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 image we are to identify the class of matter. We need to determine whether the substance(s) depicted is/are solid, liquid, or gas and whether the images show an element, a compound, or a mixture that is homogeneous or heterogeneous.

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. Homogeneous mixtures have a uniform distribution and composition, and heterogeneous mixtures contain regions of different composition.

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. This is a heterogeneous mixture.

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 image we are to identify the class of matter. We need to determine whether the substance(s) depicted is/are solid, liquid, or gas and whether the images show an element, a compound, or a mixture that is homogeneous or heterogeneous.

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. Homogeneous mixtures have a uniform distribution and composition, and heterogenous mixtures contain regions of different composition.

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. This is a homogeneous mixture.

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 diatomic 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. One pure diatomic element (red–red) condenses to a slightly disordered phase, whereas the other diatomic element (blue–blue) remains in the gas phase. Therefore, answer a describes the reaction pictured.

Think About It

Cooling of air to different temperatures in a controlled fashion separates the components of air.

1.5. **Collect and Organize**

From the diagram showing gaseous CO_2 at room temperature, we are to describe what the particulate image would be after cooling this gas to 180 K.

Analyze

Looking up the information on the internet for carbon dioxide, $CO_2(g)$, we find that it has a sublimation temperature of –78°C or 195 K. This temperature is higher than 180 K. Therefore, CO_2 at 180 K will be in the solid phase.

Solve

The particulate image of CO_2 at 180 K will show the linear CO_2 molecules condensed at the bottom of the box on the right with the molecules touching and forming a regular pattern.

Think About It

Solid CO_2 is also known as dry ice, and at normal pressure (1 atm) the only phase change we observe is sublimation, not melting or boiling.

1.6. **Collect and Organize**

From the diagram showing a mixture of gaseous diatomic substances, we are to describe what the particulate image would be after cooling this mixture from 298 K to 70 K.

Analyze

Using the atomic color palette on the inside back cover of the textbook, we can identify these three gases as hydrogen (white, H_2), nitrogen (blue, N_2), and oxygen (red, O_2). From Appendix 3.2 we obtain the melting point and boiling point for each of these gases: hydrogen (mp = –259.14°C, bp = –252.87°C), nitrogen (mp = –210.00°C, bp = –195.8°C), oxygen (mp = –218.8°C, bp = –182.95°C). We can then compare these to the temperature to which we are cooling the mixture, 70 K, which we can convert to kelvin through the following equation:

$$(T)°\text{C} = T(\text{K}) - 273.15$$
$$\text{or } (T)°\text{C} = 70 - 273.15 = -203°\text{C}$$

Solve

Because 70 K or –203°C is higher than both the melting point and the boiling point of hydrogen, it is in the gas phase; the white diatomic molecules in the particulate picture will remain far apart and will be scattered in the volume of the box. Because 70 K or –203°C is between the melting point and the boiling point of both nitrogen and oxygen, N_2 and O_2 will be in the liquid phase; the blue and red diatomic molecules in the particulate picture will be condensed at the bottom of the box, but will not be lined up in any regular pattern, signifying that they are in the liquid state.

Think About It

At a temperature of, for example, –215°C or 58 K, the three gases will be in three different phases; hydrogen in the gas phase, oxygen in the liquid phase, and nitrogen in the solid phase.

1.7. **Collect and Organize**

Using the atomic color palette on the inside back cover of the textbook, we can identify these atoms in these molecules. Chemical formulas describe the type and number of atoms in a molecule.

Analyze

The color palette identifies white atoms as hydrogen, red atoms as oxygen, black atoms as carbon, and green atoms as chlorine. To determine the chemical formula, we indicate the number of each type of atom as a subscript.

Solve

(a) CH_2O
(b) $C_2H_6O_2$
(c) CCl_4

Think About It

For carbon-containing compounds, it is standard form to list the atoms in the following order: C, H, N, O.

1.8. **Collect and Organize**

Using the atomic color palette on the inside back cover of the textbook, we can identify these atoms in these molecules. Chemical formulas describe the type and number of atoms in a molecule.

Analyze

The color palette identifies white atoms as hydrogen, red atoms as oxygen, and black atoms as carbon. To determine the chemical formula, we indicate the number of each type of atom as a subscript.

Solve

(a) C_3H_8O
(b) $C_4H_{10}O$
(c) C_4H_8O

Think About It
For these carbon-containing compounds, it is standard form to list the atoms in the following order: C, H, O.

1.9. **Collect and Organize**
Given that the pill manufactured by a pharmaceutical company is to weigh 3.25 mg, we are asked to compare the precision and accuracy of the data in the two graphs of masses of 4 pills.

Analyze
Precision in these pill samples means that the four pills have masses that do not vary much; accuracy in these pill samples means that the four pills, on average, have a mass that is close to the desired mass of 3.25 mg.

Solve
The graph for Sample A shows values that vary, but that are close to the desired value of 3.25 mg—this sample is *accurate but not precise*. The graph for Sample B shows values that do not vary much, none of which is close to the desired value of 3.25 mg—this sample is *precise but not accurate*.

Think About It
A sample that was *both precise and accurate* would show all four pills close in value to each other and all very close to the desired mass of 3.25 mg.

