text{qt}}$$

For the soft drink already priced per half-liter, the price per liter will be double.

Solve

$$\frac{\$1.00}{24\ \text{oz}} \times \frac{32\ \text{oz}}{1\ \text{qt}} \times \frac{1\ \text{qt}}{0.9464\ \text{L}} = \$1.41/\text{L}$$

$$\frac{\$0.75}{0.50\ \text{L}} = \$1.50/\text{L}$$

Comparing the two prices in common units, we find that buying the soft drink in the 24 oz bottles, not the half-liter bottles, is better.

Think About It

We can also solve this problem by converting the half-liter volume to ounces. In that case, the price per ounce in the 24 oz bottle would be 4.2¢, whereas the price per ounce in the half-liter bottle would be 4.4¢. The conclusion is the same in either case.

1.59. **Collect and Organize**

We can solve this by converting the time for the runner to complete the race into seconds and then converting the distance of the race from kilometers into meters. The runner's speed is the ratio of distance (meters) to time (seconds).

Analyze

Conversions for time that we need are

$$\frac{60\ \text{s}}{1\ \text{min}}$$

To convert kilometers into miles, we need

$$\frac{1000\ \text{m}}{1\ \text{km}}$$

Solve

The time for the runner to complete the race is

$$\left(41\ \text{min} \times \frac{60\ \text{s}}{1\ \text{min}}\right) + 23\ \text{s} = 2483\ \text{s}$$

The distance of the race in kilometers is

$$10.0\ \text{km} \times \frac{1000\ \text{m}}{\text{km}} = 1.00 \times 10^4\ \text{m}$$

The runner's average speed then is

$$\frac{1.00 \times 10^4\ \text{m}}{2483\ \text{s}} = 4.03\ \text{m/s}$$

Think About It

The answer makes sense because a walking speed is around 3 mph, or 1.3 m/s. Running could easily be imagined at 9 mph, or 4.0 m/s.

1.60. **Collect and Organize**

This is a calculation of speed in which we have to convert time measured in minutes and seconds into only seconds. The ratio of distance around the racetrack (converted from miles to meters) and the time in seconds will give Secretariat's speed in the race.

Analyze

We have to convert 1 min 59.4 s into seconds by using this conversion:

$$\frac{1\ \text{min}}{60\ \text{s}}$$

To convert miles to meters we will need to use the following conversions:

$$\frac{1\ \text{km}}{0.6214\ \text{mi}} \quad \text{and} \quad \frac{1000\ \text{m}}{1\ \text{km}}$$

We can then use the following to find Secretariat's speed in the race:

$$\text{speed} = \frac{\text{distance in miles}}{\text{time in hours}} \quad \text{and} \quad \text{speed} = \frac{\text{distance in meters}}{\text{time in seconds}}$$

Solve

(a) One minute and 59.4 s is 119.4 s. Converting seconds to hours gives

$$119.4\ \text{s} \times \frac{1\ \text{min}}{60\ \text{s}} \times \frac{1\ \text{hr}}{60\ \text{min}} = 0.03317\ \text{hr}$$

Secretariat's speed in miles per hour was

$$\text{average speed} = \frac{1.25\ \text{mi}}{0.03317\ \text{hr}} = 37.7\ \text{mph}$$

(b) One minute and 59.4 s is 119.4 s. Converting the 1.25 mile distance to meters gives

$$1.25\ \text{mi} \times \frac{1\ \text{km}}{0.6214\ \text{mi}} \times \frac{1000\ \text{m}}{1\ \text{km}} = 2.01 \times 10^3\ \text{m}$$

Secretariat's average speed during the race is

$$\text{average speed} = \frac{2.01 \times 10^3\ \text{m}}{119.4\ \text{s}} = 16.8\ \text{m/s}$$

Think About It

A horse can gallop faster than a person can run and about as fast as a moving car.

1.61. **Collect and Organize**

In this problem we need to use the density of magnesium to find the mass of a specific size block of the metal.

Analyze

Density is defined as the mass of a substance per unit volume. Appendix 3 gives the density of magnesium as 1.738 g/cm^3. We have to find the volume of the block of magnesium by multiplying the length by the height by the depth (the result will be in cubic centimeters). We can then find mass through the following formula:

$$\text{mass (g)} = \text{density (g/cm}^3\text{)} \times \text{volume (cm}^3\text{)}$$

Solve

The volume of the block of magnesium is

$$2.5\ \text{cm} \times 3.5\ \text{cm} \times 1.5\ \text{cm} = 13\ \text{cm}^3$$

Therefore, the mass of the block is

$$13\ \text{cm}^3 \times 1.738\ \text{g/cm}^3 = 23\ \text{g}$$

Think About It

The mass of a sample depends on the amount of substance present. Here we have about 23 g. For a quick estimate, a block of magnesium of about 10 cm^3 would weigh more than 1.7 times that of 1 cm^3, or 17 g. Because we have more than 10 cm^3 of this sample and the density is a little greater than 1.7 g/cm^3, our answer of 23 g is reasonable.

1.62. **Collect and Organize**

In this problem we need to use the density of osmium to find the mass of a specific size block of the metal. Perhaps to find out whether we could lift it with one hand, we also have to convert it into pounds, since that is the unit we more closely associate with weights in the United States.

Analyze

Density is defined as the mass of a substance per unit volume. Appendix 3 gives the density of osmium as 22.57 g/cm^3. We have to find the volume of the block of osmium by multiplying the length by the height by the depth (the result will be in cubic centimeters). We can then find mass through the following formula:

$$\text{mass (g)} = \text{density (g/cm}^3\text{)} \times \text{volume (cm}^3\text{)}$$

We can use the conversion of grams to pounds for the comparison:

$$\frac{453.6\ \text{g}}{1\ \text{lb}}$$

Solve

The volume of the block of osmium is

$$6.5\ \text{cm} \times 9.0\ \text{cm} \times 3.25\ \text{cm} = 190\ \text{cm}^3$$

Therefore, the mass of the block is

$$190\ \text{cm}^3 \times 22.57\ \text{g/cm}^3 = 4300\ \text{g}$$

To convert this into the more familiar pounds:

$$4300\ \text{g} \times \frac{1\ \text{lb}}{453.6\ \text{g}} = 9.5\ \text{lb}$$

Nearly 10 pounds is fairly heavy, but it could be lifted with one hand.

Think About It
The block of osmium, though, will be surprisingly heavy as you pick it up because its volume is relatively small.

1.63. **Collect and Organize**
In this problem we use the density to find the volume of sulfuric acid the chemist needs. This situation uses the definition density = mass/volume.

Analyze
We can easily solve this problem by rearranging the density equation:

$$\text{density} = \frac{\text{mass}}{\text{volume}} \quad \text{or} \quad \text{volume} = \frac{\text{mass}}{\text{density}}$$

Solve

$$\text{volume needed} = \frac{35.0 \text{ g}}{1.84 \text{ g/mL}} = 19.0 \text{ mL}$$

Think About It
With a density of about 2 g/cm^3 to get a mass of about 40 g, we might estimate that the chemist would need 20 mL. This estimate shows that our answer is reasonable.

1.64. **Collect and Organize**
In this problem we use the density to find the mass of ethanol in 65.0 mL. This situation uses the definition density = mass/volume.

Analyze
We can easily solve this problem by rearranging the density equation:

$$\text{density} = \frac{\text{mass}}{\text{volume}} \quad \text{or} \quad \text{mass} = \text{volume} \times \text{density}$$

Solve

$$\text{mass of ethanol} = 65.0 \text{ mL} \times \frac{0.789 \text{ g}}{\text{mL}} = 51.3 \text{ g}$$

Think About It
With a density of less than a gram per milliliter, we expect that we would have a mass lower than 65 g for the 65 mL sample of ethanol.

