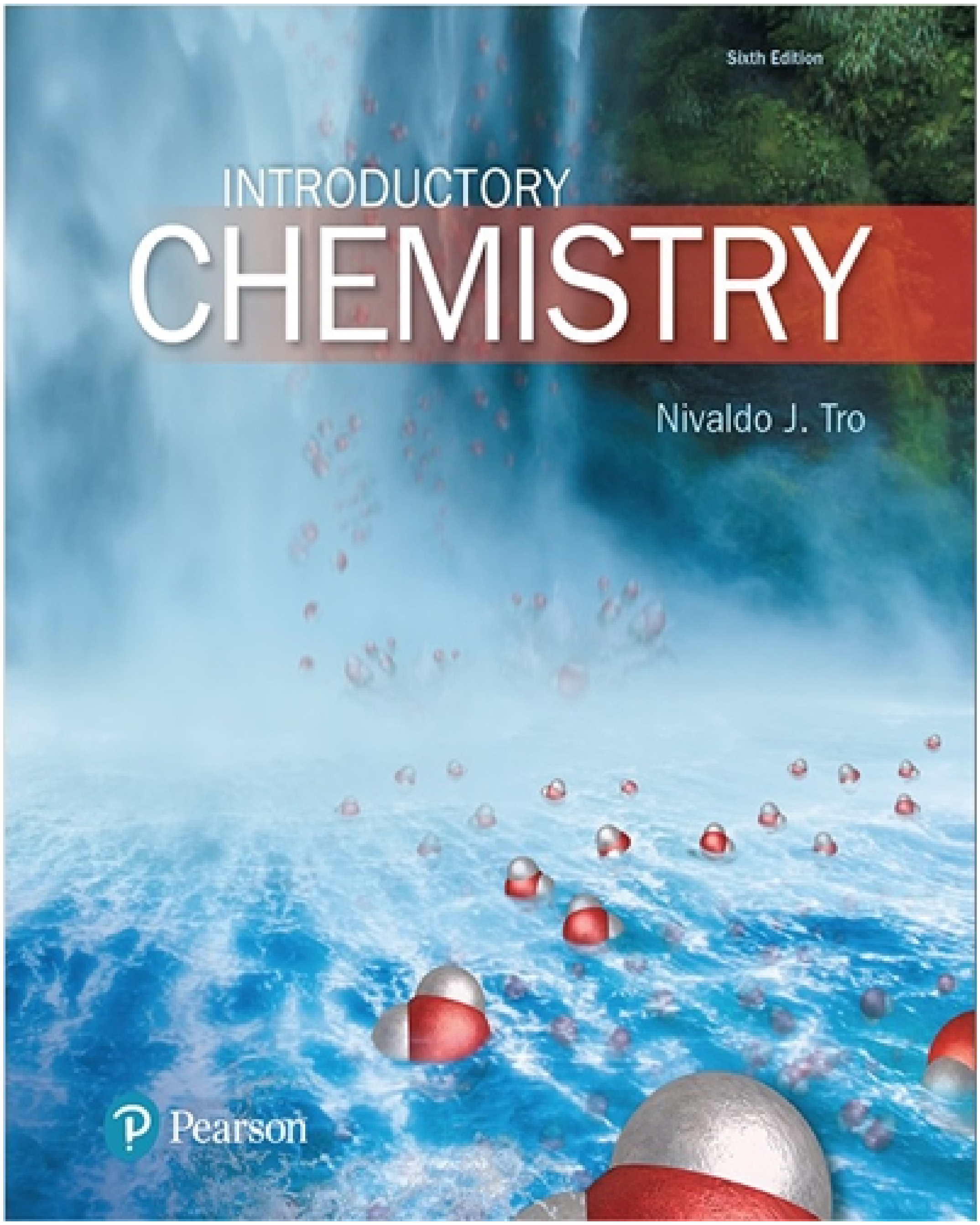
Test Bank for Introductory Chemistry 6th Edition by Tro



Test Bank

Introductory Chemistry, 6e (Tro)
Chapter 2 Measurement and Problem Solving

2.1 True/False Questions

1) Numbers are usually written so that the uncertainty is in the last reported digit.
Answer: TRUE
Diff: 1 Var: 1 Page Ref: 2.1
Learning Outcome: 2.2
Global Outcome: G1

2) The decimal number 0.0000010 expressed in scientific notation is 1.0×10^{6}.
Answer: FALSE
Diff: 1 Var: 1 Page Ref: 2.2
Learning Outcome: 2.1
Global Outcome: G4

3) The decimal number 0.0210 expressed in scientific notation is 2.10×10^{-2}.
Answer: TRUE
Diff: 1 Var: 1 Page Ref: 2.2
Learning Outcome: 2.2
Global Outcome: G4

4) The mass of an object, 4.55×10^{-3} g, expressed in decimal notation is 0.000455 g.
Answer: FALSE
Diff: 1 Var: 1 Page Ref: 2.2
Learning Outcome: 2.2
Global Outcome: G4

5) If you count 7 pennies, you can only report one significant figure in that measurement.
Answer: FALSE
Diff: 1 Var: 1 Page Ref: 2.3
Learning Outcome: 2.3
Global Outcome: G4

6) Exact numbers have an unlimited number of significant figures.
Answer: TRUE
Diff: 1 Var: 1 Page Ref: 2.3
Learning Outcome: 2.3
Global Outcome: G1

7) Zeros located between two numbers are not significant.
Answer: FALSE
Diff: 1 Var: 1 Page Ref: 2.3
Learning Outcome: 2.3
Global Outcome: G1

8) Zeros located after a number and after a decimal point are significant.
Answer: TRUE
Diff: 1 Var: 1 Page Ref: 2.3
Learning Outcome: 2.3
Global Outcome: G1

9) Trailing zeros at the end of a number, but before an implied decimal point, are ambiguous.
Answer: TRUE
Diff: 1 Var: 1 Page Ref: 2.3
Learning Outcome: 2.3
Global Outcome: G1

10) Trailing zeros before a decimal point but after a non-zero number are considered significant figures.
Answer: TRUE
Diff: 1 Var: 1 Page Ref: 2.3
Learning Outcome: 2.3
Global Outcome: G1

11) The number 0.010100 has five significant figures.
Answer: TRUE
Diff: 1 Var: 1 Page Ref: 2.3
Learning Outcome: 2.3
Global Outcome: G4

12) The number 4,450,000.0 has 3 significant figures.
Answer: FALSE
Diff: 1 Var: 1 Page Ref: 2.3
Learning Outcome: 2.3
Global Outcome: G4

13) The number 7.20×10^3 contains three significant figures.
Answer: TRUE
Diff: 1 Var: 1 Page Ref: 2.3
Learning Outcome: 2.3
Global Outcome: G4

14) When the temperature of an object is reported as 23.7°C, the actual temperature can be assumed to be between 23.6°C and 23.8°C.
Answer: TRUE
Diff: 1 Var: 1 Page Ref: 2.3
Learning Outcome: 2.2
Global Outcome: G4

15) Scientific numbers are reported so that every digit is certain except the last, which is estimated.
Answer: TRUE
Diff: 1 Var: 1 Page Ref: 2.3
Learning Outcome: 2.2
Global Outcome: G1

16) When the number 65.59 is rounded to contain 2 significant figures, it becomes 66.0.
Answer: FALSE
Diff: 1 Var: 1 Page Ref: 2.4
Learning Outcome: 2.3
Global Outcome: G4

17) When the number 2.35 is rounded to contain 2 significant figures it becomes 2.4.
Answer: TRUE
Diff: 1 Var: 1 Page Ref: 2.4
Learning Outcome: 2.3
Global Outcome: G4

18) In multiplication and division calculations, the answer will have the same number of decimal places as the number carrying the fewest decimal places.
Answer: FALSE
Diff: 1 Var: 1 Page Ref: 2.4
Learning Outcome: 2.4
Global Outcome: G1

19) In multiplication or division calculations, the answer will have the same number of decimal places as the number carrying the most decimal places.
Answer: FALSE
Diff: 1 Var: 1 Page Ref: 2.4
Learning Outcome: 2.4
Global Outcome: G1

20) In addition or subtraction, the result carries the same number of decimal places as the quantity carrying the fewest decimal places.
Answer: TRUE
Diff: 1 Var: 1 Page Ref: 2.4
Learning Outcome: 2.5
Global Outcome: G1

21) The mass of an object depends on gravity.
Answer: FALSE
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G1

22) The base unit of length in the SI system is the cm.
Answer: FALSE
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G1

23) The base unit of mass in the SI system is the kg.
Answer: TRUE
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G1

24) The prefix nano represents the multiplier 0.000000001.
Answer: TRUE
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G4

25) The prefix micro represents the multiplier 0.001.
Answer: FALSE
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G4

26) A nine gigagram mass is heavier than a nine nanogram mass.
Answer: TRUE
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G4

27) The prefix in the name of a polygon indicates how many sides this geometric figure has, so a "decagon" would have ten sides.
Answer: TRUE
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G2

28) There are 1000 kilometers in one meter.
Answer: FALSE
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.8
Global Outcome: G4

29) You do not need to write units in calculations as long as you can remember them.
Answer: FALSE
Diff: 1 Var: 1 Page Ref: 2.6
Learning Outcome: 2.8
Global Outcome: G1

30) Conversion factors are constructed from any two quantities known to be equivalent.
Answer: TRUE
Diff: 1 Var: 1 Page Ref: 2.6
Learning Outcome: 2.8
Global Outcome: G1

31) A conversion factor is a fraction with one unit on top and a different unit on the bottom.
Answer: TRUE
Diff: 1 Var: 1 Page Ref: 2.6
Learning Outcome: 2.8
Global Outcome: G1

32) A solution map diagrams the steps required to get from the starting point to the end point of a calculation problem.
Answer: TRUE
Diff: 1 Var: 1 Page Ref: 2.6
Learning Outcome: 2.8
Global Outcome: G1

33) A *solution map* is the section near the back of the textbook that provides the answers to assigned problems.
Answer: FALSE
Diff: 1 Var: 1 Page Ref: 2.6
Learning Outcome: 2.8
Global Outcome: G1

34) One mile measures 5,280 feet long, so one square mile is equivalent to 5,280 square feet.
Answer: FALSE
Diff: 1 Var: 1 Page Ref: 2.8
Learning Outcome: 2.8
Global Outcome: G4

35) Given that 1 inch equals 2.54 centimeters, then 1 cubic inch equals 16.387 cubic centimeters.
Answer: TRUE
Diff: 1 Var: 1 Page Ref: 2.8
Learning Outcome: 2.8
Global Outcome: G4

36) All solids have the same density.
Answer: FALSE
Diff: 1 Var: 1 Page Ref: 2.9
Global Outcome: G7

37) Suppose a symmetrical metal rod of the element lead has a density of 11.4 g/cm^3. If this rod is cut in half, the density of each piece is now 5.7 g/cm^3.
Answer: FALSE
Diff: 1 Var: 1 Page Ref: 2.9
Learning Outcome: 2.10a
Global Outcome: G9