1.10. **Collect and Organize**
From the representations [A] through [I] in Figure P1.10, 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 compound, or shows an 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 or more substances that form a homogeneous solid; 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] saline (dissolved NaCl in water) and [A] brass (a solid solution of copper and zinc) are homogeneous mixtures that have uniform composition and properties.
(e) The pure substances in the list that are compounds 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 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 find the term *alloy* used for a solid solution of metal elements.

1.11. **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.

1.12. **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.

1.13. **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 that we encounter in chemistry, though, his theory is true.

1.14. **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 of the experimental evidence that had accumulated pointed 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 a nonstoichiometric compound such as $Fe_{0.95}O$, in which the proportions of the elements composing the material can vary and the elements are not in strict whole-number proportions.

1.15. **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, when analyzed 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?

1.16. **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.

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

Think About It

Other examples of this are: nitrogen reacting with oxygen to give various NO_x species like 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.

1.17. **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.

1.18. **Collect and Organize**

We are asked to give an example of a scientific theory that accurately predicted the results of an experiment before it was carried out.

Analyze

A theory is a concise and testable explanation of natural phenomena based on observation and experimentation. There are many examples in science where theory predicted the results of an experiment first.

Solve

Answers may vary, but you might give this as a chemistry example: Mendeleev's formulation of the periodic table predicted the existence of elements such as gallium and germanium and predicted their physical properties such as densities, melting points, and boiling points along with their chemical reactivities.

Think About It

More recent examples include the prediction of the existence of gravitational waves (LIGO Lab) and the prediction of the existence and properties of the Higgs boson.

1.19. **Collect and Organize**

We are asked to consider whether a scientific hypothesis can be disproven.

Analyze

A scientific hypothesis is a testable, yet tentative, explanation for an observation (or set of observations) in the natural world.

Solve

You can disprove a scientific hypothesis through an experiment that does not give the predicted outcome.

Think About It

An important feature of scientific inquiry that distinguishes it from other forms of inquiry is that the hypotheses are testable and that failure results in a reexamination of the hypotheses.

1.20. **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.

1.21. **Collect and Organize**

For the foods listed, we are to determine which are heterogeneous mixtures.

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 a homogeneous mixture of water and small amounts of dissolved minerals such as salts of sodium, magnesium, and calcium that give the water its flavor.

1.22. **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. If the coffee contains unfiltered sediment or the vinegar contains remnants of the mother of vinegar (a cellulose disc containing acetic acid bacteria added to an alcohol to change it into vinegar), then it would be considered a heterogeneous mixture.

1.23. **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
Distinct 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 (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.

1.24. **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.

Think About It
Nile River water (c) and a piece of wood (a) are heterogeneous because they have distinct regions that are discernible. Nile River water contains sediment and there is visible uneven distribution of heartwood and knots, for example, in a piece of wood.

1.25. **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. It is not a widely used process to purify water because boiling water is energy- and time-intensive. Filtration would be both cheaper and faster than distillation.

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.

1.26. **Collect and Organize**
Referring to Figure 1.8(b) in the textbook, we are to decide which compounds interact more strongly with the stationary phase on the basis of their relative positions as the liquid phase migrates up the solid phase in a 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 yellow-colored compounds at the bottom bind more tightly with the stationary phase than the green ones or the yellow ones at the top; they did not move as far up the stationary phase with the mobile phase.

Think About It
Figure 1.8(b) shows just one kind of chromatography method, namely, paper chromatography on paper. Other examples 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.

1.27. **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 or is resistant to reaction with another 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*.

1.28. **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.

1.29. **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 at normal temperatures and pressures) and by their densities, melting points, and boiling points.

Think About It
These three substances are also very different at the atomic level. Oxygen (O_2) is a pure element made up of diatomic molecules; water is a compound made up of discrete molecules composed of hydrogen and oxygen atoms (H_2O); and table sugar is a solid compound made up of carbon, hydrogen, and oxygen atoms.

1.30. **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 solid composed of sodium cations and chloride anions. Sand is a covalent network solid most commonly composed of silica, a compound of silicon and oxygen. Copper is a pure element and a metallic crystal.

1.31. **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. Because sodium is more dense than kerosene, with which it does not react chemically, Na can, with great care, be stored in the lab in a container under kerosene.

1.32. **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.

1.33. **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.

1.34. **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.

1.35. **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 more dense 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; those fires cannot be extinguished with a CO_2 fire extinguisher.

1.36. **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 contacting oxygen-containing air and then rusting.

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

Analyze
Figure A1.37 shows the arrangement of the water molecules in both those phases.

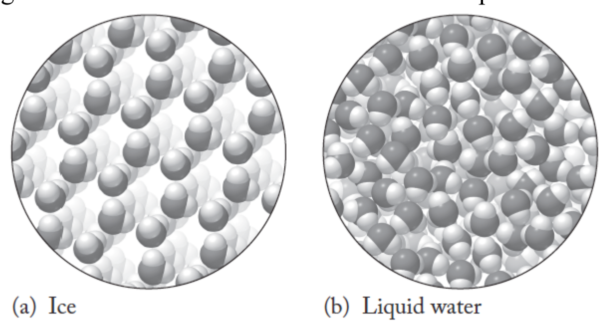


Figure A1.37

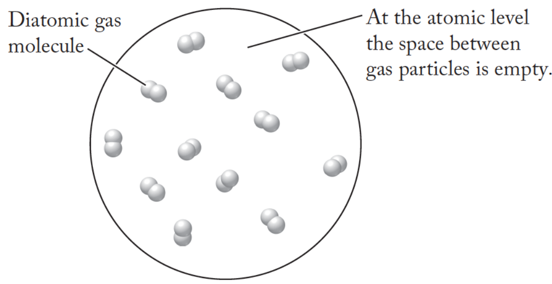
Solve
Water molecules in both the ice and liquid forms contain interactions that link individual molecules closely together. The arrangement of the molecules in liquid water have no long-range structure or ordering, whereas in ice the molecules are arranged in a rigid hexagonal arrangement with voids within the structure.