1.65. **Collect and Organize**
This problem asks us to convert weights from ounces to grams and then to kilograms.

Analyze
Conversions for weight (mass) that we need are

$$\frac{1 \text{ oz}}{28.35 \text{ g}} \quad \text{and} \quad \frac{1 \text{ kg}}{1000 \text{ g}}$$

Solve

$$0.934 \text{ oz} \times \frac{28.35 \text{ g}}{1 \text{ oz}} = 26.5 \text{ g}$$

$$26.5 \text{ g} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.0265 \text{ kg}$$

Think About It

Because the silver dollar weighs just under an ounce, its mass will be slightly less than 28.35 g, so our answer of 26.5 g makes sense.

1.66. **Collect and Organize**

To calculate the value of a kilogram of dimes, we need to first find out how many dimes are in 1 kg. Since we are given the mass of one dime, a kilogram of dimes will contain 1 kg divided by the mass of one dime. To find the value, then, of the dimes, we have to multiply the number of dimes by $0.10.

Analyze

To find the number of dimes, we have to convert 1 kg to 1000 g to use the conversion

$$\frac{1\text{ dime}}{2.5\text{ g}}$$

Solve

$$\text{number of dimes} = 1000\text{ g} \times \frac{1\text{ dime}}{2.5\text{ g}} = 400\text{ dimes}$$

$$400\text{ dimes} \times \frac{\$0.10}{1\text{ dime}} = \$40.00$$

Think About It

This answer is a reasonable amount because if each dime weighed only 1 g, the value of the kilogram of dimes would be $100.00 by a quick mental computation. Likewise, if a dime weighed 10 g, the value would be $10.00. Our answer is between these two quick calculations, so it is reasonable.

1.67. **Collect and Organize**

To answer this question we need to use the density of copper to compute the mass of the copper sample that is 125 cm^3 in volume. Next, we use that mass to find out how much volume (in cubic centimeters) that mass of gold would occupy.

Analyze

We need the density both of copper and of gold from Appendix 3 to convert from volume to mass (for copper) and then from mass to volume (for gold). These densities are 8.96 g/mL for copper and 19.3 g/mL for gold. One milliliter is equivalent to 1 cm^3, so the densities are 8.96 g/cm^3 and 19.3 g/cm^3, respectively. The density formulas that we need are

$$\text{mass of copper} = \text{density of copper} \times \text{volume}$$

$$\text{volume of gold} = \frac{\text{mass}}{\text{density of gold}}$$

Solve

$$\text{mass of copper} = 8.96\text{ g/cm}^3 \times 125\text{ cm}^3 = 1120\text{ g}$$

$$\text{volume of gold} = \frac{1120\text{ g}}{19.3\text{ g/cm}^3} = 58.0\text{ cm}^3$$

Think About It

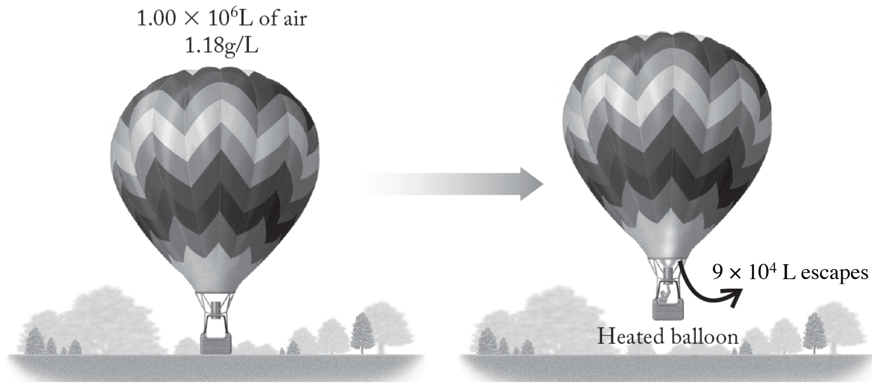
Because gold is more than twice as dense as copper, we would expect the volume of a gold sample to have about half the volume of that of the same mass of copper.

1.68. **Collect and Organize**

Given the volume and density of the air inside a hot-air balloon at a cooler temperature and the volume of air that escapes the balloon upon heating, we are to calculate the density of the air left in the balloon.

Analyze
First, we should calculate the mass of air inside the balloon at lower temperature by using the volume of the balloon and the density of the air at that lower temperature. Then from that same density, we can calculate the mass of air that escapes from the balloon upon heating and subtract that from the initial mass of air present. Finally, we can calculate the density from the mass of the air left in the balloon and the volume of the balloon when heated.

Solve
Pictorially, the process for the balloon is as follows:



The mass of air initially present in the balloon is

$$1.00\times10^6\ \text{L}\times\frac{1.18\ \text{g}}{\text{L}}=1.180\times10^6\ \text{g}$$

The mass of air that escapes the balloon is

$$9\times10^4\ \text{L}\times\frac{1.18\ \text{g}}{\text{L}}=1.062\times10^5\ \text{g}$$

The mass of air remaining in the heated balloon is

$$\left(1.180\times10^6-1.062\times10^5\right)\text{g}=1.074\times10^6\,\text{g}$$

The density of the air in the heated balloon is

$$\text{density}=\frac{1.074\times10^6\ \text{g}}{1.00\times10^6\ \text{L}}=1.07\ \text{g/L}$$

Think About It
The air inside the balloon became less dense as it was heated, and that is what causes a hot-air balloon's "lift."

1.69. **Collect and Organize**
Using the density of mercury, we can find the volume of 1.00 kg of mercury.

Analyze
Appendix 3 gives the density of mercury as 13.546 g/mL. Because this property is expressed in grams per milliliter, not kilograms per milliliter, we have to convert kilograms into grams by using the conversion factor

$$\frac{1000\ \text{g}}{1\ \text{kg}}$$

Once we have the mass in grams, we can use the rearranged formula for density to find volume:

$$\text{volume of mercury (mL)}=\frac{\text{mass of mercury (g)}}{\text{density of mercury (g/mL)}}$$

Solve

$$1.00\ \text{kg} \times \frac{1000\ \text{g}}{1\ \text{kg}} = 1.00 \times 10^3\ \text{g}$$

$$\text{volume of mercury} = \frac{1.00 \times 10^3\ \text{g}}{13.546\ \text{g/mL}} = 73.8\ \text{mL}$$

Think About It

That result is a fairly small amount that weighs 1 kg. That value is the result of mercury's relatively high density.

1.70. **Collect and Organize**

For this problem we need to compare the student's measurement of the density of her piece of jewelry with the known density of silver.

Analyze

We can calculate the density of the piece of jewelry by dividing the mass of the piece of jewelry by its volume according to the formula for density.

Solve

$$\text{density of the piece of jewelry} = \frac{3.17\ \text{g}}{0.3\ \text{mL}} = 10.6\ \text{g/mL, or 11 g to two significant digits}$$

The density of silver is 10.50 g/mL. Because these densities match very closely, the jewelry could be made of pure silver.

Think About It

The difference in the densities between the piece of jewelry and pure silver is less than 5%. A better comparison of densities would require more significant digits for the measurements of mass and volume of the piece of jewelry.

1.71. **Collect and Organize**

Because we are not directly given the mass and volume of the two planets, Earth and Venus, we have to use their relative masses and volumes to find the density of Venus compared with that of Earth.