38) If you are given the mass and density of an object, you can calculate the volume by using the equation:
V = m/d.
Answer: TRUE
Diff: 1 Var: 1 Page Ref: 2.9
Learning Outcome: 2.10a
Global Outcome: G1

39) If you know the density of a liquid and its volume, the mass of the liquid may be calculated using the equation: m = V/d.
Answer: FALSE
Diff: 1 Var: 1 Page Ref: 2.9
Learning Outcome: 2.10a
Global Outcome: G1

40) The density of iron is 7.86 g/cm^3 while the density of lead is 11.4 g/cm^3. If you had one cm^3 of each metal, the piece of iron would have a greater mass.
Answer: FALSE
Diff: 1 Var: 1 Page Ref: 2.9
Learning Outcome: 2.10a
Global Outcome: G2

2.2 Multiple Choice Questions

1) The correct scientific notation for the number 0.00050210 is:
A) 5.0210×10^4
B) 5.021×10^{-4}
C) 5.021×10^4
D) 5.0210×10^{-4}
E) none of the above
Answer: D
Diff: 1 Var: 1 Page Ref: 2.2
Learning Outcome: 2.1
Global Outcome: G4

2) The correct scientific notation for the number 500.0 is:
A) 5×10^2
B) 5.00×10^2
C) 5.000×10^2
D) 5×10^{-2}
E) none of the above
Answer: C
Diff: 1 Var: 1 Page Ref: 2.2
Learning Outcome: 2.1
Global Outcome: G4

3) The distance between the two hydrogen atoms in a molecule of water is 0.000000000172 m. Express this distance in scientific notation.
A) 1.72 $\times 10^{-9}$ m
B) 1.72 $\times 10^{-10}$ m
C) 0.172 $\times 10^{-10}$ m
D) 17.2 $\times 10^{9}$ m
E) 1.72 $\times 10^{10}$ m
Answer: B
Diff: 1 Var: 1 Page Ref: 2.2
Learning Outcome: 2.1
Global Outcome: G4

4) The wavelength of blue light is 0.00000045 m. Express this wavelength in scientific notation.
A) 4.5 $\times 10^{-6}$ m
B) 4.5 $\times 10^{6}$ m
C) 4.5 $\times 10^{-7}$ m
D) 4.5 $\times 10^{7}$ m
E) 0.45 $\times 10^{-7}$ m
Answer: C
Diff: 1 Var: 1 Page Ref: 2.2
Learning Outcome: 2.1
Global Outcome: G4

5) The correct decimal representation of 1.201 $\times 10^{-7}$ is:
A) 12010000
B) 0.0001201
C) 0.0000001201
D) 1201.000
E) none of the above
Answer: C
Diff: 1 Var: 1 Page Ref: 2.2
Learning Outcome: 2.1
Global Outcome: G4

6) The correct decimal representation of 6.453 $\times 10^{3}$ is:
A) 6,453
B) 0.006453
C) 6.5 $\times 10^{3}$
D) 6.453
E) none of the above
Answer: A
Diff: 1 Var: 1 Page Ref: 2.2
Learning Outcome: 2.1
Global Outcome: G4

7) Suppose a thermometer has marks at every one degree increment and the mercury level on the thermometer is exactly between the 25 and 26 degree Celsius marks. We should properly report the temperature measurement as:
A) 25°C
B) 26°C
C) 25.5°C
D) 25.50°C
E) 25.55°C
Answer: C
Diff: 1 Var: 1 Page Ref: 2.3
Learning Outcome: 2.2
Global Outcome: G3

8) In the number 48.93, which digit is estimated?
A) 4
B) 8
C) 9
D) 3
E) None of the above, all digits are certain.
Answer: D
Diff: 1 Var: 1 Page Ref: 2.3
Learning Outcome: 2.2
Global Outcome: G1

9) There are exactly 2.54 centimeters in 1 inch. When using this conversion factor, how many significant figures are you limited to?
A) 1
B) 3
C) ambiguous
D) depends on if you are using it in multiplication/division or addition/subtraction
E) infinite number of significant figures
Answer: E
Diff: 1 Var: 1 Page Ref: 2.3
Learning Outcome: 2.3
Global Outcome: G4

10) The correct number of significant figures in the number 865,000 is:
A) 3
B) 6
C) 4
D) ambiguous
E) none of the above
Answer: D
Diff: 1 Var: 1 Page Ref: 2.3
Learning Outcome: 2.3
Global Outcome: G4

11) The correct number of significant figures in the number 1.250100 is:
A) 5
B) 7
C) 4
D) ambiguous
E) none of the above
Answer: B
Diff: 1 Var: 1 Page Ref: 2.3
Learning Outcome: 2.3
Global Outcome: G4

12) The correct number of significant figures in the number 0.027090 is:
A) 7
B) 6
C) 5
D) ambiguous
E) none of the above
Answer: C
Diff: 1 Var: 1 Page Ref: 2.3
Learning Outcome: 2.3
Global Outcome: G4

13) The correct number of significant figures in the number "9.080×10^4" is:
A) 3
B) 4
C) 5
D) ambiguous
E) none of the above
Answer: B
Diff: 1 Var: 1 Page Ref: 2.3
Learning Outcome: 2.3
Global Outcome: G4

14) The correct number of significant figures in the number 4.0×10^{-2} is:
A) 1
B) 2
C) 3
D) ambiguous.
E) none of the above
Answer: B
Diff: 1 Var: 1 Page Ref: 2.3
Learning Outcome: 2.3
Global Outcome: G4

15) The correct number of significant figures in the number 0.002320 is:
A) 7
B) 4
C) 3
D) ambiguous
E) none of the above
Answer: B
Diff: 1 Var: 1 Page Ref: 2.3
Learning Outcome: 2.3
Global Outcome: G4

16) Which of the following statements is NOT part of the rules for determining significant figures?
A) Non-zero digits at the end of a number are not significant.
B) Zeroes between two numbers are significant.
C) Zeroes to the left of the first non-zero number are not significant.
D) Trailing zeroes at the end of a number, but before an implied decimal point are ambiguous.
E) All of the above statements are part of the rules.
Answer: A
Diff: 1 Var: 1 Page Ref: 2.3
Learning Outcome: 2.3
Global Outcome: G1

17) When the value 4.449 is rounded to two significant figures, the number should be reported as:
A) 4.4
B) 4.5
C) 4.44
D) 4.45
E) none of the above
Answer: A
Diff: 1 Var: 1 Page Ref: 2.4
Learning Outcome: 2.3
Global Outcome: G4

18) How many significant digits should be reported in the answer to the following calculation?
$(4.3 - 3.7) \times 12.3 =$
A) 1
B) 2
C) 3
D) 4
E) none of the above
Answer: A
Diff: 2 Var: 1 Page Ref: 2.4
Learning Outcome: 2.6
Global Outcome: G4

19) Determine the answer for the equation below with correct number of significant figures:
3.215 × 13.2 ÷ 0.218 = ________
A) 194.669
B) 195
C) 194.7
D) 194.67
E) none of the above
Answer: B
Diff: 2 Var: 1 Page Ref: 2.4
Learning Outcome: 2.6
Global Outcome: G4

20) Determine the answer for the equation below with correct number of significant figures:
1.2 × 1.79 = ________
A) 2.148
B) 2.15
C) 2.1
D) 2.2
E) none of the above
Answer: C
Diff: 2 Var: 1 Page Ref: 2.4
Learning Outcome: 2.4
Global Outcome: G4

21) Determine the answer to the following equation with correct number of significant figures:
106 ÷ 9.02 × 1.9 = ________
A) 22.32816
B) 22.328
C) 22.3
D) 22
E) none of the above
Answer: D
Diff: 2 Var: 1 Page Ref: 2.4
Learning Outcome: 2.4
Global Outcome: G4

22) Determine the answer to the following equation with correct number of significant figures:
2.02 + 8.102 - 0.0297 = ________
A) 10.0923
B) 10.09
C) 10.1
D) 10.092
E) none of the above
Answer: B
Diff: 2 Var: 1 Page Ref: 2.4
Learning Outcome: 2.5
Global Outcome: G4

23) Determine the answer to the following equation with correct number of significant figures:
13.96 - 4.9102 + 71.5 = ________
A) 80.5498
B) 81
C) 80.5
D) 80.55
E) none of the above
Answer: C
Diff: 2 Var: 1 Page Ref: 2.4
Learning Outcome: 2.5
Global Outcome: G4

24) Determine the answer to the following equation with correct number of significant figures:
(4.123 × 0.12) + 24.2 = ________
A) 25
B) 24.695
C) 24.70
D) 24.7
E) none of the above
Answer: D
Diff: 2 Var: 1 Page Ref: 2.4
Learning Outcome: 2.6
Global Outcome: G4

25) Determine the answer to the following equation with correct number of significant figures:
(17.103 + 2.03) × 1.02521 = ________
A) 19.6153
B) 19.62
C) 19.6
D) 20
E) none of the above
Answer: B
Diff: 2 Var: 1 Page Ref: 2.4
Learning Outcome: 2.6
Global Outcome: G4

26) The correct prefix for the multiplier 1,000,000 is:
A) mega.
B) milli.
C) micro.
D) nano.
E) none of the above
Answer: A
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G4

27) The correct prefix for the multiplier 1,000 is:
A) mega.
B) milli.
C) micro.
D) nano.
E) none of the above
Answer: E
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G4

28) The correct prefix for the multiplier 0.1 is:
A) tera.
B) deci.
C) femto.
D) pico.
E) none of the above
Answer: B
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G4

29) The correct prefix for the multiplier 0.000001 is:
A) mega.
B) milli.
C) micro.
D) nano.
E) none of the above
Answer: C
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G4

30) The correct prefix for the multiplier 100 is:
A) mega.
B) hecto.
C) centi.
D) nano.
E) none of the above
Answer: B
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G1

31) The correct prefix for the multiplier 10 is:
A) deca.
B) deci.
C) tera.
D) centi.
E) none of the above
Answer: A
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G1

32) The correct prefix for the multiplier 1,000,000,000 is:
A) mega.
B) milli.
C) tera.
D) giga.
E) none of the above
Answer: D
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G4

33) The correct multiplier for the prefix pico is:
A) 10^{-3}
B) 10^{-6}
C) 10^{-9}
D) 10^{-12}
E) none of the above
Answer: D
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G4

34) The correct multiplier for the prefix femto is:
A) 10^{-15}
B) 10^{-12}
C) 10^{12}
D) 10^{9}
E) none of the above
Answer: A
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G4

35) The correct multiplier for the prefix milli is:
A) 10^{-3}
B) 10^{-6}
C) 10^{-9}
D) 10^{-12}
E) none of the above
Answer: A
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G4

36) The correct multiplier for the prefix micro is:
A) 10^{3}
B) 10^{-6}
C) 10^{-9}
D) 10^{6}
E) none of the above
Answer: B
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G4

37) What is the base SI unit for length?
A) mile
B) centimeter
C) foot
D) meter
E) none of the above
Answer: D
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G1