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

1.38. **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.

1.39. **Collect and Organize**
We are to determine which phase (solid, liquid, or gas–all of which are present at the *triple point*) 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 (more degrees of freedom). 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.

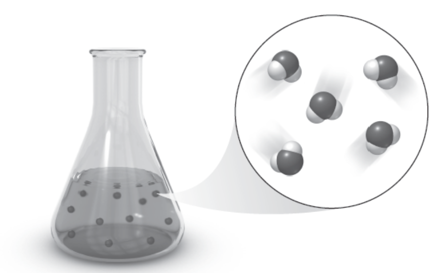
Solve
Because of their freedom of movement, gases have the greatest particle motion; because of the restriction of their solid lattice, solids have the least particle motion.

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.

1.40. **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, at water's boiling point, the bubbles do not contain hydrogen and oxygen gas from the decomposition of water. Water vapor, also known as steam, is invisible; the "steam" seen around hot drinks on cold days results from droplets of liquid water that condensed as the vapor cooled.

1.41. **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: It goes directly from the solid ice crystals in snow to water vapor in air.

Think About It
A more familiar example of sublimation is that of dry ice, which is solid CO_2. At ambient temperature and pressure dry ice sublimes, rather than melts, to give a "fog" for stage shows. The cold gaseous CO_2 condenses moisture from humid air to produce the fog.

1.42. **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 A1.42 shows these processes and their relative energy transformations. Up arrows show absorption of energy, and down arrows show release of energy for the processes.

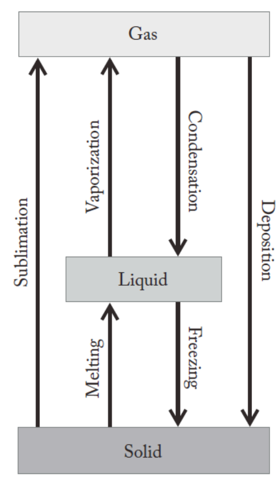


Figure A1.42

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.

1.43. **Collect and Organize**
We are asked how 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.

1.44. **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:

$$\mathrm{PE} = mgh$$

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

Gravitational potential energy is stored energy, which depends on an object's position (or relative height, *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, its potential energy is converted to kinetic energy.

1.45. **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 areas with high thermal energy to those with low thermal energy. Heat is an extrinsic property; the amount of heat in a substance depends on the quantity of substance, and it is measured by taking the temperature.

Solve
All of the 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.

1.46. **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 (such as that 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."

1.47. **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

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

Solve

For the subcompact car:

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

For the dump truck:

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

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

$$\frac{\mathrm{KE}_2}{\mathrm{KE}_1} = \frac{\frac{1}{2}(18{,}000\ \mathrm{kg})u_2^{\,2}}{\frac{1}{2}(1400\ \mathrm{kg})u_2^{\,2}} = \frac{18{,}000\ \mathrm{kg}}{1400\ \mathrm{kg}} = 13$$

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 much more kinetic energy when traveling faster because kinetic energy depends on the *square* of the velocity of an object, as well as its mass.

1.48. **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

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

Kinetic energy is usually expressed in joules ($1\ \mathrm{J} = 1\ \mathrm{kg} \cdot \mathrm{m/s^2}$), and so by strict standards we should convert the speed, given in kilometers or 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 92 mph fastball:

$$\mathrm{KE} = \frac{1}{2}m_1(148\ \mathrm{km/h})^2$$

For the 78 mph changeup:

$$\mathrm{KE} = \frac{1}{2}m_2(125\ \mathrm{km/h})^2$$

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

$$\frac{\mathrm{KE}_1}{\mathrm{KE}_2} = \frac{\frac{1}{2}m_1(148\ \mathrm{km/h})^2}{\frac{1}{2}m_2(125\ \mathrm{km/h})^2} = \frac{(148\ \mathrm{km/h})^2}{(125\ \mathrm{km/h})^2} \times 100 = 140\%$$

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 slightly more kinetic energy because of its larger mass.

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

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

Solve
SI units, which are based on the original metric system, can be easily converted into a larger or smaller unit by multiplying or dividing by multiples of 10. Customary U.S. 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.

1.50. **Collect, Organize, and Analyze**
In this question we are to suggest two reasons why SI units are widely used in science.

Solve
SI units are used widely in science because the SI system combines prefixes with units of measure and allows clear and concise descriptions of natural phenomena over a wide range of scales, from subatomic to supergalactic. Also, the SI system is universal, in that it is the system understood and used in nearly all countries.

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.

1.51. **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 points 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 A1.51 that a 10°C range is much larger than a 10°F range. A room temperature of 68°F is equivalent to 20°C.