Analyze

The relative masses and volumes of the two planets can be expressed as

$$\text{mass of Venus} = 0.815 \times \text{mass of Earth}$$

$$\text{volume of Venus} = 0.88 \times \text{volume of Earth}$$

To find the density of Venus, we will have to rearrange these into

$$\frac{\text{mass of Earth}}{\text{volume of Earth}} \times \frac{\text{volume of Earth}}{\text{volume of Venus}} \times \frac{\text{mass of Venus}}{\text{mass of Earth}} = \frac{\text{mass of Venus}}{\text{volume of Venus}}$$

or

$$\text{density of Earth} \times \frac{100}{88} \times \frac{81.5}{100} = \text{density of Venus}$$

Solve

$$\frac{5.5\ \text{g}}{\text{cm}^3} \times \frac{100}{88} \times \frac{81.5}{100} = 5.1\ \text{g/cm}^3$$

Think About It

With Earth being larger than Venus, and more massive, immediately predicting whether Venus would be more or less dense than Earth is hard. However, because the difference in the mass (18.5%) between Earth and Venus is greater than the difference in volume (12%), it makes sense that the density of Venus is lower than that of Earth.

1.72. **Collect and Organize**

In this problem, we have to calculate the volume of Earth from its given mass and density. Then we must convert this volume into cubic kilometers. We then consider how the density due to gravitational squeezing would compare.

Analyze

The volume of Earth in cubic kilometers can be calculated from

$$\frac{\text{mass of Earth}}{\text{density of Earth}} \times \left(\frac{1\text{ m}}{100\text{ cm}}\right)^3 \times \left(\frac{1\text{ km}}{1000\text{ m}}\right)^3$$

Solve

(a) $\dfrac{6.0\times10^{27}\text{ g}}{5.5\text{ g/cm}^3} \times \left(\dfrac{1\text{ m}}{100\text{ cm}}\right)^3 \times \left(\dfrac{1\text{ km}}{1000\text{ m}}\right)^3 = 1.1\times10^{12}\text{ km}^3$

(b) Gravitational squeezing would reduce the volume of the core and would, therefore, make the calculated density of Earth higher if not corrected. The natural density corrected for gravitational squeezing would be less than 5.5 g/cm^3.

Think About It

The density of Earth is not uniform and varies from crust to core and even between regions within the same layer.

1.73. **Collect and Organize**

To determine whether a cube made of high-density polyethylene (HDPE) will float on water, we need to compare the density of the HDPE with that of water. If HDPE's density is less than water's, the cube will float.

Analyze

To compare the densities of the two substances (water and HDPE), we need to have them in the same units. We can approach this in either of two ways—convert the seawater density to kilograms per cubic meter or convert the HDPE density to grams per cubic centimeter. Let's do the latter, using the following conversions:

$$\frac{100\text{ cm}}{1\text{ m}} \text{ and } \frac{1000\text{ g}}{1\text{ kg}}$$

To calculate the density of the HDPE sample, we must divide the mass of the cube of HDPE in grams by the volume in cubic centimeters.

Solve

$$\text{volume of the HDPE cube} = \left(1.20\times10^{-2}\text{ m}\right)^3 \times \left(\frac{100\text{ cm}}{1\text{ m}}\right)^3 = 1.728\text{ cm}^3$$

$$\text{mass of the HDPE cube in grams} = 1.70\times10^{-3}\text{ kg} \times \frac{1000\text{ g}}{1\text{ kg}} = 1.70\text{ g}$$

$$\text{density of the HDPE cube} = \frac{1.70\text{ g}}{1.728\text{ cm}^3} = 0.984\text{ g/cm}^3$$

That density is less than the density of the seawater (1.03 g/cm^3), so the cube of HDPE will float on water.

Think About It

Certainly boats are made of other materials (such as iron) that are denser than water. Those boats float because the mass of the water they displace is greater than their mass.

1.74. **Collect and Organize**

In this problem we are asked to calculate the sun's density in grams per cubic centimeter given the mass in kilograms (we have to convert to grams) and the radius of the sun in meters (from which we have to find volume in cubic centimeters).

Analyze

First, we can use the fact that 1000 g = 1 kg to convert the mass of the sun from kilograms to grams. Second, we have to determine the volume of the sun through the formula

$$\text{volume} = \frac{4}{3}\pi r^3$$

That volume can be computed in cubic centimeters if we first convert the radius in kilometers to centimeters by using the equivalencies that 1 km = 1000 m and 1 m = 100 cm.

Solve

$$\text{mass of the sun} = 2\times10^{30}\ \text{kg}\times\frac{1000\ \text{g}}{1\ \text{kg}} = 2\times10^{33}\ \text{g}$$

$$\text{radius of the sun (cm)} = 7.0\times10^{5}\ \text{km}\times\frac{1000\ \text{m}}{1\ \text{km}}\times\frac{100\ \text{cm}}{1\ \text{m}} = 7.0\times10^{10}\ \text{cm}$$

$$\text{volume of the sun} = \frac{4}{3}\pi\left(7.0\times10^{10}\ \text{cm}\right)^3 = 1.4\times10^{33}\ \text{cm}^3$$

$$\text{density of the sun} = \frac{2\times10^{33}\ \text{g}}{1.4\times10^{33}\ \text{cm}^3} = 1.4\ \text{g/cm}^3$$

Think About It

The density of the sun is much less than that of Earth (5.5 g/cm^3), which is not surprising because the sun is composed mostly of gases.

1.75. **Collect and Organize**

Given that the mass of the Golden Jubilee diamond is 545.67 carats (with 1 carat = 0.200 g), we are to calculate the mass of the diamond in grams and in ounces.

Analyze

First, we can use the fact that 1 carat = 0.200 g to convert the mass of the diamond from carats to grams. Then we can use the fact that 1 ounce = 28.35 g to convert the result in grams to ounces.

Solve

$$\text{mass of the diamond in grams} = 545.67\ \text{carats}\times\frac{0.200\ \text{g}}{1\ \text{carat}} = 109\ \text{g}$$

$$\text{mass of the diamond in ounces} = 109\ \text{g}\times\frac{1\ \text{ounce}}{28.35\ \text{g}} = 3.85\ \text{ounces}$$

Think About It

From these conversion factors we can determine the number of ounces in 1 carat:

$$1\ \text{carat}\times\frac{0.200\ \text{g}}{\text{carat}}\times\frac{1\ \text{ounce}}{28.35\ \text{g}} = 7.05\times10^{-3}\ \text{ounce}$$

1.76. **Collect and Organize**

Given that the density of the diamond is 3.51 g/cm^3, we are to calculate the volume of the Golden Jubilee diamond, which has a mass of 109 grams.

Analyze

To obtain the volume of the diamond we simply need to divide the mass of the diamond by the density of diamond.

Solve

$$\text{volume of the Golden Jubilee diamond} = 109\ \text{g} \times \frac{1\ \text{cm}}{3.51\ \text{g}} = 31.1\ \text{cm}^3$$

Think About It

The Golden Jubilee diamond is valued between 4 and 12 million dollars.

1.77. **Collect and Organize**

For the values given, we are asked to choose those that contain three significant figures.

Analyze

Writing all the values in scientific notation will help determine the number of significant figures in each.

(a) 7.02
(b) 6.452
(c) $302 = 3.02 \times 10^2$
(d) 6.02×10^{23}
(e) $12.77 = 1.277 \times 10^1$
(f) 3.43

Solve

The values that have three significant figures are (a) 7.02, (c) 302, (d) 6.02×10^{23}, and (f) 3.43.

Think About It

Remember that a zero between two other digits is always significant.

1.78. **Collect and Organize**

For each value given, we are asked to choose those that contain four significant figures.

Analyze

Writing all the values in scientific notation will help determine the number of significant figures in each.