38) What is the base SI unit for mass?
A) kilogram
B) gram
C) pound
D) ton
E) none of the above
Answer: A
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G1

39) The base SI unit for temperature is:
A) Fahrenheit.
B) Kelvin.
C) Celsius.
D) atmospheres.
E) none of the above
Answer: B
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G1

40) Which measurement below represents the heaviest mass?
A) 1 mg
B) 1 kg
C) 1 pg
D) 1 Mg
E) 1 dg
Answer: D
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G2

41) Which of the following sets of units is NOT in the order of increasing size?
A) μg < g < kg
B) mL < dL < L
C) ns < ms < s
D) cm < μm < km
E) μmol < mmol < mol
Answer: D
Diff: 2 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G2

42) An American nickel five cent coin has a mass of approximately 5 grams. Five grams is equivalent to which term?
A) 5000 kilograms
B) 5000 milligrams
C) 50 centigrams
D) 5000 micrograms
E) none of the above
Answer: B
Diff: 2 Var: 1 Page Ref: 2.5
Learning Outcome: 2.8
Global Outcome: G2|G4

43) Which of the following would NOT be considered a correct conversion factor?
A) 1 dozen eggs = 12 eggs
B) 12 eggs = 1 dozen eggs
C) 1 pair of shoes = 1 shoe
D) 100 pennies = 1 dollar
E) 5 cents = 1 nickel
Answer: C
Diff: 1 Var: 1 Page Ref: 2.5
Learning Outcome: 2.8
Global Outcome: G2

44) The common English unit in which the speed of an automobile is expressed is miles/hr. What is the set of base SI units for speed?
A) mile/s
B) km/hr
C) km/s
D) m/s
E) none of the above
Answer: D
Diff: 3 Var: 1 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G1

45) The typical problem-solving procedure involves four steps in the order:
A) sort, strategize, solve, check.
B) strategize, solve, sort, check.
C) check, strategize, sort, solve.
D) solve, sort, check, strategize.
Answer: A
Diff: 1 Var: 1 Page Ref: 2.6
Learning Outcome: 2.8
Global Outcome: G9

46) How many inches are in 25.8 cm?
A) 0.10
B) 28.3
C) 0.0984
D) 10.2
E) none of the above
Answer: D
Diff: 2 Var: 1 Page Ref: 2.6
Learning Outcome: 2.8
Global Outcome: G4

47) How many inches are in 2.80 ft?
A) 34
B) 33.6
C) 0.233
D) 4.29
E) none of the above
Answer: B
Diff: 2 Var: 1 Page Ref: 2.6
Learning Outcome: 2.8
Global Outcome: G4

48) How many grams are in 1.48×10^{7} μg?
A) 1.48×10^{3}
B) 1.48×10^{13}
C) 1.48
D) 14.8
E) none of the above
Answer: D
Diff: 2 Var: 1 Page Ref: 2.6
Learning Outcome: 2.8
Global Outcome: G4

49) How many milliliters are in 17.5 L?
A) 175
B) 1.75×10^{-2}
C) 1.75×10^{3}
D) 1.75×10^{4}
E) none of the above
Answer: D
Diff: 2 Var: 1 Page Ref: 2.6
Learning Outcome: 2.8
Global Outcome: G4

50) How many microliters are in 41.0 mL?
A) 4.1×10^{3}
B) 4.1×10^{10}
C) 0.041
D) 4.10×10^{4}
E) none of the above
Answer: D
Diff: 2 Var: 1 Page Ref: 2.6
Learning Outcome: 2.8
Global Outcome: G4

51) How many liters are in 333 mL?
A) 3.33×10^5
B) 0.333
C) 33.3
D) 3.33
E) none of the above
Answer: B
Diff: 2 Var: 1 Page Ref: 2.6
Learning Outcome: 2.8
Global Outcome: G4

52) How many low dose 81 mg aspirin tablets can be made from 1.21 kg of aspirin?
A) 1.5×10^3 tablets
B) 1.5×10^4 tablets
C) 1.5×10^5 tablets
D) 1.21×10^3 tablets
E) 1.21×10^4 tablets
Answer: B
Diff: 2 Var: 1 Page Ref: 2.7
Learning Outcome: 2.8
Global Outcome: G4

53) A 12-oz can of soda pop costs eighty-nine cents. A 2.00 L bottle of the same variety of soda pop costs $2.29. How many times more expensive it is to buy the 12-oz can of pop compared to buying it in a 2.00 L bottle? (1.00 L = 1.057 quart and 1 quart contains 32 oz)
A) 1.9
B) 2.2
C) 2.6
D) 2.8
E) 4.2
Answer: B
Diff: 3 Var: 1 Page Ref: 2.7
Learning Outcome: 2.8
Global Outcome: G4

54) How many cm^3 are there in 2.5 m^3?
A) 2.5×10^6
B) 2.5×10^{-2}
C) 2.5×10^2
D) 2.5×10^{-6}
E) none of the above
Answer: A
Diff: 2 Var: 1 Page Ref: 2.8
Learning Outcome: 2.9
Global Outcome: G4

55) How many cm^3 are there in 1.25 ft^3?
A) 38.1
B) 5.49×10^3
C) 246
D) 3.54×10^4
E) none of the above
Answer: D
Diff: 2 Var: 1 Page Ref: 2.8
Learning Outcome: 2.9
Global Outcome: G4

56) A room has dimensions of 10.0 ft × 20.0 ft × 8.00 ft. Given that there are three feet in a yard, what is the volume of the room in yd^3?
A) 178
B) 59.3
C) 1.60×10^3
D) 533
E) none of the above
Answer: B
Diff: 3 Var: 1 Page Ref: 2.8
Learning Outcome: 2.9
Global Outcome: G4

57) What is the volume of a cube with dimensions 11.0 cm × 11.0 cm × 11.0 cm in m^3?
A) 1.331×10^{-3}
B) 1.33×10^3
C) 1.33×10^{-3}
D) 1.3×10^3
E) none of the above
Answer: C
Diff: 2 Var: 1 Page Ref: 2.8
Learning Outcome: 2.9
Global Outcome: G4

58) Which term below is equivalent to one milliliter?
A) 1 cc
B) 1 mL
C) 1 cm^3
D) all of the above
E) none of the above
Answer: D
Diff: 1 Var: 1 Page Ref: 2.8
Learning Outcome: 2.8
Global Outcome: G4

59) A plastic block has dimensions of 2.2 cm × 3.0 cm × 1.5 cm and a mass of 12.4 grams. Will the block float in water and why?
A) Yes, because the density of the block is 1.3 g/mL which is less than the density of water.
B) Yes, because the density of the block is 0.80 g/mL which is less than the density of water.
C) No, because the density of the block is 1.3 g/mL which is greater than the density of water.
D) No, because the density of the block is 0.80 g/mL which is greater than the density of water.
E) none of the above
Answer: C
Diff: 3 Var: 1 Page Ref: 2.9
Learning Outcome: 2.10a
Global Outcome: G9

60) Suppose a boat engine leaks 938 milliliters of oil into a lake. The mass of this spilled oil is 823 grams. The oil will not mix with the lake water. Which statement is true?
A) The oil will sink because its density of 0.877 g/mL is greater than the density of water.
B) The oil will float because its density of 0.877 g/mL is less than the density of water.
C) The oil will sink because its density of 1.14 g/mL is greater than the density of water.
D) The oil will float because its density of 1.14 g/mL is less than the density of water.
E) none of the above
Answer: B
Diff: 3 Var: 1 Page Ref: 2.9
Learning Outcome: 2.10a
Global Outcome: G7

61) A lead ball has a mass of 55.0 grams and a density of 11.4 g/cm^3. What is the volume of the ball?
A) 0.207 mL
B) 0.207 L
C) 4.82 mL
D) 4.82 L
E) none of the above
Answer: C
Diff: 2 Var: 1 Page Ref: 2.9
Learning Outcome: 2.11
Global Outcome: G4

62) Given the density of Au is 19.3 g/cm^3, determine the mass of gold (in grams) in an ingot with the dimensions of 10.0 in × 4.00 in × 3.00 in.
A) 3.80×10^4
B) 102
C) 2.32×10^3
D) 0.161
E) none of the above
Answer: A
Diff: 2 Var: 1 Page Ref: 2.9
Learning Outcome: 2.11
Global Outcome: G4

63) What is the density (g/mL) of an object that has a mass of 14.01 grams and, when placed into a graduated cylinder, causes the water level to rise from 25.2 mL to 33.6 mL?
A) 0.60
B) 1.7
C) 1.8
D) 2.4
E) none of the above
Answer: B
Diff: 3 Var: 1 Page Ref: 2.9
Learning Outcome: 2.10a
Global Outcome: G9

64) An object weighing 1.840 kg has a volume of 0.0015 m^3. What is the density of the object in g/cm^3?
A) 1.2
B) 0.0012
C) 0.82
D) 0.0028
E) none of the above
Answer: A
Diff: 3 Var: 1 Page Ref: 2.9
Learning Outcome: 2.10a
Global Outcome: G4

65) Given the following list of densities, which materials would float in a molten vat of lead provided that they do not themselves melt? Densities (g/mL): lead = 11.4, glass = 2.6, gold = 19.3, charcoal = 0.57, platinum = 21.4.
A) gold and platinum
B) glass and charcoal
C) gold, platinum, glass and coal
D) gold and charcoal
E) none of the above
Answer: B
Diff: 2 Var: 1 Page Ref: 2.9
Learning Outcome: 2.10a
Global Outcome: G9

66) A popular science demonstration is to take several liquids that will not mix together and "stack" these liquids in a tall glass cylinder. Suppose the following three liquids were placed in the same tall, narrow glass cylinder:

SUBSTANCE	DENSITY g/mL
vinegar	1.01
motor oil	0.87
corn syrup	1.36

These liquids would stack in which order?
A) corn syrup on top, motor oil in the middle, vinegar on the bottom
B) vinegar on top, motor oil in the middle, corn syrup on the bottom
C) motor oil on top, corn syrup in the middle, vinegar on the bottom
D) corn syrup on top, vinegar in the middle, motor oil on the bottom
E) motor oil on top, vinegar in the middle, corn syrup on the bottom
Answer: E
Diff: 2 Var: 1 Page Ref: 2.9
Learning Outcome: 2.10a
Global Outcome: G3|G9

67) The distance from New York City to Washington, DC is approximately 235 miles. Identify the correct solution map to convert from miles to kilometers using the prefix multipliers and the given conversion factors: 1 mile = 5280 ft; 1 ft = 12 in; 1 in = 2.54 cm.