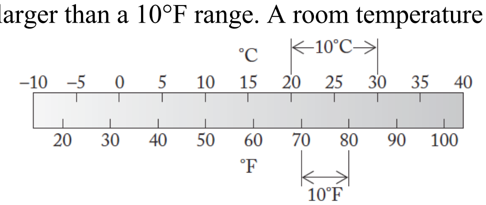


Figure A1.51

1.52. **Collect and Organize**

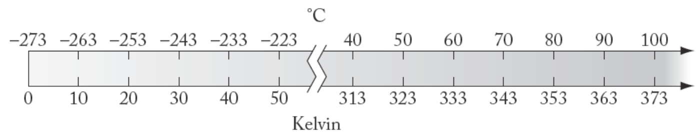
For this question we are to compare and contrast the Celsius and Kelvin scales.

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 a degree Celsius.



Think About It

Neither the Celsius nor the Fahrenheit scale sets a lower limit on temperature, but the Kelvin scale does: absolute zero, or 0 K.

1.53. **Collect and Organize**

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

Analyze

The Kelvin scale is the absolute temperature scale, and it is based on the idea that temperature has a lower limit.

Solve

The Kelvin scale is an absolute temperature scale: It has no negative temperatures, and it places its zero value at the lowest possible temperature, namely, absolute zero, or 0 K.

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.

1.54. **Collect and Organize**

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

Analyze

The equation converting between the temperatures is given as

$$T(°\text{C}) = (5/9)[T(°\text{F}) - 32]$$

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

$$T(°\text{C}) = (5/9)\,[T(°\text{C}) - 32]$$

Solve

Rearranging this equation and solving for °C,

$$T(°\text{C}) = (5/9)\,[T(°\text{C}) - 32]$$
$$(9/5)\,T(°\text{C}) = [T(°\text{C}) - 32]$$
$$[(9/5)\,T(°\text{C})] - T(°\text{C}) = -32$$
$$(4/5)\,T(°\text{C}) = -32$$
$$T(°\text{C}) = -40°\text{C} = -40°\text{F}$$

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

1.55. **Collect and Organize**
For each of the unit conversions we are asked to write the conversion factor.

Analyze
All of the conversions are based in the metric system and so will be expressed in factors of 10, using prefixes.

Solve
(a) To convert liters to milliliters, we use 1000 mL / 1 L.
(b) To convert kilometers to meters, we use 1000 m / 1 km.
(c) To convert centigrams to kilograms, we use 1 kg / 1 × 10^5 cg.
(d) To convert cubic meters to cubic centimeters, we use $(100\text{ cm})^3 / (1\text{ m})^3$ or $1 \times 10^6\text{ cm}^3 / \text{m}^3$.

Think About It
Conversions in the metric system are easy, but you have to be careful to "move the decimal place" in the correct direction; to do this, think about which unit is larger and which is smaller.

1.56. **Collect and Organize**
For each of the unit conversions we are asked to write the conversion factor.

Analyze
All of the conversions involve factors of 10.

Solve
(a) To convert picoseconds to seconds, we use 1 s / 1 × 10^{12} ps.
(b) To convert meters to centimeters, we use 100 cm / 1 m.
(c) To convert nanoseconds to milliseconds, we use 1 ms / 1 × 10^6 ns.
(d) To convert square meters to square kilometers, we use $(1\text{ km})^2 / (1000\text{ m})^2$ or $1\text{ km}^2 / 1 \times 10^6\text{ m}^2$.

Think About It
A Googol is 10^{100} or 1 followed by 100 zeros.

1.57. **Collect and Organize**
For a single strand of silk that is 4.0 × 10^3 m long, we are to assign the number of significant figures in that value and convert it to kilometers, centimeters, inches, and feet.

Analyze
Significant figures for a value expressed in scientific notation are those before and after the decimal point in the number before 10^x. To convert meters to kilometers, we use 1 km / 1000 m; to convert meters to centimeters, we use 100 cm / 1 m; to convert meters to inches, we use 100 cm / 1 m and 1 in / 2.54 cm; to convert meters to feet, we use 100 cm / 1 m with 1 in / 2.54 cm and 1 ft / 12 in.

Solve
(a) There are two significant figures in 4.0 × 10^3 m.
(b)

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

$$4.0\times10^3\text{ m}\times\frac{100\text{ cm}}{\text{m}}=4.0\times10^5\text{ cm}$$

$$4.0\times10^3\text{ m}\times\frac{100\text{ cm}}{\text{m}}\times\frac{1\text{ in}}{2.54\text{ cm}}=1.6\times10^5\text{ in}$$

$$4.0\times10^3\ \text{m}\times\frac{100\ \text{cm}}{\text{m}}\times\frac{1\ \text{in}}{2.54\ \text{cm}}\times\frac{1\ \text{ft}}{12\ \text{in}}=1.3\times10^4\ \text{ft}$$

Think About It

The conversion from meters to miles would give a little over 2 mi when estimated. For a natural piece of silk to be that long is surprising.

1.58. **Collect and Organize**

For the Olympic "mile" measuring 1500.0 meters, we are to assign the number of significant figures in that value and convert it to kilometers, centimeters, inches, and feet.

Analyze

Zeros at the end of a value containing no decimal point may or may not be significant figures, but zeros after a decimal point are considered significant. To convert meters to kilometers, we use 1 km / 1000 m; to convert meters to centimeters, we use 100 cm / 1 m; to convert meters to inches, we use 100 cm / 1 m and 1 in / 2.54 cm; to convert meters to feet, we use 100 cm / 1 m with 1 in / 2.54 cm and 1 ft / 12 in.