(a) $0.0592 = 5.92 \times 10^{-2}$
(b) $0.08206 = 8.206 \times 10^{-2}$
(c) 8.314
(d) $273.15 = 2.7315 \times 10^2$
(e) 5.091×10^3
(f) 9.490

Solve

The values that have four significant figures are (b) 0.08206, (c) 8.314, (e) 5.091×10^3, and (f) 9.490.

Think About It

Remember that zeros at the end of the number may be significant, or they may simply be acting as placeholders.

1.79. **Collect and Organize**

We are to express the result of each calculation to the correct number of significant figures.

Analyze

Section 1.8 in the textbook gives the rules regarding the significant figures that carry over in calculations. Remember to operate on the weak-link principle.

Solve

(a) The least well-known value has two significant figures, so the calculator result of 9.225×10^2 is reported as 9.2×10^2.

(b) The sum results in the least well-known digit in the hundredths place to give the sum known to four significant digits, which determines the significant digits to be four for the multiplication and division steps, so the calculator result of 1.29334×10^{-16} is reported as 1.293×10^{-16}.

(c) The numerator is known only to the tenths place for three significant digits and the denominator is known to four significant digits. The least well-known value, then, has three significant figures, so the calculator result of 1.5336×10^{-23} is reported as 1.53×10^{-23}.

(d) The numerator is known only to the tenths place for three significant digits and the denominator is known to four significant digits. The least well-known value, then, has three significant figures, so the calculator result of 3.726×10^{-6} is reported as 3.73×10^{-6}.

Think About It

Indicating the correct number of significant figures for a calculated value indicates the level of confidence we have in our calculated value. Reporting too many significant figures would indicate a higher level of precision in our number than we actually have.

1.80. **Collect and Organize**

We are to express the result of each calculation to the correct number of significant figures.

Analyze

Section 1.8 in the textbook gives the rules regarding the significant figures that carry over in calculations. Remember to operate on the weak-link principle.

Solve

(a) The least well-known value has two significant figures, so the calculator result of 1.5506×10^{-1} is reported as 1.6×10^{-1}.

(b) The least well-known value has three significant figures, so the calculator result of 388.77 is reported as 389.

(c) The least well-known value has three significant figures, so the calculator result of 6.3746×10^{3} obtained by multiplying 389 in^3 by $(2.54 \text{ cm/in})^3$ is reported as 6.37×10^{3} cm^3.

(d) The least well-known value has two significant figures, so the calculator result of 8.68 for the average of those numbers (the sum of the numbers divided by five) is reported as 8.7.

Think About It

Indicating the correct number of significant figures for a calculated value indicates the level of confidence we have in our calculated value. Reporting too many significant figures would indicate a higher level of precision in our number than we actually have.

1.81. **Collect and Organize**

We are asked in this problem to convert from kelvin to degrees Celsius.

Analyze

The relationship between the Kelvin temperature scale and the Celsius temperature scale is given by

$$K = {}^{\circ}C + 273.15$$

Rearranging this gives the equation to convert Kelvin to Celsius temperatures:

$${}^{\circ}C = K - 273.15$$

Solve

$${}^{\circ}C = 4.2 \text{ K} - 273.15 = -269.0{}^{\circ}C$$

Think About It

Because 4.2 K is very cold, we would expect that the Celsius temperature would be very negative. It should not, however, be lower than –273.15 K, since that is the lowest temperature possible.

1.82. **Collect and Organize**

This question asks us to convert a Celsius temperature into kelvin.

Analyze
The relationship between the Kelvin temperature scale and the Celsius temperature scale is given by

$$K = {}^\circ C + 273.15$$

Solve

$$K = -253^\circ C + 273.15 = 20.\ K$$

Think About It
That is a low temperature for the Celsius temperature scale. It is still above the lowest possible temperature (0 K, or –273.15˚C); it has to be!

1.83. **Collect and Organize**
Given the boiling point of ethyl chloride in degrees Celsius, we are to compute the boiling point in ˚F and K.

Analyze
The relationship between the Kelvin temperature scale and the Celsius temperature scale is given by

$$K = {}^\circ C + 273.15$$

The relationship between the Celsius and Fahrenheit temperature scales is given by

$${}^\circ C = \frac{5}{9}\left({}^\circ F - 32\right)$$

We will have to rearrange this expression to find ˚F from ˚C:

$${}^\circ F = \frac{9}{5}\left({}^\circ C\right) + 32$$

Solve
The boiling point of ethyl chloride in the Fahrenheit and Kelvin scales is

$$K = 12.3^\circ C + 273.15 = 285.4\ K$$

$${}^\circ F = \frac{9}{5}\left(12.3^\circ C\right) + 32 = 54.1^\circ F$$

Think About It
Notice that the answer is reported to four significant figures for the temperature in Kelvin and to two significant figures for the temperature in Fahrenheit because of the addition and multiplication rule.

1.84. **Collect and Organize**
Given the temperature of dry ice as –78˚C, we are to compute that temperature in ˚F and K.

Analyze
The relationship between the Kelvin temperature scale and the Celsius temperature scale is given by

$$K = {}^\circ C + 273.15$$

The relationship between the Celsius and Fahrenheit temperature scales is given by

$${}^\circ C = \frac{5}{9}\left({}^\circ F - 32\right)$$

We will have to rearrange this expression to find ˚F from ˚C:

$${}^\circ F = \frac{9}{5}\left({}^\circ C\right) + 32$$

Solve
The equivalents of –78˚C in the Kelvin and Fahrenheit scales are

$$K = -78^\circ C + 273.15 = 195\ K$$

$$°F = \frac{9}{5}(-78°C) + 32 = -110°F$$

Think About It
Both temperatures seem reasonable. The Kelvin scale gives a high value since its zero temperature is very, very low. However, the Fahrenheit temperature is lower than the Celsius temperature since the Fahrenheit degree is smaller than the Celsius degree.

1.85. **Collect and Organize**
This question asks us to convert the coldest temperature recorded on Earth from Fahrenheit to Celsius degrees and K.

Analyze
Since the Celsius and Kelvin scales are similar (offset by 273.15°), once we convert from Fahrenheit to Celsius, finding the Kelvin temperature will be straightforward. The equations we need are

$$°C = \frac{5}{9}(°F - 32)$$
$$K = °C + 273.15$$

Solve

$$°C = \frac{5}{9}(-128.6°F - 32) = -89.2°C$$
$$K = -89.2°C + 273.15 = 183.9\ K$$

Think About It
This temperature is cold on any scale!

1.86. **Collect and Organize**
This question asks us to convert the hottest temperature recorded on Earth from Fahrenheit to Celsius degrees and K.

Analyze
Since the Celsius and Kelvin scales are similar (offset by 273.15°), once we convert from Fahrenheit to Celsius, finding the Kelvin temperature will be straightforward. The equations we need are

$$°C = \frac{5}{9}(°F - 32)$$
$$K = °C + 273.15$$

Solve

$$°C = \frac{5}{9}(134°F - 32) = 56.7°C$$
$$K = 56.7°C + 273.15 = 329.8\ K$$

Think About It
These values are expected based on the Celsius and Kelvin temperature scales.

1.87. **Collect and Organize**
We are asked to compare the critical temperature (T_c) of three superconductors. The critical temperatures, however, are given in three different temperature scales, so for the comparison, we will need to convert them to a single scale.