A) $235\text{ mile} \times \dfrac{1\text{ ft}}{5280\text{ mile}} \times \dfrac{12\text{ in}}{1\text{ ft}} \times \dfrac{1\text{ in}}{2.54\text{ cm}} \times \dfrac{10^{-2}\text{ cm}}{1\text{ m}} \times \dfrac{1\text{ km}}{10^{3}\text{ m}}$

B) $235\text{ mile} \times \dfrac{5280\text{ ft}}{1\text{ mile}} \times \dfrac{1\text{ ft}}{12\text{ in}} \times \dfrac{2.54\text{ in}}{1\text{ ft}} \times \dfrac{1\text{ m}}{10^{-2}\text{ cm}} \times \dfrac{10^{3}\text{ km}}{1\text{ m}}$

C) $235\text{ mile} \times \dfrac{5280\text{ ft}}{1\text{ mile}} \times \dfrac{12\text{ in}}{1\text{ ft}} \times \dfrac{2.54\text{ cm}}{1\text{ in}} \times \dfrac{10^{-2}\text{ m}}{1\text{ cm}} \times \dfrac{1\text{ km}}{10^{3}\text{ m}}$

D) $235\text{ mile} \times \dfrac{12\text{ in}}{1\text{ ft}} \times \dfrac{1\text{ in}}{2.54\text{ cm}} \times \dfrac{10^{-2}\text{ cm}}{1\text{ m}} \times \dfrac{1\text{ km}}{10^{3}\text{ m}}$

E) $235\text{ mile} \times \dfrac{12\text{ in}}{1\text{ ft}} \times \dfrac{2.54\text{ cm}}{1\text{ in}} \times \dfrac{1\text{ m}}{10^{-2}\text{ cm}} \times \dfrac{10^{3}\text{ km}}{1\text{ m}}$

Answer: C
Diff: 3 Var: 1 Page Ref: 2.10
Learning Outcome: 2.8
Global Outcome: G4

68) The Olympic Games shot put field event uses a 16 pound (lb) shot. Identify the correct solution map to convert from pounds to kilograms using prefix multipliers and the given conversions of 16 oz = 1 lb and 453.6 g = 16 oz.

A) $16\ \text{lb} \times \frac{1\ \text{lb}}{16\ \text{oz}} \times \frac{16\ \text{oz}}{453.6\ \text{g}} \times \frac{10^3\ \text{g}}{1\ \text{kg}}$

B) $16\ \text{lb} \times \frac{16\ \text{oz}}{1\ \text{lb}} \times \frac{453.6\ \text{g}}{16\ \text{oz}} \times \frac{10^3\ \text{kg}}{1\ \text{g}}$

C) $16\ \text{lb} \times \frac{16\ \text{oz}}{1\ \text{lb}} \times \frac{453.6\ \text{g}}{16\ \text{oz}} \times \frac{1\ \text{kg}}{10^3\ \text{g}}$

D) $16\ \text{lb} \times \frac{1\ \text{oz}}{16\ \text{lb}} \times \frac{453.6\ \text{g}}{16\ \text{oz}} \times \frac{1\ \text{kg}}{10^3\ \text{g}}$

Answer: C
Diff: 3 Var: 1 Page Ref: 2.10
Learning Outcome: 2.8
Global Outcome: G4

69) Metals expand to a larger volume when heated. If a piece of metal was heated, which one of the following statements would be TRUE?
A) The newly calculated density value of the metal would not change from the initial value.
B) The newly calculated density value would decrease.
C) The newly calculated density value would increase.
D) The mass of the metal would also increase.
E) none of the above
Answer: B
Diff: 2 Var: 1 Page Ref: 2.9
Learning Outcome: 2.10a
Global Outcome: G2

70) The jet fuel in an airplane has a mass of 97.5 kg and a density of 0.804 g/cm^3. What is the volume of this jet fuel?
A) $7.84 \times 10^{-2}\ cm^3$
B) $7.84 \times 10^{4}\ cm^3$
C) $1.21 \times 10^{2}\ cm^3$
D) $1.21 \times 10^{5}\ cm^3$
E) none of the above
Answer: D
Diff: 3 Var: 1 Page Ref: 2.9
Learning Outcome: 2.11
Global Outcome: G2

2.3 Algorithmic Questions

1) The exponential 10^4 is equal to which decimal number?
A) 10,000
B) 1
C) 10
D) 100
E) none of the above
Answer: A
Diff: 1 Var: 5 Page Ref: 2.2
Learning Outcome: 2.1
Global Outcome: G4

2) The decimal value 10 is equal to which exponential?
A) 10^4
B) 10^3
C) 10^2
D) 10^1
E) none of the above
Answer: D
Diff: 1 Var: 5 Page Ref: 2.2
Learning Outcome: 2.1
Global Outcome: G4

3) The decimal value 0.01 is equal to which exponential?
A) 10^{-3}
B) 10^{-2}
C) 10^{-4}
D) 10^{-5}
E) none of the above
Answer: B
Diff: 1 Var: 5 Page Ref: 2.2
Learning Outcome: 2.1
Global Outcome: G4

4) The exponential 10^{-3} is equal to which decimal number?
A) 0.1
B) 0.001
C) -0.00001
D) -0.0001
E) none of the above
Answer: B
Diff: 1 Var: 5 Page Ref: 2.2
Learning Outcome: 2.1
Global Outcome: G4

5) How would the number 8,155 be written in scientific notation?
A) 8.155×10^3
B) 8.155×10^{-1}
C) 8.155×10^1
D) 8.155×10^{-3}
E) none of the above
Answer: A
Diff: 1 Var: 5 Page Ref: 2.2
Learning Outcome: 2.1
Global Outcome: G4

6) How would the number 1.09×10^1 be expressed in decimal form?
A) 109
B) 0.109
C) 1.09
D) 10.9
E) none of the above
Answer: D
Diff: 1 Var: 5 Page Ref: 2.2
Learning Outcome: 2.1
Global Outcome: G4

7) How many significant figures are in the number 2903?
A) 2
B) 5
C) 4
D) 3
E) none of the above
Answer: C
Diff: 1 Var: 5 Page Ref: 2.3
Learning Outcome: 2.3
Global Outcome: G1

8) How many significant figures are represented by the following number that is written in scientific notation? 2.5×10^3
A) 0
B) 1
C) 2
D) 3
E) none of the above
Answer: C
Diff: 2 Var: 5 Page Ref: 2.3, 2.4
Learning Outcome: 2.3
Global Outcome: G4

9) When rounding the number 2.348615 to 4 significant figures, what is the correct value?
A) 2.3490
B) 2.340
C) 2.349
D) 2.348
E) none of the above
Answer: C
Diff: 2 Var: 5 Page Ref: 2.4
Learning Outcome: 2.3
Global Outcome: G1

10) How many significant figures should be reported in the answer to the following calculation?
$(1.40) \times (17.1) =$
A) 0
B) 1
C) 2
D) 3
E) none of the above
Answer: D
Diff: 2 Var: 5 Page Ref: 2.4
Learning Outcome: 2.4
Global Outcome: G4

11) How many significant figures should be reported in the answer to the following calculation?
$(8.50) \times (29.0) \times (1.0947) =$
A) 3
B) 2
C) 4
D) 5
E) none of the above
Answer: A
Diff: 2 Var: 5 Page Ref: 2.4
Learning Outcome: 2.4
Global Outcome: G4

12) How many significant figures should be reported in the answer to the following calculation?
$$\frac{(13.21)\,(14.021)}{(2.00)} =$$
A) 3
B) 4
C) 2
D) 5
E) none of the above
Answer: A
Diff: 2 Var: 50+ Page Ref: 2.4
Learning Outcome: 2.4
Global Outcome: G4

13) How many significant figures should be reported in the answer to the following calculation?
(4.921) + (16.2) =
A) 3
B) 2
C) 1
D) 4
E) none of the above
Answer: A
Diff: 2 Var: 25 Page Ref: 2.4
Learning Outcome: 2.5
Global Outcome: G4

14) How many significant figures should be reported in the answer to the following calculation?
(43.980) × (19.0023 + 25) =
A) 3
B) 2
C) 4
D) 1
E) none of the above
Answer: B
Diff: 2 Var: 50+ Page Ref: 2.4
Learning Outcome: 2.6
Global Outcome: G4

15) The prefix *micro* represents which multiplier?
A) 0.000001
B) 1,000,000
C) 0.001
D) 1,000
E) none of the above
Answer: A
Diff: 1 Var: 5 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G1

16) The multiplier 0.01 is represented by which prefix?
A) kilo-
B) deci-
C) centi-
D) milli-
E) none of the above
Answer: C
Diff: 1 Var: 5 Page Ref: 2.5
Learning Outcome: 2.7
Global Outcome: G1

17) The metric prefix k would be presented as 10 to the power of:
A) -3
B) 3
C) 12
D) -9
Answer: B
Diff: 2 Var: 4 Page Ref: 2.6
Learning Outcome: 2.7
Global Outcome: G1

18) How many inches are in 6.32 cm?
A) 16.1
B) 2.49
C) 3.78
D) 8.86
E) none of the above
Answer: B
Diff: 2 Var: 5 Page Ref: 2.6
Learning Outcome: 2.8
Global Outcome: G4

19) How many in^3 are in 2.20 cm^3?
A) 36.1
B) 10.6
C) 0.1340
D) 7.45
E) none of the above
Answer: C
Diff: 2 Var: 4 Page Ref: 2.8
Learning Outcome: 2.9
Global Outcome: G4

20) What is the density of 96 mL of a liquid that has a mass of 90.5 g?
A) 0.94 g/mL
B) 1.1 g/mL
C) 186.5 g/mL
D) 28.4 g/mL
E) none of the above
Answer: A
Diff: 2 Var: 5 Page Ref: 2.9
Learning Outcome: 2.10a
Global Outcome: G4

21) What is the volume of 19.6 g of a liquid that has a density of 0.967 g/mL?
A) 16.9 mL
B) 20.3 mL
C) 14.7 mL
D) 17.9 mL
E) none of the above
Answer: B
Diff: 2 Var: 5 Page Ref: 2.9
Learning Outcome: 2.11
Global Outcome: G4

Periodic Table of the Elements

PERIOD	GROUP 1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B
1	1 **H** 1.01 hydrogen								
2	3 **Li** 6.94 lithium	4 **Be** 9.01 beryllium							
3	11 **Na** 22.99 sodium	12 **Mg** 24.31 magnesium							
4	19 **K** 39.10 potassium	20 **Ca** 40.08 calcium	21 **Sc** 44.96 scandium	22 **Ti** 47.88 titanium	23 **V** 50.94 vanadium	24 **Cr** 52.00 chromium	25 **Mn** 54.94 manganese	26 **Fe** 55.85 iron	27 **Co** 58.93 cobalt
5	37 **Rb** 85.47 rubidium	38 **Sr** 87.62 strontium	39 **Y** 88.91 yttrium	40 **Zr** 91.22 zirconium	41 **Nb** 92.91 niobium	42 **Mo** 95.95 molybdenum	43 **Tc** (99) technetium	44 **Ru** 101.07 ruthenium	45 **Rh** 102.91 rhodium
6	55 **Cs** 132.91 cesium	56 **Ba** 137.33 barium	57 **La** 138.91 lanthanum	72 **Hf** 178.49 hafnium	73 **Ta** 180.95 tantalum	74 **W** 183.85 tungsten	75 **Re** 186.21 rhenium	76 **Os** 190.23 osmium	77 **Ir** 192.22 iridium
7	87 **Fr** (223) francium	88 **Ra** (226) radium	89 **Ac** (227) actinium	104 **Rf** (261) rutherfordium	105 **Db** (262) dubnium	106 **Sg** (263) seaborgium	107 **Bh** (262) bohrium	108 **Hs** (265) hassium	109 **Mt** (266) meitnerium

Key:

1	Atomic number
H	Element symbol
1.01	Atomic mass*
hydrogen	Element name

Lanthanide series	58 **Ce** 140.12 cerium	59 **Pr** 140.91 praseodymium	60 **Nd** 144.24 neodymium	61 **Pm** (147) promethium	62 **Sm** 150.36 samarium	63 **Eu** 151.97 europium
Actinide series	90 **Th** (232) thorium	91 **Pa** (231) protactinium	92 **U** (238) uranium	93 **Np** (237) neptunium	94 **Pu** (244) plutonium	95 **Am** (243) americium

*The mass number of an important radioactive isotope—not the atomic mass—is shown in parentheses for those elements with no stable isotopes.