Solve

(a) The distance measurement 1500.0 m has five significant figures.

(b)

$$1500.0\ \text{m}\times\frac{1\ \text{km}}{1000\ \text{m}}=1.5000\ \text{km}$$

$$1500.0\ \text{m}\times\frac{100\ \text{cm}}{\text{m}}=1.5000\times10^5\ \text{cm}$$

$$1500.0\ \text{m}\times\frac{100\ \text{cm}}{\text{m}}\times\frac{1\ \text{in}}{2.54\ \text{cm}}=5.9055\times10^4\ \text{in}$$

$$1500.0\ \text{m}\times\frac{100\ \text{cm}}{\text{m}}\times\frac{1\ \text{in}}{2.54\ \text{cm}}\times\frac{1\ \text{ft}}{12\ \text{in}}=4.9213\times10^3\ \text{ft}$$

Think About It

The Olympic mile is 1500.0 m, about 93% the length of a regular mile (1 mi = 1609.3 m).

1.59. **Collect and Organize**

For Secretariat's time (1 minute 59.4 seconds) and distance (2.01 kilometers, 1.25 miles), we are asked to determine the number of significant figures. Then we will calculate the horse's speed in meters per second and in miles per hour.

Analyze

The number of significant figures for the time will be the result of the addition of one minute (60 seconds, exact) with 59.4 seconds. The ratio of distance around the racetrack (in miles or meters) and the time in seconds will give Secretariat's speed in the race. To get speeds in m/s and mi/h, we will need the following conversions: 1000 m / 1 km, 1 min / 60 s, 1 h / 60 min.

Solve

(a) One minute is exactly 60 seconds. Adding this to 59.4 seconds gives a total time of 119.4 s. The rule for adding numbers states that the resulting number has the same number of significant figures to the right of the decimal as that of the measured number with the fewest digits to the right of the decimal. This gives us 4 significant figures for this value.

(b) Each of the distance values (2.01 km and 1.25 miles) has three significant figures.

(c) Secretariat's average speed in meters per second is

$$\text{average speed} = \frac{2.01\ \text{km}\times\dfrac{1000\ \text{m}}{1\ \text{km}}}{119.4\ \text{s}}=16.8\ \text{m/s}$$

Secretariat's average speed in miles per hour is

$$\text{average speed} = \frac{1.25 \text{ miles}}{119.4 \text{ s} \times \dfrac{1 \text{ min}}{60 \text{ s}} \times \dfrac{1 \text{ h}}{60 \text{ min}}} = 37.7 \text{ miles/h}$$

Think About It

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

1.60. **Collect and Organize**

From the values given for speed and energy, we are asked first to determine the number of significant figures for each value. To determine the Calories required by a wheelchair marathoner in a race, we are given that the marathoner moves at 8.28 m/s for the 42.195 km distance, expending 665 Calories per hour.

Analyze

To calculate the Calories required we will multiply the Calories per hour by the total time it takes for the marathoner to complete the race. The time for the marathoner to complete the race will be determined by

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

Solve

(a) Both the speed and the energy values have three significant figures.

(b) $$\text{time to complete marathon} = \frac{42.195 \text{ km}}{\dfrac{8.28 \text{ m}}{1 \text{ s}} \times \dfrac{1 \text{ km}}{1000 \text{ m}} \times \dfrac{60 \text{ s}}{1 \text{ min}} \times \dfrac{60 \text{ min}}{1 \text{ h}}} = 1.41556 \text{ h or } 1.42 \text{ h (three significant figures)}$$

$$\text{Calories required} = 1.41556 \text{ h} \times \frac{665 \text{ Calories}}{\text{h}} = 941 \text{ Calories}$$

Think About It

Notice that answer has three significant figures as well.

1.61. **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 pumped out, 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 factor

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

The time to remove 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

$$50.0 \text{ m} \times 25.0 \text{ m} \times \left(25 \text{ cm} \times \frac{1 \text{ m}}{100 \text{ cm}}\right) = 312.5 \text{ m}^3$$

Converting this into liters,

$$312.5 \text{ m}^3 \times \frac{1 \text{ L}}{1 \times 10^{-3} \text{ m}^3} = 3.125 \times 10^5 \text{ L}$$

The amount of time to siphon this water is

$$\frac{3.125\times10^5\ \text{L}}{5.2\ \text{L/s}}\times\frac{1\ \text{min}}{60\ \text{s}}\times\frac{1\ \text{h}}{60\ \text{min}}=17\ \text{h}$$

Think About It

This may be a surprisingly long time to pump only 25 cm of water from the pool, but the total volume to be removed is quite large because of the pool's size.

1.62. **Collect and Organize**

To compare the prices of the soft drinks in U.S. and Canadian dollars, we will have to convert to a common unit of volume, either ounces or liters.

Analyze

Along with the conversions of CAD to USD and of quarts to fluid ounces, we will need the conversion of 1 qt = 0.9464 L. From these we can convert the price of the soft drink in USD to CAD per liter and then compare the prices.

Solve

$$\text{price in CAD per liter (Canada)} = \frac{2.17\ \text{CAD}}{2.0\ \text{L}}=1.1\ \text{CAD/L}$$

$$\text{price in CAD per liter (United States)} = \frac{1.00\ \text{USD}}{24\ \text{oz}}\times\frac{\text{CAD}}{0.7947\ \text{USD}}\frac{32\ \text{oz}}{\text{qt}}\times\frac{\text{qt}}{0.9464\ \text{L}}=1.8\ \text{CAD/L}$$

Comparing the two prices in common units, we find that the Canadian soft drink is a better buy than the U.S. beverage.