Analyze

Which temperature scale we use as the common one does not matter, but since the critical temperatures are low, expressing all the temperatures in kelvin might be easiest. The equations we will need are

$$\text{K} = {^\circ}\text{C} + 273.15 \text{ and } {^\circ}\text{C} = \frac{5}{9}\left({^\circ}\text{F} - 32\right)$$

Solve

The T_c for $YBa_2Cu_3O_7$ is already expressed in kelvin, $T_c = 93.0$ K.
The T_c of Nb_3Ge is expressed in degrees Celsius and can be converted to kelvin by

$$\text{K} = -250.0^\circ\text{C} + 273.15 = 23.2 \text{ K}$$

The T_c of $HgBa_2CaCu_2O_6$ is expressed in Fahrenheit degrees. To get this temperature in kelvin, first convert to Celsius degrees:

$$^\circ\text{C} = \frac{5}{9}\left(-231.1^\circ\text{F} - 32\right) = -146.2^\circ\text{C}$$

$$\text{K} = -146.2^\circ\text{C} + 273.15 = 127.0 \text{ K}$$

The superconductor with the highest T_c is $HgBa_2CaCu_2O_6$ with a T_c of 127.0 K.

Think About It

The superconductor with the lowest T_c is Nb_3Ge with a T_c of 23.2 K, more than 100 K lower than the T_c of $HgBa_2CaCu_2O_6$.

1.88. **Collect and Organize**

Given the boiling points of O_2 and N_2, we are to decide which gas would condense first as air is cooled.

Analyze

One temperature is in degrees Celsius and one is in kelvin, so we should first convert one of the temperatures to the other scale for comparison. Let's use the Kelvin scale. That means we convert the boiling point of O_2 to kelvin:

$$-183^\circ\text{C} + 273.15 = 90 \text{ K}$$

Upon cooling, the gas with the highest boiling point will condense first.

Solve

Oxygen will condense at 90 K and nitrogen will condense at 77 K, so as we lower the temperature of air, the oxygen will condense first.

Think About It

Argon is also a component (albeit small) of air and has a boiling point of –185.9˚C, or 83.6 K, so upon cooling of air, argon will condense after oxygen and before nitrogen.

1.89. **Collect and Organize**

In this question we are to determine the number of suspect data points that can be identified by using Grubbs' test.

Analyze

Grubbs' test is a test to statistically detect whether a particular data point is an outlier in a data set.

Solve

Because we test through Grubbs' test whether a particular data point is an outlier, we test only one data point at a time.

Think About It

If a data point is determined to be an outlier through Grubbs' test, it can be removed from the data set.

1.90. **Collect and Organize**

For a given value n, we are to determine which confidence interval from among 50%, 90%, and 95% is the largest.

Analyze

The confidence interval is a range of values around a calculated mean; the higher the confidence level value, the wider the range of the confidence interval. Table 1.5 shows that the value of t increases with increasing confidence level. The increase t in the equation

$$\mu = \bar{x} \pm \frac{ts}{\sqrt{n}}$$

indicates an increase in the confidence interval.

Solve

The 95% confidence interval is the largest.

Think About It

A confidence interval of 95% means that the probability of the true value lying within that interval is 95%.

1.91. **Collect and Organize**

We are to decide whether the measure of mean ± standard deviation or a 95% confidence interval has the greater variability.

Analyze

The equation to determine the confidence interval is

$$\mu = \bar{x} \pm \frac{ts}{\sqrt{n}}$$

where μs is the true mean value, $\bar{x}$ is the mean, t is the t value for a particular confidence level, s is the standard deviation, and n is the number of values in the data set.

Solve

Mean standard deviation is slightly greater because the span of 95% confidence interval for seven data points is

$$\pm\left(\frac{ts}{\sqrt{n}}\right) = \pm\left(\frac{2.447 \times s}{\sqrt{7}}\right) = 0.9249s$$

Think About It

Remember that built into the calculation of standard deviation and confidence levels is the assumption that the data vary randomly. The conclusion would be reversed when $n < 7$.

1.92. **Collect and Organize**

We are to consider in this question whether a data point that is not an outlier at the 95% confidence level could be an outlier at the 99% confidence level.

Analyze

The 99% confidence interval is wider than the 95% confidence interval.

Solve

For the same number of measurements n, the higher the confidence level the greater the Z value for Grubbs' test. If a data point is not an outlier at the 95% confidence level, the calculated Z is less than the reference Z value. Then at the 99% confidence level, the calculated Z is smaller than the reference Z value. Therefore, this data point will not be an outlier at the 99% confidence level.

Think About It

However, if a data point is an outlier in the 99% confidence interval, it also will be an outlier in the 95% confidence interval.

1.93. **Collect and Organize**

Given the data from three manufacturers of circuit boards for copper line widths, we are to calculate the mean and standard deviation, determine which of the data sets would include the data point of 0.500 μm in the 95% confidence interval, and decide which manufacturer was "precise and accurate" and which was "precise but not accurate."

Analyze

To calculate the mean, we sum all the values of the data set and divide by the number of data points in that data set. To calculate the standard deviation, we use the following formula

$$s = \sqrt{\frac{\sum_i \left(x_i - \bar{x}\right)^2}{n-1}}$$

To calculate the 95% confidence intervals for the data sets we use

$$\mu = \bar{x} \pm \frac{t\,s}{\sqrt{n}}$$

Solve

(a) For each manufacturer, the mean and standard deviations are:

Manufacturer 1

$$\bar{x} = \frac{0.512 + 0.508 + 0.516 + 0.504 + 0.513}{5} = 0.5106$$

$$s = \sqrt{\frac{(0.512-0.511)^2 + (0.508-0.511)^2 + (0.516-0.511)^2 + (0.504-0.511)^2 + (0.513-0.511)^2 +}{5-1}} = 0.0047$$

Manufacturer 2

$$\bar{x} = \frac{0.514 + 0.513 + 0.514 + 0.514 + 0.512}{5} = 0.5134$$

$$s = \sqrt{\frac{(0.514-0.513)^2 + (0.513-0.513)^2 + (0.514-0.513)^2 + (0.514-0.513)^2 + (0.512-0.513)^2 +}{5-1}} = 0.0009$$

Manufacturer 3

$$\bar{x} = \frac{0.500 + 0.501 + 0.502 + 0.502 + 0.501}{5} = 0.5012$$

$$s = \sqrt{\frac{(0.500-0.501)^2 + (0.501-0.501)^2 + (0.502-0.501)^2 + (0.502-0.501)^2 + (0.501-0.501)^2 +}{5-1}} = 0.0008$$

(b) For each manufacturer, the 95% confidence interval is:

Manufacturer 1

$$\mu = 0.5106 \pm \frac{2.776 \times 0.0047}{\sqrt{5}} = 0.5106 \pm 0.0058$$

This range would be 0.5048–0.5164 μm and would not include the 0.500 μm data point.

Manufacturer 2

$$\mu = 0.5134 \pm \frac{2.776 \times 0.0009}{\sqrt{5}} = 0.5134 \pm 0.0011$$

This range would be 0.5123–0.5145 μm and would not include the 0.500 μm data point.

Manufacturer 3

$$\mu = 0.5012 \pm \frac{2.776 \times 0.0008}{\sqrt{5}} = 0.5012 \pm 0.0010$$

This range would be 0.5002–0.5022 μm and would include the 0.500 μm data point for three significant digits.

(c) The manufacturer that is both precise (smallest spread of values) and accurate (closest average to 0.500 μm) is Manufacturer 3. The manufacturer that is precise (smallest spread of values) but not accurate (far from the average to 0.500 μm) is Manufacturer 2.

Think About It

In manufacturing electronic circuit boards the specifications must be very strictly adhered to. Manufacturer 3, which prints boards with the highest precision and accuracy, will win the contract.

1.94. **Collect and Organize**

For a given set of glucose measurements for a patient we are to calculate the mean and standard deviation as well as determine whether a patient with a glucose level above 120 mg/dL is diabetic by examining the 95% confidence interval for the data provided.