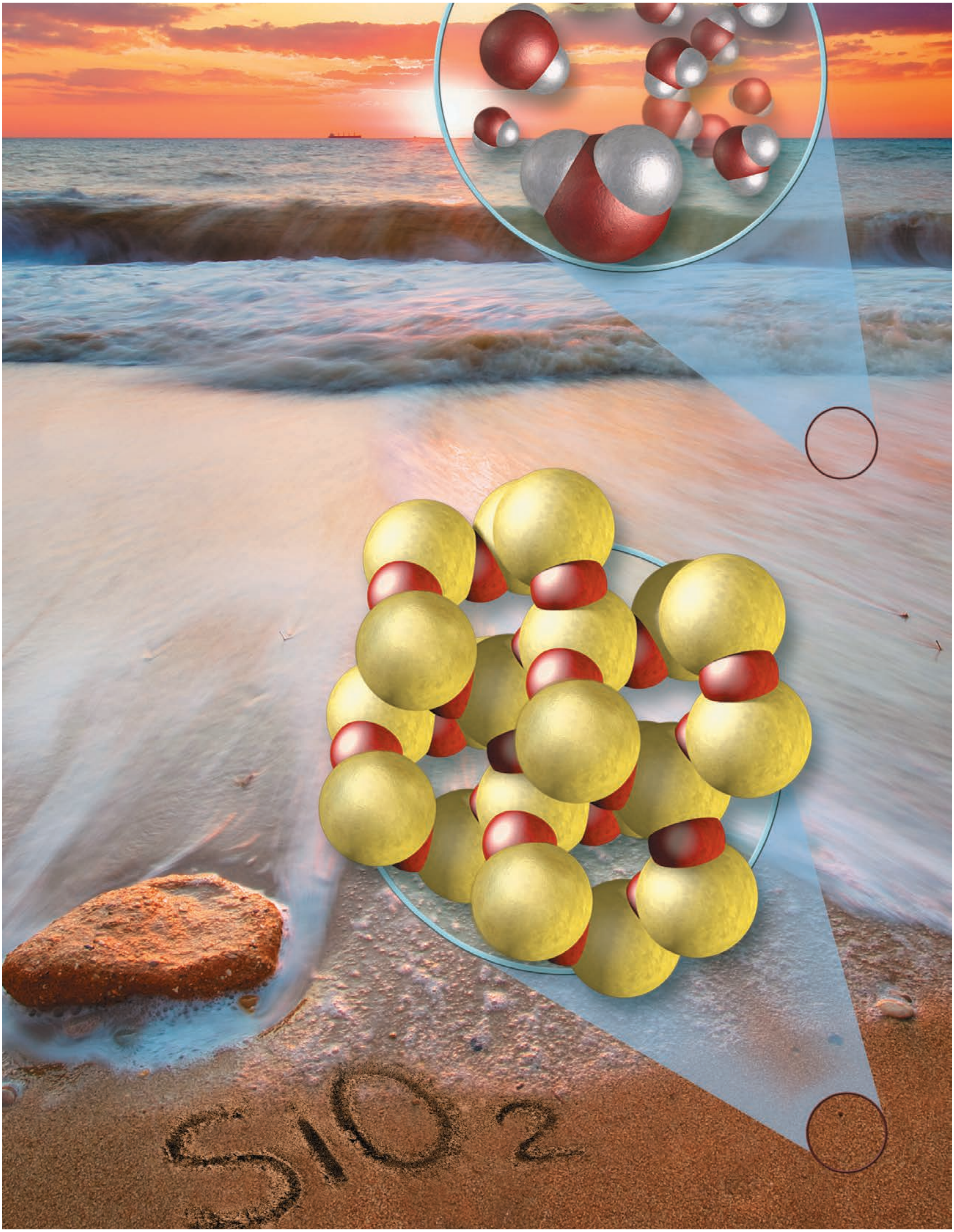
Metals

Metalloids

Nonmetals

10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
								2 **He** 4.00 helium
			5 **B** 10.81 boron	6 **C** 12.01 carbon	7 **N** 14.01 nitrogen	8 **O** 16.00 oxygen	9 **F** 19.00 fluorine	10 **Ne** 20.18 neon
			13 **Al** 26.98 aluminum	14 **Si** 28.09 silicon	15 **P** 30.97 phosphorus	16 **S** 32.06 sulfur	17 **Cl** 35.45 chlorine	18 **Ar** 39.95 argon
28 **Ni** 58.69 nickel	29 **Cu** 63.55 copper	30 **Zn** 65.39 zinc	31 **Ga** 69.72 gallium	32 **Ge** 72.63 germanium	33 **As** 74.92 arsenic	34 **Se** 78.97 selenium	35 **Br** 79.90 bromine	36 **Kr** 83.80 krypton
46 **Pd** 106.42 palladium	47 **Ag** 107.87 silver	48 **Cd** 112.41 cadmium	49 **In** 114.82 indium	50 **Sn** 118.71 tin	51 **Sb** 121.75 antimony	52 **Te** 127.60 tellurium	53 **I** 126.90 iodine	54 **Xe** 131.29 xenon
78 **Pt** 195.08 platinum	79 **Au** 196.97 gold	80 **Hg** 200.59 mercury	81 **Tl** 204.38 thallium	82 **Pb** 207.2 lead	83 **Bi** 208.98 bismuth	84 **Po** (209) polonium	85 **At** (210) astatine	86 **Rn** (222) radon
110 **Ds** (281) darmstadtium	111 **Rg** (280) roentgenium	112 **Cn** (285) copernicium	113 **Nh** (284) nihonium	114 **Fl** (289) flerovium	115 **Mc** (289) moscovium	116 **Lv** (293) livermorium	117 **Ts** (294) tennessine	118 **Og** (294) oganesson

64 **Gd** 157.25 gadolinium	65 **Tb** 158.93 terbium	66 **Dy** 162.50 dysprosium	67 **Ho** 164.93 holmium	68 **Er** 167.26 erbium	69 **Tm** 168.93 thulium	70 **Yb** 173.04 ytterbium	71 **Lu** 174.97 lutetium
96 **Cm** (247) curium	97 **Bk** (247) berkelium	98 **Cf** (251) californium	99 **Es** (252) einsteinium	100 **Fm** (257) fermium	101 **Md** (258) mendelevium	102 **No** (259) nobelium	103 **Lr** (260) lawrencium


SiO2

1 The Chemical World

"Imagination is more important than knowledge."
—Albert Einstein (1879–1955)

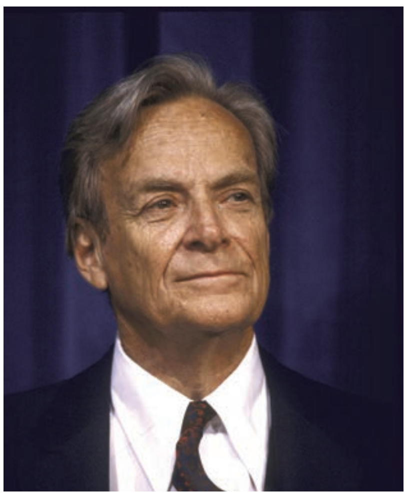
CHAPTER OUTLINE

1.1 Sand and Water 3
1.2 Chemicals Compose Ordinary Things 4
1.3 The Scientific Method: How Chemists Think 5
1.4 Analyzing and Interpreting Data 8
1.5 A Beginning Chemist: How to Succeed 10

1.1 Sand and Water

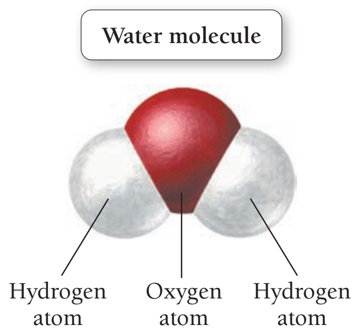
I love the beach but hate sand. Sand gets everywhere and even comes home with you. Sand is annoying because sand particles are so small. They stick to your hands, to your feet, and to any food you might be trying to eat for lunch. But the smallness of sand particles pales in comparison to the smallness of the particles that compose them. Sand—like all other kinds of ordinary matter—is composed of atoms. Atoms are unimaginably small. A single sand grain contains more atoms than there are sand grains on the largest of beaches.

The idea that matter is composed of tiny particles is among the greatest discoveries of humankind. Nobel laureate Richard Feynman (1918–1988), in a lecture to first-year physics students at the California Institute of Technology, said that the most important idea in all human knowledge is that *all things are made of atoms*. Why is this idea so important? Because it establishes how we should go about understanding the properties of the things around us. If we want to understand how matter behaves, we must understand how the particles that compose that matter behave.



▲ Richard Feynman (1918–1988), Nobel Prize–winning physicist and popular professor at California Institute of Technology.

Atoms, and the molecules they compose, determine how matter behaves—if they were different, matter would be different. The nature of water molecules, for example, determines how water behaves. If water molecules were different—even in a small way—then water would be a different sort of substance. For example, we know that a water molecule is composed of two hydrogen atoms bonded to an oxygen atom with a shape that looks like this:



◀ A single grain of sand on a large beach contains more atoms than there are grains of sand on the entire beach.

How would water be different if the shape of the water molecule was different? What if the hydrogen atoms bonded to oxygen to form a linear molecule instead of a bent one?

Hypothetical linear water molecule

The answer to this question is not altogether simple. We don't know exactly how our hypothetical linear water would behave, but we do know it would be much different than ordinary water. For example, linear water would probably have a much lower boiling point than ordinary water. In fact, it may even be a gas (instead of a liquid) at room temperature. Imagine what our world would be like if water was a gas at room temperature. There would be no rivers, no lakes, no oceans, and probably no people (since liquid water is such an important part of what composes us).

There is a direct connection between the world of atoms and molecules and the world we experience every day (▼ **FIGURE 1.1**). Chemists explore this connection. They seek to understand it. A good, simple definition of **chemistry** is *the science that tries to understand how matter behaves by studying how atoms and molecules behave*.