Think About It

We can also solve this problem by converting to USD/L:

$$\text{price in USD per liter (Canada)} = \frac{2.17\ \text{CAD}}{2.0\ \text{L}}\times\frac{0.7947\ \text{USD}}{1.00\ \text{CAD}}=0.86\ \text{USD/L}$$

$$\text{price in CAD per liter (United States)} = \frac{1.00\ \text{USD}}{24\ \text{oz}}\times\frac{32\ \text{oz}}{1\ \text{qt}}\times\frac{1\ \text{qt}}{0.9464\ \text{L}}=1.4\ \text{USD/L}$$

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**

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 densities of copper and 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/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.

1.66. **Collect and Organize**

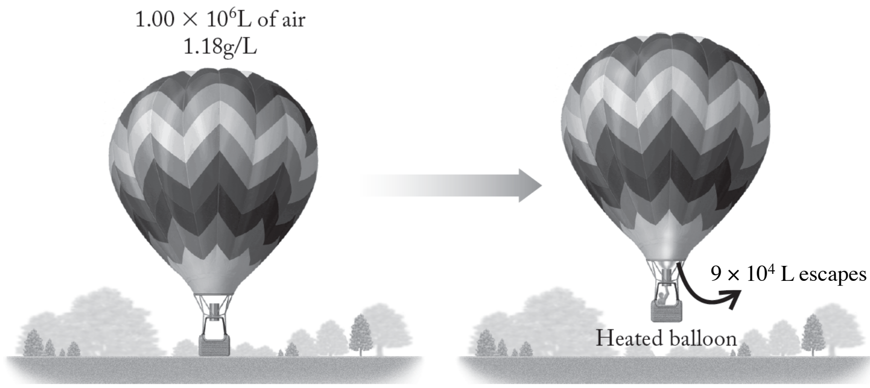
Given the volume and density of the air inside a hot-air balloon at a cooler temperature and the volume of air that escapes the balloon upon heating, we are to calculate the density of the air left in the balloon.

Analyze

For a hot air balloon, the volume of the air inside does not change when the air inside it is heated. 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 balloon's volume.

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 this is what causes a hot-air balloon's "lift."

1.67. **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 given (5.5 g/cm^3).

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.

1.68. **Collect and Organize**

In this problem, we have to calculate the volume of Earth from its given mass (6.0×10^{27} g) and density (5.5 g/cm^3). Then we must convert this volume into cubic kilometers. We then consider how the "natural" density due to gravitational squeezing would compare to the given value.

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) $\dfrac{6.0 \times 10^{27}\ \text{g}}{5.5\ \text{g/cm}^3} \times \left(\dfrac{1\ \text{m}}{100\ \text{cm}}\right)^3 \times \left(\dfrac{1\ \text{km}}{1000\ \text{m}}\right)^3 = 1.1 \times 10^{12}\ \text{km}^3$

(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.

1.69. **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 (seawater 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:

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

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

$$\text{volume of the HDPE cube} = \left(1.20 \times 10^{-2}\ \text{m}\right)^3 \times \left(\frac{100\ \text{cm}}{1\ \text{m}}\right)^3 = 1.728\ \text{cm}^3$$

$$\text{mass of the HDPE cube in grams} = 1.70 \times 10^{-3}\ \text{kg} \times \frac{1000\ \text{g}}{1\ \text{kg}} = 1.70\ \text{g}$$

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

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.

1.70. **Collect and Organize**

In this problem we are asked to calculate the sun's density in grams per cubic centimeter given its estimated mass of 2×10^{30} kg and radius of 7.0×10^5 km. The mass will have to be converted to grams, and the radius will have to be changed to meters and then centimeters (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

So that you can check your calculation, note that the answer given above is reported to two, not one significant figure(s). 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.

1.71. **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 545.67 carats to grams. Then we can use the fact that 1 pound = 453.59 g and 1 lb = 16 ounces to convert the result in grams to ounces.

Solve

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

$$\text{mass of the diamond in ounces} = 545.67\ \text{carats}\times\frac{0.200\ \text{g}}{1\ \text{carat}}\times\frac{1\ \text{lb}}{453.59\ \text{g}}\times\frac{16\ \text{ounces}}{1\ \text{lb}} = 3.85\ \text{ounces}$$

Think About It

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

$$1\ \text{carat}\times\frac{0.200\ \text{g}}{1\ \text{carat}}\times\frac{1\ \text{lb}}{453.59\ \text{g}}\times\frac{16\ \text{ounces}}{1\ \text{lb}} = 7.05\times10^{-3}\ \text{ounces}$$

1.72. **Collect and Organize**

Given that the density of diamond is 3.51 g/cm^3, we are to calculate the volume of the Golden Jubilee diamond, which has a mass of 545.67 carats, or 109 g as determined in the previous problem.

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 and is about the volume of a regular-sized marshmallow.

1.73. **Collect and Organize**

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

Analyze

Section 1.7 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 3.72604×10^{-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.

1.74. **Collect and Organize**

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

Analyze

Section 1.7 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 388.769 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 cm/in)^3 is reported as 6.37×10^3 cm^3.

(d) The sum of the values gives a value with three significant figures. When divided by the exact number 5, the least well-known value has three 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 8.68.