Analyze

To calculate the mean, we sum all the values of the data set and divide by the number of data points in that data set. To calculate the standard deviation, we use the following formula

$$s = \sqrt{\frac{\sum_i (x_i - \bar{x})^2}{n-1}}$$

To calculate the 95% confidence intervals for the data sets, we use

$$\mu = \bar{x} \pm \frac{t\,s}{\sqrt{n}}$$

Solve

(a) The mean and standard deviations are

$$\bar{x} = \frac{106 + 99 + 109 + 108 + 105}{5} = 105$$

$$s = \sqrt{\frac{(106-105)^2 + (99-105)^2 + (109-105)^2 + (108-105)^2 + (105-105)^2 +}{5-1}} = 3.94$$

(b) The 95% confidence interval is

$$\mu = 105 \pm \frac{2.776 \times 3.94}{\sqrt{5}} = 105 \pm 5$$

This range would be 100–110 mg/dL and would not include the 120 mg/dL data point.

Think About It

Statistical measures such as the mean, standard deviation, and confidence interval can help us make decisions in many areas—medicine, politics, and business, for example.

1.95. **Collect and Organize**

In this question we will use Grubbs' test to determine whether the value 3.41 should be considered an outlier in a data set.

Analyze

To determine whether a data point is an outlier, we use the formula

$$Z = \frac{|x_i - \bar{x}|}{s}$$

where x_i is the data point being tested, $\bar{x}$ is the mean of the data, and s is the standard deviation. If the value of Z is greater than 1.887 ($n = 6$ for this data set) then that data point is an outlier.

Solve

The mean and standard deviations for this data set are

$$\bar{x} = \frac{3.15+3.03+3.09+3.11+3.12+3.41}{6} = 3.15$$

$$s = \sqrt{\frac{(3.15-3.15)^2+(3.03-3.15)^2+(3.09-3.15)^2+(3.11-3.15)^2+(3.12-3.15)^2+(3.41-3.15)^2}{6-1}} = 0.1327$$

Applying Grubbs' test:

$$Z = \frac{|x_i - \bar{x}|}{s} = \frac{|3.41-3.15|}{0.1327} = 1.959$$

That value is greater than 1.887, so that data point is an outlier.

Think About It

This data point then can be discarded from the data set.

1.96. **Collect and Organize**

In this question we will use Grubbs' test to determine whether any of the values in the given data set are outliers.

Analyze

To determine whether data point is an outlier, we use the formula

$$Z = \frac{|x_i - \bar{x}|}{s}$$

where x_i is the data point being tested, $\bar{x}$ is the mean of the data, and s is the standard deviation. If the value of Z is greater than 1.887 (n = 6 for this data set) then that data point is an outlier.

Solve

The mean and standard deviations for this data set are

$$\bar{x} = \frac{61+75+64+65+64+66}{6} = 66$$

$$s = \sqrt{\frac{(61-66)^2+(75-66)^{22}+(64-66)^2+(65-66)^{22}+(64-66)^2+(66-66)^2}{6-1}} = 4.796$$

Applying Grubbs' test to each data point at 95% confidence

$$Z = \frac{|x_i - \bar{x}|}{s} = \frac{|61-66|}{4.796} = 1.0$$

$$Z = \frac{|x_i - \bar{x}|}{s} = \frac{|75-66|}{4.796} = 1.9$$

$$Z = \frac{|x_i - \bar{x}|}{s} = \frac{|64-66|}{4.796} = 0.42$$

$$Z = \frac{|x_i - \bar{x}|}{s} = \frac{|65-66|}{4.796} = 0.21$$

$$Z = \frac{|x_i - \bar{x}|}{s} = \frac{|66-66|}{4.796} = 0.0$$

The Grubbs test for the value of 75 is greater than 1.887, so that data point is an outlier for the commonly used 95% confidence level.

Think About It

This data point then can be discarded from the data set.

1.97. **Collect and Organize**

This question considers the runoff of nitrogen every year into a stream caused by a farmer's application of fertilizer. We must consider that not all the fertilizer contains nitrogen and not all the fertilizer runs off into the stream. We must also account for the flow of the stream in taking up the nitrogen runoff.

Analyze

First, we have to determine the amount of nitrogen in the fertilizer (10% of 1.50 metric tons, or 1500 kg since 1 metric ton = 1000 kg). Then we need to find how much of that nitrogen gets washed into the stream (15% of the mass of N in the fertilizer). Our final answer must be in milligrams of N, so we can convert the mass of N that gets washed into the stream from kilograms to milligrams.

$$\text{mass of fertilizer in kg} \times 0.10 = \text{mass of N in fertilizer in kg}$$

$$\text{mass of N in fertilizer in kg} \times 0.15 = \text{mass of N washed into the stream in kg}$$

$$\text{mass of N that washes into the stream in kg} \times \frac{1000\text{ g}}{1\text{ kg}} \times \frac{1000\text{ mg}}{1\text{ g}} = \text{mass of N that washes into the stream in mg}$$

Next, we need to know how much water flows through the farm each year via the stream. To find this, we must convert the rate of flow in cubic meters per minute to liters per year. We can convert this through one line by using dimensional analysis with the following conversions:

$$\frac{1000\text{ L}}{1\text{ m}^3},\quad \frac{1\text{ hr}}{60\text{ min}},\quad \frac{1\text{ d}}{24\text{ hr}},\quad \text{and}\quad \frac{1\text{ yr}}{365.25\text{ d}}$$

Solve

The amount of N washed into the stream each year is

$$1500\text{ kg} \times 0.10 = 150\text{ kg of N in the fertilizer}$$

$$150\text{ kg} \times 0.15 = 22.5\text{ kg of N washed into the stream in one year}$$

$$22.5\text{ kg} \times \frac{1000\text{ g}}{1\text{ kg}} \times \frac{1000\text{ mg}}{1\text{ g}} = 2.25 \times 10^7\text{ mg of N washed into the stream in one year}$$

The amount of stream water flowing through the field each year is

$$\frac{1.4\text{ m}^3}{1\text{ min}} \times \frac{1000\text{ L}}{1\text{ m}^3} \times \frac{60\text{ min}}{1\text{ hr}} \times \frac{24\text{ hr}}{1\text{ d}} \times \frac{365.25\text{ d}}{1\text{ yr}} = 7.36 \times 10^8\text{ L/yr}$$

The additional concentration of N added to the stream by the fertilizer is

$$\frac{2.25 \times 10^7\text{ mg of N/yr}}{7.36 \times 10^8\text{ L/yr}} = 0.031\text{ mg/L}$$

Think About It

The calculated amount of nitrogen added to the stream seems reasonable. The concentration is relatively low because the stream is moving fairly swiftly and the total amount of nitrogen that washes into the stream over the year is not too great. The problem, however, does not tell us whether this amount would harm the plant and animal life in the stream.

1.98. **Collect and Organize**

For this problem we try to identify which cylinder is made of aluminum and which is made of titanium by comparing experimentally determined densities with the known densities.

Analyze

(a) To calculate the volume of each cylinder from its dimensions, we will have to use the equation for volume of a cylinder:

$$\text{volume of cylinder} = \text{height of cylinder} \times \pi \times (\text{radius})^2$$

where radius = $0.5 \times$ diameter.

(b) To calculate the volume from the water displacement method, we need only find the difference in water volume for each cylinder from the diagram in Figure P1.98.

(c) To determine the method with the most significant figures, we will compare the answers in parts a and b.