▲ **FIGURE 1.1 Virtually everything around you is composed of chemicals.**

1.2 Chemicals Compose Ordinary Things

▶ Recognize that chemicals make up virtually everything we come into contact with in our world. *(Note: Most of the sections in the chapters in this book link to a Learning Objective (LO), which is listed at the beginning of the section.)*

We just saw how chemists are interested in substances such as sand and water. But are these substances chemicals? Yes. In fact, everything that we can hold or touch is made of chemicals. When most people think of chemicals, however, they may envision a can of paint thinner in their garage, or recall a headline about a river polluted by industrial waste. But chemicals compose ordinary things, too. Chemicals compose the air we breathe and the water we drink. They compose toothpaste, Tylenol®, and toilet paper. Chemicals make up virtually everything with which we come into contact. Chemistry explains the properties and behavior of chemicals, in the broadest sense, by helping us understand the molecules that compose them.

▲ Chemists are interested in knowing why ordinary things, such as water, are the way they are. When a chemist sees a pitcher of water, she thinks of the molecules that compose the liquid and how those molecules determine its properties.

▲ People often have a very narrow view of chemicals, thinking of them only as dangerous poisons or pollutants.

As you experience the world around you, molecules are interacting to create your reality. Imagine watching a sunset. Molecules are involved in every step. Molecules in the air interact with light from the sun, scattering away the blue and green light and leaving the red and orange light to create the color you see. Molecules in your eyes absorb that light and, as a result, are altered in a way that sends a signal to your brain. Molecules in your brain then interpret the signal to produce images and emotions. This whole process—mediated by molecules—creates the evocative experience of seeing a sunset.

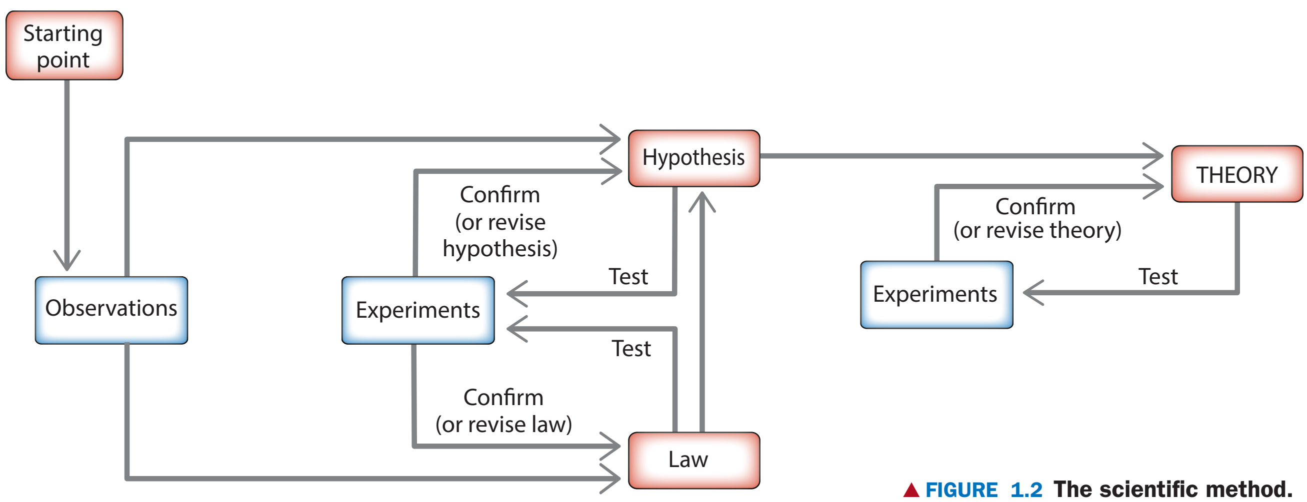
Chemists are interested in why ordinary substances are the way they are. Why is water a liquid? Why is salt a solid? Why does soda fizz? Why is a sunset red? Throughout this book, you will learn the answers to these questions and many others. *You will learn the connections between the behavior of matter and the structure of the particles that compose it.*

1.3 The Scientific Method: How Chemists Think

▶ Identify and understand the key characteristics of the scientific method: observation, the formulation of hypotheses, the testing of hypotheses by experiment, and the formulation of laws and theories.

Chemists use the **scientific method**—a way of learning that emphasizes observation and experimentation—to understand the world. The scientific method stands in contrast to ancient Greek philosophies that emphasized *reason* as the way to understand the world. Although the scientific method is not a rigid procedure that automatically leads to a definitive answer, it does have key characteristics that distinguish it from other ways of acquiring knowledge. These key characteristics include observation, the formulation of hypotheses, the testing of hypotheses by experiment, and the formulation of laws and theories.

The first step in acquiring scientific knowledge (▼ **FIGURE 1.2**) is often the **observation** or measurement of some aspect of nature. Some observations are simple, requiring nothing more than the naked eye. Other observations rely



▲ **FIGURE 1.2 The scientific method.**

on the use of sensitive instrumentation. Occasionally, an important observation happens entirely by chance. Alexander Fleming (1881–1955), for example, discovered penicillin when he observed a bacteria-free circle around a certain mold that had accidentally grown on a culture plate. Regardless of how these observations occur, they usually involve the measurement or description of some aspect of the physical world. For example, Antoine Lavoisier (1743–1794), a French chemist who studied *combustion*, burned substances in closed containers. He carefully measured the mass of each container and its contents before and after burning the substance inside, noting that there was no change in the mass during combustion. Lavoisier made an *observation* about the physical world.

Combustion means burning. The mass of an object is a measure of the quantity of matter within it.

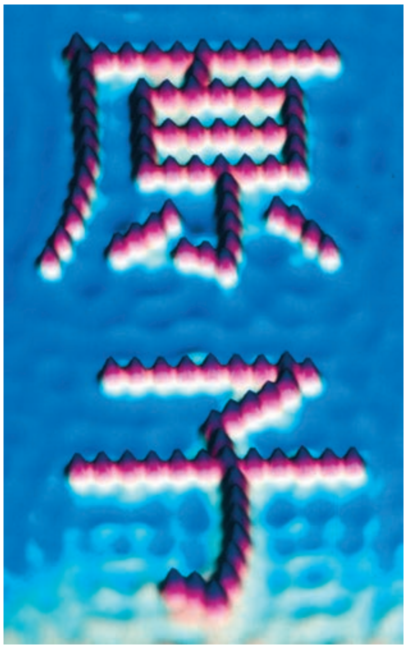
Observations often lead scientists to formulate a **hypothesis**, a tentative interpretation or explanation of the observations. Lavoisier explained his observations on combustion by hypothesizing that combustion involved the combination of a substance with a component of air. A good hypothesis is *falsifiable*, which means that further testing has the potential to prove it wrong. Hypotheses are tested by **experiments**, highly controlled observations designed to validate or invalidate hypotheses. The results of an experiment may confirm a hypothesis or show the hypothesis to be mistaken in some way. In the latter case, the hypothesis may have to be modified, or even discarded and replaced by an alternative hypothesis. Either way, the new or revised hypothesis must also be tested through further experimentation.

Sometimes a number of similar observations lead to the development of a **scientific law**, a brief statement that summarizes past observations and predicts future ones. For example, based on his observations of combustion, Lavoisier developed the **law of conservation of mass**, which states, "In a chemical reaction matter is neither created nor destroyed." This statement grew out of Lavoisier's observations, and it predicted the outcome of similar experiments on *any* chemical reaction. Laws are also subject to experiments, which can prove them wrong or validate them.

Scientific theories are also called *models*.

One or more well-established hypotheses may form the basis for a scientific **theory**. Theories provide a broader and deeper explanation for observations and laws. They are models of the way nature is, and they often predict behavior that extends well beyond the observations and laws on which they are founded. A good example of a theory is the **atomic theory** of John Dalton (1766–1844). Dalton explained the law of conservation of mass, as well as other laws and observations, by proposing that all matter was composed of small, indestructible particles called atoms. Dalton's theory was a model of the physical world—it went beyond the laws and observations of the time to explain these laws and observations.

▶ (Right) Painting of the French chemist Antoine Lavoisier and his wife, Marie, who helped him in his work by illustrating his experiments, recording results, and translating scientific articles from English. [*Source:* Jacques Louis David (French, 1748–1825). "Antoine-Laurent Lavoisier (1743–1794) and His Wife (Marie-Anne-Pierrette Paulze, 1758–1836)," 1788, oil on canvas, H. 102-1/4 in. W. 76-5/8 in. (259.7 × 194.6 cm). The Metropolitan Museum of Art, Purchase, Mr. and Mrs. Charles Wrightsman Gift, in honor of Everett Fahy, 1977. (1977.10) Image copyright © The Metropolitan Museum of Art.] (Far right) John Dalton, the English chemist who formulated the atomic theory.



▲ **FIGURE 1.3 Are atoms real?** The atomic theory has 200 years of experimental evidence to support it, including recent images, such as this one, of atoms themselves. This image shows the Kanji (a system of Japanese writing using Chinese characters) for "atom" written with individual iron atoms on top of a copper surface.

Theories are also tested and validated by experiments. Notice that the scientific method begins with observation, and then laws, hypotheses, and theories are developed based on those observations. Experiments, which are carefully controlled observations, determine the validity of laws, hypotheses, or theories. If a law, hypothesis, or theory is inconsistent with the findings of an experiment, it must be revised and new experiments must be conducted to test the revisions. Over time, scientists eliminate poor theories, and good theories—those consistent with experiments—remain. Established theories with strong experimental support are the most powerful pieces of scientific knowledge. People unfamiliar with science sometimes say, "That is just a theory," as if theories were mere speculations. However, well-tested theories are as close to truth as we get in science. For example, the idea that all matter is made of atoms is "just a theory," but it is a theory with 200 years of experimental evidence to support it, including the recent imaging of atoms themselves (◀ FIGURE 1.3). Established theories should not be taken lightly—they are the pinnacle of scientific understanding.

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PEARSON eText 2.0

CONCEPTUAL CHECKPOINT 1.1

Which statement most resembles a scientific theory?

(a) When the pressure on a sample of oxygen gas is increased 10%, the volume of the gas decreases by 10%.

(b) The volume of a gas is inversely proportional to its pressure.

(c) A gas is composed of small particles in constant motion.

(d) A gas sample has a mass of 15.8 g and a volume of 10.5 L.

Note: The answers to all Conceptual Checkpoints appear at the end of the chapter.

EVERYDAY CHEMISTRY

Combustion and the Scientific Method

Early chemical theories attempted to explain common phenomena such as combustion. Why did things burn? What was happening to a substance when it burned? Could something that was burned be unburned? Early chemists burned different substances and made observations to try to answer these questions. They observed that substances stop burning when placed in a closed container. They found that many metals burn to form a white powder that they called a *calx* (now we know that these white powders are oxides of the metal) and that the metal could be recovered from the calx, or unburned, by combining the calx with charcoal and heating it.