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.

1.75. **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

$$T(\text{K}) = T(°\text{C}) + 273.15$$

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

$$T(°\text{C}) = (5/9)\,[T(°\text{F}) - 32]$$

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

$$T(°\text{F}) = (9/5)\,[T(°\text{C})] + 32$$

Solve

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

$$T(\text{K}) = 12.3°\text{C} + 273.15 = 285.4\text{K}$$

$$T(°\text{F}) = (9/5) \times (12.3°\text{C}) + 32 = 54.1°\text{F}$$

Think About It

Notice that the answer is reported to four significant figures for the temperature in Kelvin because of the addition and multiplication rule. The answer is reported to three significant figures for the temperature in Fahrenheit, rather than two, because the 32 in the conversion equation is considered an exact number.

1.76. **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

$$T(\text{K}) = T(°\text{C}) + 273.15$$

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

$$T(°\text{C}) = (5/9)\,[T(°\text{F}) - 32]$$

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

$$T(°\text{F}) = (9/5)\,[T(°\text{C})] + 32$$

Solve

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

$$T(\text{K}) = -78°\text{C} + 273.15 = 195\text{K}$$

$$T(°\text{F}) = (9/5) \times (-78°\text{C}) + 32 = -110°\text{F}$$

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—about half the size of—the Celsius degree.

1.77. **Collect and Organize**

This question asks us to convert the coldest temperature recorded on Earth from degrees Fahrenheit to °C 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

$$T(°C) = (5/9)\,[T(°F) – 32]$$
$$T(K) = T(°C) + 273.15$$

Solve

$$T(°C) = (5/9)\,(–128.6°F) – 32 = –89.2°C$$
$$T(K) = –89.2°C + 273.15 = 183.9K$$

Think About It

This temperature is cold on any scale!

1.78. **Collect and Organize**

This question asks us to convert the hottest temperature recorded on Earth from degrees Fahrenheit to °C 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

$$T(°C) = (5/9)\,[T(°F) – 32]$$
$$T(K) = T(°C) + 273.15$$

Solve

$$T(°C) = (5/9)\,(134°F) – 32 = 56.7°C$$
$$T(K) = 56.7°C + 273.15 = 329.8K$$

Think About It

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

1.79. **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

$$T(°C) = (5/9)\,[T(°F) – 32]$$
$$T(K) = T(°C) + 273.15$$

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

$$T(K) = –250°C + 273.15 = 23.2K$$

The T_c of $HgBa_2CaCu_2O_6$ is expressed in °F. To get this temperature in kelvin, first convert to °C:

$$T(°C) = (5/9)\,(–231.1°F) – 32 = –146.2°C$$
$$T(K) = –146.2°C + 273.15 = 127.0\ K$$

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 $HgBa_2CaCu_2O_6$.

1.80. **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:

$$T(\text{K}) = -183°\text{C} + 273.15 = 90\ \text{K}$$

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 –185.8°C, or 87.3 K, so upon cooling of air, argon will condense after oxygen and before nitrogen.

1.81. **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.

1.82. **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%.

1.83. **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 μ 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 a 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 opposite conclusion would be reached when $n < 7$.

1.84. **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.

1.85. **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

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

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

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

Solve

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

Manufacturer 1

$$\bar{x} = \frac{0.512 + 0.508 + 0.516 + 0.504 + 0.513}{5} = 0.511$$

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

Manufacturer 2

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

$$s = \sqrt{\frac{(0.542 - 0.513)^2 + (0.513 - 0.513)^2 + (0.514 - 0.513)^2 + (0.514 - 0.513)^2 + (0.512 - 0.513)^2}{5 - 1}} = 0.0009$$

Manufacturer 3

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

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

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

Manufacturer 1

$$\mu = 0.511 \pm \frac{2.776 \times 0.0047}{\sqrt{5}} = 0.511 \pm 0.0058$$

This range would be 0.5052–0.5168 μm; the 0.504 μm data point would be an outlier.

Manufacturer 2

$$\mu = 0.513 \pm \frac{2.776 \times 0.0009}{\sqrt{5}} = 0.513 \pm 0.0011$$

This range would be 0.5119–0.5141 μm and would include all the data points in the set.

Manufacturer 3

$$\mu = 0.501 \pm \frac{2.776 \times 0.0008}{\sqrt{5}} = 0.501 \pm 0.0010$$

This range would be 0.5000–0.5020 μm and would include all the data points in the set.

(c) A data set that is both precise (small spread of values) and accurate (mean close to the target value of 0.500 μm) is that of Manufacturer 3. A set that is precise (small spread of values) but not accurate (mean far from the target of 0.500 μm) is the one from Manufacturer 2.

Think About It

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

1.86. **Collect and Organize**

For a given set of glucose measurements for a patient at risk of diabetes, we are to calculate the mean and standard deviation as well as determine whether a glucose level above 120 mg/dL is within 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

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

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 so 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.

1.87. **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 at the 95% confidence level.

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.

1.88. **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 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

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

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

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

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

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

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

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

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

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.

1.89. **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 the fertilizer and of the N in it). 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 does not, however, tell us whether this amount would harm the plant and animal life in the stream.

1.90. **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 P1.90.

(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' dimensions 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 the densities in g/mL:

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

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

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. We can determine that Cylinder A is made from the less dense metal, aluminum, and Cylinder B is titanium. The calculated values are close to but not exactly equal to the given densities (d_{Al} = 2.699g/mL and d_{Ti} = 4.54 g/mL).