(d) To compute the density for each cylinder, we use the equation for density:

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

Solve

(a) Volumes of the cylinders from their measured dimensions:

$$\text{volume of Cylinder A} = 5.1\text{ cm} \times \pi \times (0.60\text{ cm})^2 = 5.8\text{ cm}^3$$

$$\text{volume of Cylinder B} = 5.9\text{ cm} \times \pi \times (0.65\text{ cm})^2 = 7.8\text{ cm}^3$$

(b) Volumes of cylinders from water displacement measurements:

$$\text{volume of Cylinder A} = 30.8\text{ mL} - 25.0\text{ mL} = 5.8\text{ mL}$$

$$\text{volume of Cylinder B} = 32.8\text{ mL} - 25.0\text{ mL} = 7.8\text{ mL}$$

(c) Neither. As seen in the above calculations, both the volume measurement from the water displacement method and from the cylinders' dimension have two significant figures for the volume calculation.

(d) From part a:

$$\text{density of Cylinder A} = \frac{15.560\text{ g}}{5.8\text{ cm}^3} = 2.7\text{ g/cm}^3$$

$$\text{density of Cylinder B} = \frac{35.536\text{ g}}{7.8\text{ cm}^3} = 4.6\text{ g/cm}^3$$

From part b we obtain answers with two significant figures for the density:

$$\text{density of Cylinder A} = \frac{15.560\text{ g}}{5.8\text{ mL}} = 2.7\text{ g/mL}$$

$$\text{density of Cylinder B} = \frac{35.536\text{ g}}{7.8\text{ mL}} = 4.6\text{ g/mL}$$

Think About It

How we make measurements is important for the values we can report for those measurements. In this problem, neither method provided more significant figures for the calculation.

1.99. **Collect and Organize**

In this problem we need to express each mixture of chlorine and sodium as a ratio. The mixture closest to the ratio for chlorine to sodium will be the one with the desired product, leaving neither sodium nor chlorine left over.

Analyze

First, we must calculate the ratio of chlorine to sodium in sodium chloride. This is a simple ratio of the masses of those two substances:

$$\frac{\text{mass of chlorine}}{\text{mass of sodium}} = \text{ratio of the two components}$$

We can compare the ratios of the other mixtures by making the same calculations.

Solve

In sodium chloride, the mass ratio of chlorine to sodium is

$$\frac{1.54\text{ g of chlorine}}{1.00\text{ g of sodium}} = 1.54$$

Repeating this calculation for the four mixtures, we obtain the ratio of chlorine to sodium:

$$\frac{17.0\text{ g}}{11.0\text{ g}} = 1.55\text{ for mixture a} \qquad \frac{12.0\text{ g}}{6.5\text{ g}} = 1.8\text{ for mixture c}$$

$$\frac{10.0\text{ g}}{6.5\text{ g}} = 1.5\text{ for mixture b} \qquad \frac{8.0\text{ g}}{6.5\text{ g}} = 1.2\text{ for mixture d}$$

Both mixtures a and b react so that neither sodium nor chlorine is left over.

Think About It

Mixture c has leftover chlorine and mixture d has leftover sodium after the reaction is complete.

1.100. **Collect and Organize**

We are to compare the floating ability of the wood of the black ironwood tree in seawater (it sinks) versus freshwater.

Analyze

Seawater, because of its dissolved salts, is denser than freshwater. We know that the ironwood sinks in the seawater.

Solve

If the ironwood sinks in the denser seawater, it will also sink in the less dense freshwater.

Think About It

For an object to float on a liquid, it has to be less dense than the liquid.

1.101. **Collect and Organize**

This problem asks us to compute the percentages of the two ingredients in trail mix as manufactured on different days.

Analyze

Because we compare each day's percentage of peanuts in the trail mix bags with the ideal range of 65%–69%, we have to compute each day's percentage of peanuts from the data given. Each day has a total of 82 peanuts plus raisins, so the percentage of the mix in peanuts for each day is calculated from the equation

$$\% \text{ peanuts} = \frac{\text{number of peanuts in mix}}{82} \times 100$$

Solve

For each day, the percentage of peanuts is

$$\frac{50}{82} \times 100 = 61\% \text{ peanuts, Day 1} \qquad \frac{48}{82} \times 100 = 59\% \text{ peanuts, Day 21}$$

$$\frac{56}{82} \times 100 = 68\% \text{ peanuts, Day 11} \qquad \frac{52}{82} \times 100 = 63\% \text{ peanuts, Day 31}$$

The only day that met the specifications for the percentage of peanuts in the trail mix was Day 11.

Think About It

On Days 1, 21, and 31, too few peanuts were in the trail mix.

1.102. **Collect and Organize**

For this problem we have to calculate the volume that each liquid takes up from its known density values and then add those volumes. We then have to use that volume to determine the height of the liquid in the cylinder.

Analyze

To find the volume of each liquid from the given mass, we can use the density equation:

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

The volume of each liquid should then be added to find the total volume. Rearranging the equation describing the volume of a cylinder as shown, we can calculate the height of the two liquids in the cylinder:

$$\text{volume of a cylinder } (V) = \pi r^2 h$$

$$h = \frac{V}{\pi r^2}$$

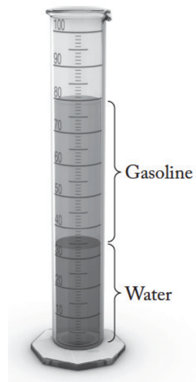
We have to be careful to watch for consistent units. Knowing that 1 cm^3 = 1 mL should help.

Solve

$$\text{volume of gasoline} = \frac{34.0\text{ g}}{0.73\text{ g/mL}} = 47\text{ mL}$$

$$\text{volume of water} = \frac{34.0\text{ g}}{1.00\text{ g/mL}} = 34.0\text{ mL}$$

$$\text{total volume} = 47 + 34.0 = 81\text{ mL}$$



Using the above equation with V = 81 mL or 81 cm^3 and the fact that the radius is half the diameter, we find that (3.2/2 = 1.6 cm) gives the height of the liquids in the cylinder.

$$h = \frac{81\text{ cm}^3}{\pi \times (1.6\text{ cm})^2} = 10\text{ cm}$$

Think About It
That is a reasonable value for the height of the liquids in the cylinder, considering that their combined volume is about 81 mL.

1.103. **Collect and Organize**
Given the correct dosage of phenobarbital per day and the details of the drug given to a patient over 3 days, we are to determine how many times over the prescribed dose was given to an overdose patient.

Analyze
We can use a common unit of milligrams of the drug to compare the prescribed amount with the overdose amount. To do so we will have to convert 0.5 grains into milligrams and multiply by the 3 days the drug was given. The actual amount given to the patient was four times 130 mg. We can then compare these two dosages in a ratio.

Solve
Amount of phenobarbital prescribed for 3 days in milligrams:

$$\frac{0.5\text{ grains}}{\text{day}} \times \frac{64.79891\text{ mg}}{\text{grain}} \times 3\text{ days} = 97.1984\text{ mg}$$

Actual amount given to patient in four doses over three days:

$$\frac{130\text{ mg}}{\text{dose}} \times 4\text{ doses} \times 3\text{ d} = 1560\text{ mg}$$

Ratio of actual dose to prescribed dose for 3 days:

$$\frac{1560\text{ mg}}{97.1984\text{ mg}} = 16\text{ times too much phenobarbital was given}$$

Think About It

An overdose of such a powerful sedative as phenobarbital can be fatal. Symptoms include shallow breathing, extreme sleepiness, and blurry vision.

1.104. **Collect and Organize**

Knowing that an adult breathes in 0.5 L of air 15 times per minute, we are to calculate the rate of volatilization that would result in a lung exposure of 0.3 μg of Hg/m^3 in the air. Second, knowing that a child breathes in 0.35 L of air 18 times per minute, we are to determine the rate of volatilization of mercury that would produce a level of 0.06 μg of Hg/m^3 in the air.