Chemists in the first part of the eighteenth century formed a theory about combustion to explain these observations. In this theory, combustion involved a fundamental substance that they called *phlogiston*. This substance was present in anything that burned and was released during combustion. Flammable objects were flammable because they contained phlogiston. When things burned in a closed container, they didn't burn for very long because the space within the container became saturated with phlogiston. When things burned in the open, they continued to burn until all of the phlogiston within them was gone. This theory also explained how metals that had burned could be unburned. Charcoal was a phlogiston-rich material—they knew this because it burned so well—and when it was combined with a calx, which was a metal that had been emptied of its phlogiston, it transferred some of its phlogiston into the calx, converting the calx back into the unburned form of the metal. The phlogiston theory was consistent with all of the observations of the time and was widely accepted as valid.

Like any theory, the phlogiston theory was tested continually by experiment. One set of experiments, conducted in the mid-eighteenth century by Louis-Bernard Guyton de Morveau (1737–1816), consisted of weighing metals before and after burning them. In every case the metals *gained* weight when they were burned. This observation is inconsistent with the phlogiston theory, which predicted that metals should *lose* weight because phlogiston was supposed to be lost during combustion. Clearly, the phlogiston theory needed modification.

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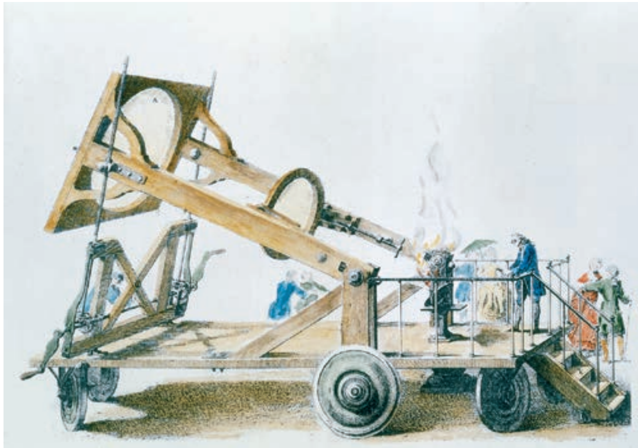
The first modification was that phlogiston was a very light substance, so that it actually "buoyed up" the materials that contained it. Thus when phlogiston was released, the material became heavier. Such a modification seemed to fit the observations but also seemed far-fetched. Antoine Lavoisier developed a more likely explanation by devising a completely new theory of combustion. Lavoisier proposed that, when a substance burned, it actually took something *out* of the air, and when it unburned, it released something back into the air. Lavoisier said that burning objects *fixed* (attached or bonded) the air and that the *fixed* air was released during unburning. In a confirming experiment (▶ FIGURE 1.4), Lavoisier roasted a mixture of calx and charcoal with the aid of sunlight focused by a giant burning lens, and found that a huge volume of "fixed air" was released in the process. The scientific method worked. The phlogiston theory was proven wrong, and a new theory of combustion took its place—a theory that, with a few refinements, is still valid today.

B1.1 CAN YOU ANSWER THIS? *What is the difference between a law and a theory? How does the example of the phlogiston theory demonstrate this difference?*



▲ **FIGURE 1.4 Focusing on combustion** The great burning lens belonging to the Academy of Sciences. Lavoisier used a similar lens in 1777 to show that a mixture of *calx* (metal oxide) and charcoal released a large volume of *fixed air* when heated.

1.4 Analyzing and Interpreting Data

▶ Identify patterns in data and interpret graphs.

We just learned how early scientists such as Lavoisier and Dalton saw patterns in a series of related measurements. Sets of measurements constitute scientific *data*, and learning to analyze and interpret data is an important scientific skill.

Identifying Patterns in Data

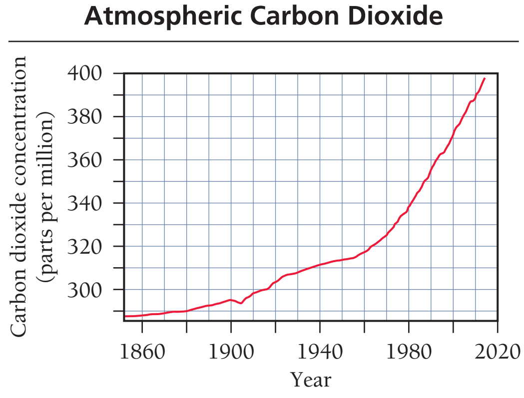
Suppose you are an early chemist trying to understand the composition of water. You know that water is composed of the elements hydrogen and oxygen. You do several experiments in which you decompose different samples of water into hydrogen and oxygen, and you get the following results:

Sample	Mass of Water Sample	Mass of Hydrogen Formed	Mass of Oxygen Formed
A	20.0 g	2.2 g	17.8 g
B	50.0 g	5.6 g	44.4 g
C	100.0 g	11.1 g	88.9 g

Do you notice any patterns in this data? The first and easiest pattern to see is that the sum of the masses of oxygen and hydrogen always sums to the mass of the water sample. For example, for the first water sample, 2.2 g hydrogen + 17.8 g oxygen = 20.0 g water. The same is true for the other samples. Another pattern, which is a bit more difficult to see, is that the ratio of the masses of oxygen and hydrogen is the same for each sample.

Sample	Mass of Hydrogen Formed	Mass of Oxygen Formed	$\frac{\text{Mass Oxygen}}{\text{Mass Hydrogen}}$
A	2.2 g	17.8 g	8.1
B	5.6 g	44.4 g	7.9
C	11.1 g	88.9 g	8.01

The ratio is 8—the small variations are due to experimental error, which is common in all measurements and observations.



▲ **FIGURE 1.5 Atmospheric carbon dioxide levels from 1860 to present.**

Seeing patterns in data is a creative process that requires you to not just merely tabulate laboratory measurements, but to see relationships that may not always be obvious. The best scientists see patterns that others have missed. As you learn to interpret data in this course, be creative and try looking at data in new ways.

Interpreting Graphs

Data is often visualized using graphs or images, and scientists must constantly analyze and interpret graphs. For example, the graph in ◀ **FIGURE 1.5** shows the concentration of carbon dioxide in Earth's atmosphere as a function of time. Carbon dioxide is a greenhouse gas that has been rising as result of the burning of fossil fuels (such as gasoline and coal). When you look at a graph such as this one, you should first examine the *x* and *y* axes and make sure you understand what each axis represents. You should also examine the numerical range of the axes. In Figure 1.5, the *y* axis does not begin at zero in order to better display the change that is occurring. How would this graph look different if the *y* axis began at zero instead of at 290? Notice also that, in this graph, the increase in carbon dioxide has not been constant over time. The rate of increase—represented by the slope of the line—has intensified since about 1960.

EXAMPLE 1.1 Interpreting Graphs

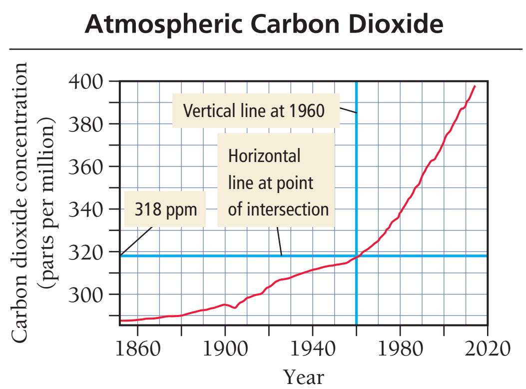
Examine the graph in Figure 1.5 and answer each question.

(a) What was the concentration of carbon dioxide in 1960?
(b) What was the concentration in 2000?
(c) How much did the concentration increase between 1960 and 2000?
(d) What is the average rate of increase over this time?
(e) If the average rate of increase remains constant, estimate the carbon dioxide concentration in 2030.

SOLUTION

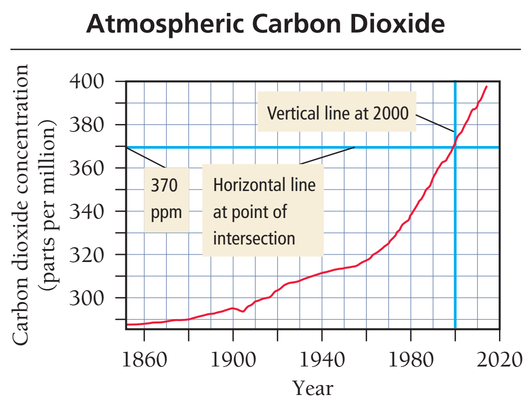
a) What was the concentration of carbon dioxide in 1960?

To determine the concentration of carbon dioxide in 1960, draw a vertical line at the year 1960. At the point where the vertical line intersects the carbon dioxide concentration curve, draw a horizontal line. The point where the horizontal line intercepts the *y* axis represents the concentration in 1960. So, the concentration in 1960 was 318 ppm.



b) What was the concentration in 2000?

Apply the same procedure as in part a, but now shift the vertical line to the year 2000. The concentration in the year 2000 was 370 ppm.



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c) How much did the concentration increase between 1960 and 2000? The increase in the carbon dioxide concentration is the difference between the two concentrations. When calculating changes in quantities such as this, take the final quantity minus the initial quantity.	$\text{increase in concentration} = \text{concentration in 2000} - \text{concentration in 1960}$ $= 390\text{ ppm} - 318\text{ ppm}$ $= 72\text{ ppm}$
d) What is the average rate of increase over this time? The average rate of increase over this time is the change in the concentration divided by the number of years that passed. Determine the number of years that have passed by subtracting the initial year from the final year. Determine the average rate of increase by dividing the change in concentration (from part c) by the number of years that you just calculated.	$\text{number of years} = \text{final year} - \text{initial year}$ $= 2000 - 1960$ $= 40\text{ years}$ $\text{average rate} = \dfrac{\text{change in concentration}}{\text{number of years}}$ $= \dfrac{72\text{ ppm}}{40\text{ years}}$ $= \dfrac{1.8\text{ ppm}}{\text{year}}$
e) If the average rate of increase remains constant, estimate the carbon dioxide concentration in 2030. Determine the increase in concentration between 2000 and 2030 by multiplying the number of years that pass in that time interval by the average rate of change (from part d). Lastly, determine the concentration in 2030 by adding the increase between 2000 and 2030 to the concentration in 2000.	$\text{increase} = 30\text{ years} \times \dfrac{1.8\text{ ppm}}{\text{year}}$ $= 54\text{ ppm}$ $\text{concentration in 2030} = 370\text{ ppm} + 54\text{ ppm}$ $= 424\text{ ppm}$

▶ **SKILLBUILDER 2.1** | What was the average rate of increase in carbon dioxide concentration between 1880 and 1920? Why might that rate be different than the rate between 1960 and 2000?

▶ **FOR MORE PRACTICE** Problem 25.

1.5 A Beginning Chemist: How to Succeed

▲ To succeed as a scientist, you must have the curiosity of a child.