1.91. **Collect and Organize**

In this problem we need to express each mixture of chlorine and sodium as a ratio. The mixture closest to a 1:1 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.

1.92. **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.

1.93. **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.

1.94. **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 a 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:

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

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

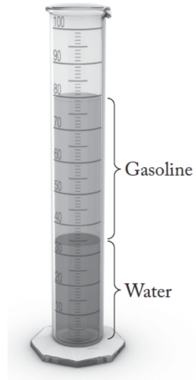
We have to be careful to watch for consistent units. Knowing that 1 cm^3 = 1 mL should help.

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. Note too that gasoline, being less dense, floats on the water in the graduated cylinder.

1.95. **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 the level of overdose, or how many times over the prescribed dose was given.

Analyze
We can use a common unit of milligrams of the drug to compare the prescribed amount with the actual 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.

1.96. **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:

$$\text{volume of air breathed in one minute} = \frac{0.5\text{ L}}{\text{breath}} \times \frac{15\text{ breaths}}{\text{min}} \times \frac{1 \times 10^{-3}\text{ m}^3}{\text{L}} = 7.5 \times 10^{-3}\text{ m}^3/\text{min}$$

$$\text{rate of volatilization} = \frac{7.5 \times 10^{-3}\text{ m}^3}{\text{min}} \times \frac{0.3\ \mu\text{g}}{\text{m}^3} = 2 \times 10^{-3}\ \mu\text{g/min}$$

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

$$\text{volume of air breathed in one minute} = \frac{0.35\text{ L}}{\text{breath}} \times \frac{18\text{ breaths}}{\text{min}} \times \frac{1 \times 10^{-3}\text{ m}^3}{\text{L}} = 6.3 \times 10^{-3}\text{ m}^3/\text{min}$$

$$\text{rate of volatilization} = \frac{6.3 \times 10^{-3}\text{ m}^3}{\text{min}} \times \frac{0.06\ \mu\text{g}}{\text{m}^3} = 4 \times 10^{-4}\ \mu\text{g/min}$$

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.

1.97. **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, if any, 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

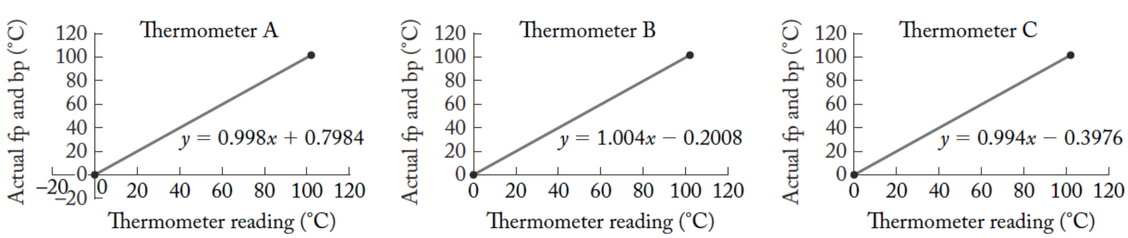
(a) To detect a 0.1˚C temperature rise, the scale on the thermometer would not have to be expanded over the range so that the 0.1˚C could be detected (the thermometers all read only to a tenth of a degree). However, if the temperature scale for the thermometer is contracted, it will detect the 0.1˚C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

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

Thermometer B is the only one of these thermometers that can accurately read a person's temperature as 36.8˚C within ±0.1˚C.

Think About It

Thermometer B would return 36.8°C if output were restricted to a 0.2°C minimum detectable change.

1.98. **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:

$$\frac{1\times10^{9}\ \text{barrels}}{1\ \text{billion}},\ \frac{42\ \text{gal}}{1\ \text{barrel}},\ \frac{1\times10^{-3}\ \text{m}^3}{1\ \text{L}},\ \frac{1\ \text{gal}}{3.7854\ \text{L}},\ \frac{1\ \text{km}}{1000\ \text{m}}$$

Solve

The amount of crude oil in liters:

$$4.9\times10^{9}\ \text{barrels}\times\frac{42\ \text{gal}}{\text{barrel}}\times\frac{3.7854\ \text{L}}{\text{gal}} = 7.8\times10^{11}\ \text{L}$$

The amount of crude oil in cubic meters:

$$4.9\times10^{9}\ \text{barrels}\times\frac{42\ \text{gal}}{\text{barrel}}\times\frac{3.7854\ \text{L}}{\text{gal}}\times\frac{1\times10^{-3}\ \text{m}^3}{\text{L}}\times\left(\frac{1\ \text{km}}{1000\ \text{m}}\right)^3 = 0.78\ \text{km}^3$$

Think About It

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

1.99. **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 = 1.6093 km; to convert from seconds to hours we use the conversions 60 s = 1 min and 60 min = 1 hour.

Solve

$$\frac{14.51\ \text{km}}{\text{s}}\times\frac{1\ \text{mi}}{1.609\ \text{km}}\times\frac{60\ \text{s}}{1\ \text{min}}\times\frac{60\ \text{min}}{1\ \text{h}} = 3.246\times10^{4}\ \text{mi/h}$$

Think About It

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

1.100. **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. We are also to find the range of values for each technique.

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 from the mean by more than 1 mg. Because the true value is 115 mg, Technique 3 is 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.