Analyze

To solve both problems, we first have to calculate the volume of air breathed in 1 min in cubic meters per minute. For that we need the conversion factor of 1 L = 1 × 10^{-3} m^3. We can then determine the rate of volatilization by multiplying this volume per minute by the exposure amount in micrograms of mercury per cubic meter.

Solve

(a) For the rate of volatilization for adult exposure:

$$\text{volume of air breathed in one minute} = \frac{0.5\ \text{L}}{\text{breath}} \times \frac{15\ \text{breaths}}{\text{min}} \times \frac{1\times10^{-3}\,\text{m}^3}{\text{L}} = 7.5\times10^{-3}\,\text{m}^3/\text{min}$$

$$\text{rate of volatilization} = \frac{7.5\times10^{-3}\,\text{m}^3}{\text{min}} \times \frac{0.3\ \mu\text{g}}{\text{m}^3} = 2\times10^{-3}\ \mu\text{g/min}$$

(b) For the rate of volatilization for child exposure:

$$\text{volume of air breathed in one minute} = \frac{0.35\ \text{L}}{\text{breath}} \times \frac{18\ \text{breaths}}{\text{min}} \times \frac{1\times10^{-3}\,\text{m}^3}{\text{L}} = 6.3\times10^{-3}\,\text{m}^3/\text{min}$$

$$\text{rate of volatilization} = \frac{6.3\times10^{-3}\,\text{m}^3}{\text{min}} \times \frac{0.06\ \mu\text{g}}{\text{m}^3} = 4\times10^{-4}\ \mu\text{g/min}$$

Think About It

Child exposure limits, especially for neurotoxins such as mercury, are set much lower than those for adults because the growing brain is disproportionately affected.

1.105. **Collect and Organize**

Given the temperatures for the freezing point and boiling point of water measured using three digital hospital thermometers, we are to determine which ones could detect a 0.1˚C increase in temperature and which would give an accurate reading of normal body temperature of 36.8˚C.

Analyze

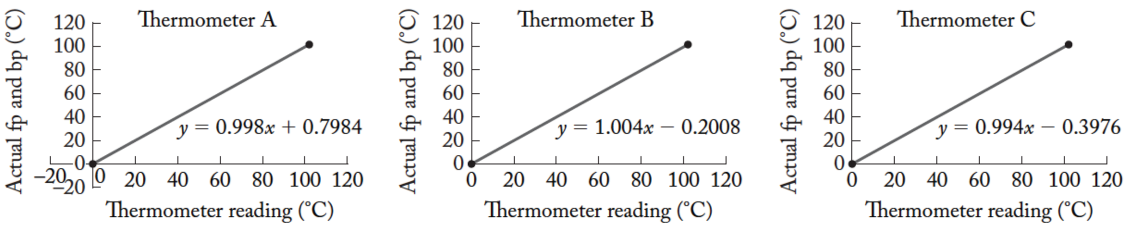
(a) To detect a 0.1˚C temperature rise, the scale on the thermometer would not have to be expanded over the range so that the 0.1˚C could be detected (the thermometers all read only to a tenth of a degree). However, if the temperature scale for the thermometer is contracted, it will detect the 0.1˚C temperature change because its intervals of 0.1˚C are smaller.

(b) To determine whether any of the thermometers can accurately measure a temperature of 36.8˚C, we need to consider the calibration curves (constructed by comparing the measured freezing and boiling points with the actual—that is, by plotting the correct temperatures vs. the measured temperatures). From the equation for the line, we can solve for the reading on the thermometer when the actual temperature is 36.8˚C.

Solve

(a) We can't tell from the data given. All reading for these thermometers end in an even number, which may mean that the minimum detectable change in temperature is 0.2˚C.

(b) The calibration curves for all three thermometers are shown below. In each graph, the slope is derived from the actual range of the freezing point and boiling point of water (100˚C–0˚C, Δy) and the range for the particular thermometer for these points (Δx).



The equation of the line gives the calibration equation for us to use in the calculation of the temperature each thermometer would read (x) for the actual temperature of 36.8˚C (y).

For thermometer A:

$$36.8^\circ\text{C} = 0.998x + 0.7984$$
$$x = 36.1^\circ\text{C}$$

For thermometer B:

$$36.8^\circ\text{C} = 1.004x - 0.2008$$
$$x = 36.9^\circ\text{C}$$

For thermometer C:

$$36.8^\circ\text{C} = 0.994x - 0.3976$$
$$x = 37.4^\circ\text{C}$$

None of these thermometers can accurately read the patient's temperature as 36.8˚C within ±0.1˚C.

Think About It

Thermometer B comes closest in measuring a temperature of 36.8˚C.

1.106. **Collect and Organize**

We are asked in this problem to convert 4.9 billion barrels of crude oil to liters and cubic kilometers.

Analyze

For this problem, we will need the following conversion factors:

$$\frac{1\times 10^{9}\text{ barrels}}{\text{billion}},\ \frac{42\text{ gal}}{\text{barrel oil}},\ \frac{1\times 10^{-3}\text{ m}^3}{\text{L}},\ \text{and}\ \frac{1\text{ km}}{1000\text{ m}}$$

Solve

The amount of crude oil in liters:

$$4.9\times 10^{9}\text{ barrels}\times\frac{42\text{ gal}}{\text{barrel}}\times\frac{3.7854\text{ L}}{\text{gal}} = 7.8\times 10^{11}\text{ L}$$

The amount of crude oil in cubic meters:

$$4.9\times 10^{9}\text{ barrels}\times\frac{42\text{ gal}}{\text{barrel}}\times\frac{3.7854\text{ L}}{\text{gal}}\times\frac{1\times 10^{-3}\text{ m}^3}{\text{L}}\times\left(\frac{1\text{ km}}{1000\text{ m}}\right)^3 = 0.78\text{ km}^3$$

Think About It

The oil gushed in this spill for 87 days—that is 9.0×10^{9} liters per day.

1.107. **Collect and Organize**

We are asked to convert the speed (the heliocentric velocity) of the *New Horizons* spacecraft from kilometers per second to miles per hour.

Analyze

To convert from kilometers to miles, we use the conversion 1 mile = 1.609 km; to convert from seconds to hours we use the conversions 60 s = 1 min and 60 min = 1 hour.

Solve

$$\frac{14.51\ \text{km}}{\text{s}} \times \frac{1\ \text{mi}}{1.609\ \text{km}} \times \frac{60\ \text{s}}{1\ \text{min}} \times \frac{60\ \text{min}}{1\ \text{hr}} = 3.246 \times 10^4\ \text{mi/hr}$$

Think About It

With the speed of light being 6.706×10^8 miles/hour this spacecraft is traveling at only 0.005% the speed of light.

1.108. **Collect and Organize**

Given the experimental data for three techniques to measure the sodium content of a candy bar, we are to determine which techniques were precise, which were accurate, and which were both.

Analyze

Precise measurements have a narrow numerical range and describe the agreement of repeated measurements. Accurate measurements give an average measurement that is close to the actual value.

Solve

Techniques 1 and 3 are both precise since their values do not vary by more than 1 mg. Because the true value is 115 mg, Technique 3 is obviously accurate as well as precise. (With small sample sizes as we have here, however, accuracy might be just "luck.") The average of the not-very-precise Technique 2 (115 mg), however, also agrees with the true value, so this technique also is accurate. Techniques 1 and 3 have a range of 2 mg for their measurements, whereas Technique 2 has a range of 10 mg.

Think About It

Remember that you can be accurate without being precise, and you can be precise without being accurate. In making lab measurements, you can calibrate instruments and learn the technique well (with lots of practice) to obtain data that are both accurate and precise.