You are a beginning chemist. This may be your first chemistry course, but it may not be your last. To succeed as a beginning chemist, keep the following ideas in mind. First, chemistry requires curiosity and imagination. If you are content knowing that the sky is blue but don't care *why* it is blue, then you may have to rediscover your curiosity. I say "rediscover" because even children—or better, *especially* children—have this kind of curiosity. To succeed as a chemist, you must have the curiosity and imagination of a child—*you must want to know the why of things.*

Second, chemistry requires calculation. Throughout this course, you will be asked to calculate answers and quantify information. *Quantification* involves measurement as part of observation—it is one of the most important tools in science. Quantification allows you to go beyond merely saying that this object is hot and that one is cold or that this one is large and that one is small. It allows you to specify the difference precisely. For example, two samples of water may feel equally hot to your hand, but when you measure their temperatures, you may find that one is 40 °C and the other is 44 °C. Even small differences can be important in a calculation or experiment, so assigning numbers to observations and manipulating those numbers become very important in chemistry.

Lastly, chemistry requires commitment. To succeed in this course, you must commit to learning chemistry. Roald Hoffmann (1937–), winner of the 1981 Nobel Prize for chemistry, said,

> *I like the idea that human beings can do anything they want to. They need to be trained sometimes. They need a teacher to awaken the intelligence within them. But to be a chemist requires no special talent, I'm glad to say. Anyone can do it, with hard work.*

Professor Hoffmann is right. The key to success in this course is hard work—that requires commitment. You must do your work regularly and carefully. If you do, you will succeed, and you will be rewarded by seeing a whole new world—the world of molecules and atoms. This world exists beneath the surface of nearly everything you encounter. I welcome you to this world and consider it a privilege, together with your professor, to be your guide.

Chapter 1 in Review

MasteringChemistry™ provides end-of-chapter exercises, feedback-enriched tutorial problems, animations, and interactive activities to encourage problem solving practice and deeper understanding of key concepts and topics.

Self-Assessment Quiz

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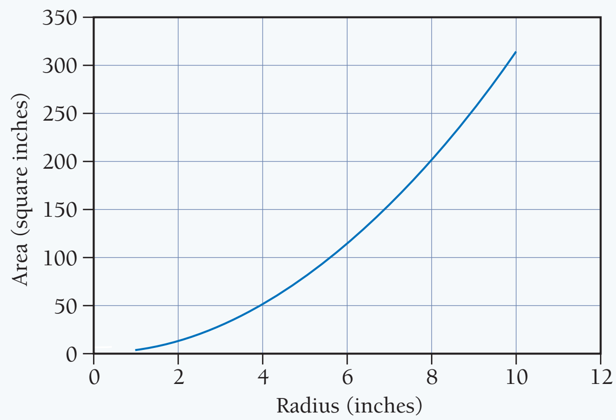
Q1. Where can you find chemicals?
- **(a)** In a hardware store
- **(b)** In a chemical stockroom
- **(c)** All around you and even inside of you
- **(d)** All of the above

Q2. Which statement best defines chemistry?
- **(a)** The science that studies solvents, drugs, and insecticides
- **(b)** The science that studies the connections between the properties of matter and the particles that compose that matter
- **(c)** The science that studies air and water pollution
- **(d)** The science that seeks to understand processes that occur only in chemical laboratories

Q3. According to the scientific method, what is a law?
- **(a)** A short statement that summarizes a large number of observations
- **(b)** A fact that can never be refuted
- **(c)** A model that gives insight into how nature is
- **(d)** An initial guess with explanatory power

Q4. Which statement is an example of an observation?
- **(a)** In a chemical reaction, matter is conserved.
- **(b)** All matter is made of atoms.
- **(c)** When a given sample of gasoline is burned in a closed container, the mass of the container and its contents does not change.
- **(d)** Atoms bond to one another by sharing electrons.

Q5. The graph below shows the area of a circle as a function of its radius. What is the radius of a circle that has an area of 155 square inches?



- **(a)** 7.0 inches
- **(b)** 6.5 inches
- **(c)** 6.8 inches
- **(d)** 6.2 inches

Q6. Which characteristic is necessary for success in understanding chemistry?
- **(a)** Curiosity
- **(b)** Calculation
- **(c)** Commitment
- **(d)** All of the above

Answers: 1: d, 2: b, 3: a, 4: c, 5: a, 6: d

Chemical Principles

Matter and Molecules

Chemists are interested in all matter, even ordinary matter such as water or air. You don't need to go to a chemical storeroom to find chemicals because they are all around you. Chemistry is the science that studies the connections between the properties of matter and the particles that compose that matter.

Relevance

Chemists want to understand matter for several reasons. First, chemists are simply curious—they want to know why. Why are some substances reactive and others not? Why are some substances gases, some liquids, and others solids? Chemists are also practical; they want to understand matter so that they can control it and produce substances that are useful to society and to humankind.

The Scientific Method

Chemists employ the scientific method, which makes use of observations, hypotheses, laws, theories, and experiments. Observations involve measuring or observing some aspect of nature. Hypotheses are tentative interpretations of observations. Laws summarize the results of a large number of observations, and theories are models that explain and give the underlying causes for observations and laws. Hypotheses, laws, and theories must be tested and validated by experiment. If they are not confirmed, they are revised and tested through further experimentation.

The scientific method is a way to understand the world. Since the inception of the scientific method, knowledge about the natural world has grown rapidly. The application of the scientific method has produced technologies that have raised living standards throughout the world with advances such as increased food production, rapid transportation, unparalleled access to information, and longer life spans.

Analyzing and Interpreting Data

A series of measurements are often referred to as data. Scientific data can be graphed to better see relationships between variables.

Virtually all scientists have to analyze and interpret the data they collect. This skill is an important part of understanding chemistry.

Success as a Beginning Chemist

To succeed as a beginning chemist, you must be curious and imaginative, be willing to do calculations, and be committed to learning the material.

To succeed as a beginning chemist, you must be curious and imaginative, be willing to do calculations, and be committed to learning the material.

Key Terms

atomic theory **[1.3]**
chemistry **[1.1]**
experiment **[1.3]**
hypothesis **[1.3]**
law of conservation of mass **[1.3]**
observation **[1.3]**
scientific law **[1.3]**
scientific method **[1.3]**
theory **[1.3]**

Exercises

Questions

Answers to all questions numbered in blue appear in the Answers section at the back of the book.

1. Why does soda fizz?
2. What are chemicals? Give some examples.
3. What do chemists try to do? How do they understand the natural world?
4. What is meant by the statement, "Matter does what molecules do"? Give an example.
5. Define *chemistry*.
6. How is chemistry connected to everyday life? How is chemistry relevant outside the chemistry laboratory?
7. Explain the scientific method.
8. Cite an example from this chapter of the scientific method at work.
9. What is the difference between a law and a theory?
10. What is the difference between a hypothesis and a theory?
11. What is wrong with the statement, "It is just a theory"?
12. What is the law of conservation of mass, and who discovered it?
13. What is the atomic theory, and who formulated it?
14. What are three things you need to do to succeed in this course?

Problems

Note: The exercises in the Problems section are paired, and the answers to the odd-numbered exercises (numbered in blue) appear in the Answers section at the back of the book.

15. Classify each statement as an observation, a law, or a theory.
    (a) When a metal is burned in a closed container, the sum of the masses of the container and its contents does not change.
    (b) Matter is made of atoms.
    (c) Matter is conserved in chemical reactions.
    (d) When wood is burned in a closed container, its mass does not change.
16. Classify each statement as an observation, a law, or a theory.
    (a) The star closest to Earth is moving away from Earth at high speed.
    (b) A body in motion stays in motion unless acted upon by a force.
    (c) The universe began as a cosmic explosion called the Big Bang.
    (d) A stone dropped from an altitude of 450 m falls to the ground in 9.6 s.

17. A student prepares several samples of the same gas and measures their mass and volume. The results are tabulated as follows. Formulate a tentative law from the measurements.

Mass of Gas (in g)	Volume of Gas (in L)
22.5	1.60
35.8	2.55
70.2	5.00
98.5	7.01

18. A student measures the volume of a gas sample at several different temperatures. The results are tabulated as follows. Formulate a tentative law from the measurements.

Temperature of Gas (in K)	Volume of Gas (in L)
298	4.55
315	4.81
325	4.96
335	5.11

19. A chemist in an imaginary universe does an experiment that attempts to correlate the size of an atom with its chemical reactivity. The results are tabulated as follows.

Size of Atom	Chemical Reactivity
small	low
medium	intermediate
large	high

(a) Formulate a law from this data.
(b) Formulate a theory to explain the law.

20. A chemist decomposes several samples of water into hydrogen and oxygen and measures the mass of the hydrogen and the oxygen obtained. The results are tabulated as follows.

Sample Number	Grams of Hydrogen	Grams of Oxygen
1	1.5	12
2	2	16
3	2.5	20

(a) Summarize these observations in a short statement.
Next, the chemist decomposes several samples of carbon dioxide into carbon and oxygen. The results are tabulated as follows:

Sample Number	Grams of Carbon	Grams of Oxygen
1	0.5	1.3
2	1.0	2.7
3	1.5	4.0

(b) Summarize these observations in a short statement.
(c) Formulate a law from the observations in **(a)** and **(b)**.
(d) Formulate a theory that might explain your law in **(c)**.

Questions for Group Work

Discuss these questions with the group and record your consensus answer.

21. The manufacturer of a particular brand of toothpaste claims that the brand contains "no chemicals." Using a few grammatically correct English sentences, describe what you think the company means by that statement. Would a scientist consider the manufacturer's statement to be correct? Why or why not?

22. Make a list (including up to ten items) of all the atoms or molecules group members can name off the top of their heads. Get at least one contribution from each group member.

23. In your own words, provide a brief definition for each of the following: observation, law, hypothesis, and theory.

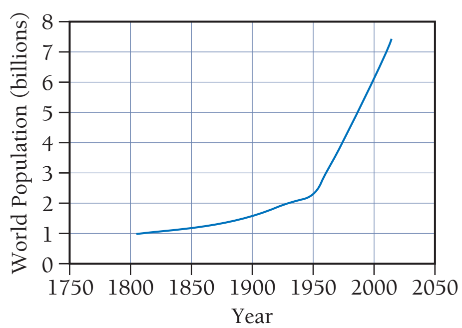
24. How curious are you? How good are your quantitative skills? How hard are you willing to work to succeed in chemistry? Answer these questions individually on a scale of 1 (= not at all) to 5 (= very), then share your answers with your group. Report the group average for each question.

Data Interpretation and Analysis

25. The graph displays world population over time. Study the graph and answer the following questions.

(a) What was the world population in 1950?
(b) What was the world population in 2010?
(c) How much did the population increase between 1950 and 2010?
(d) What is the average rate of increase over this time?
(e) If the average rate of increase remains constant, estimate the world population in 2035.

World Population Versus Time



Source: http://www.worldometers.info/world-population/

Answers to Conceptual Checkpoints

1.1 (c) Answers a and d are observations. Answer b is a scientific law. Answer c is the only answer that proposes a *model* for what a gas is like.