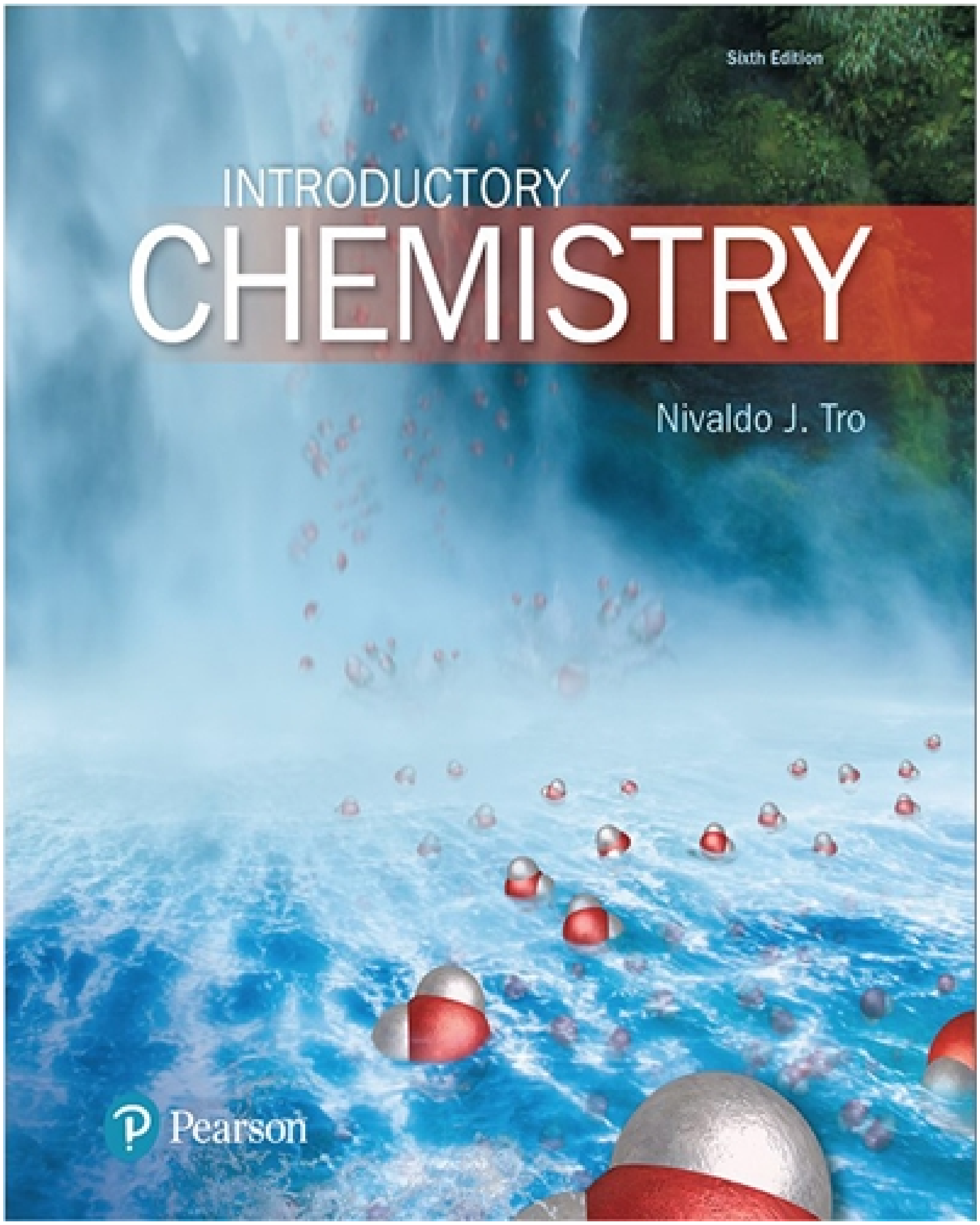
Solutions for Introductory Chemistry 6th Edition by Tro



Solutions

Measurement and Problem Solving

2

Chapter Overview

Chapter 2 introduces the student to a cornerstone of the chemical sciences, the manipulation of numbers and their associated units. These concepts are very important for the rest of the course, and in order to be successful in this course, students must understand them well. Simple and complex unit conversions as well as problem-solving strategies will be covered and explained in detail.

Lecture Outline

2.1 The Metric Mix-up: $125 Million Unit Error
2.2 Scientific Notation: Writing Large and Small Numbers
- Learning Objective: Express very large and very small numbers using scientific notation.
- A. Shorthand notation for numbers
- B. Two main pieces: decimal and power-of-10 exponent
- C. Measured value does not change, just how you report it

2.3 Scientific Figures: Writing Numbers to Reflect Precision
- Learning Objective: Report measured quantities to the right number of digits.
- Learning Objective: Determine which digits in a number are significant.
- A. How many digits can I report? How many should I report?
- B. Certain digits and estimated digits
- C. Counting significant figures
    1. All nonzero digits are significant
    2. Interior zeros are significant
    3. Trailing zeros after a decimal point are significant
    4. Trailing zeros before a decimal point are significant
    5. Leading zeros are not significant
    6. Zeros at the end of a number, but to the left of a decimal point, are ambiguous
- D. Exact numbers

2.4 Significant Figures in Calculations
- Learning Objective: Round numbers to the correct number of significant figures.
- Learning Objective: Determine the correct number of significant figures in the results of multiplication and division calculations.
- Learning Objective: Determine the correct number of significant figures in the results of addition and subtraction calculations.
- Learning Objective: Determine the correct number of significant figures in the results of calculations involving both addition/subtraction and multiplication/division.

- A. Multiplication and Division
  - 1. Result carries as many significant digits as the factor with the fewest significant digits
- B. Rounding
  - 1. If leftmost dropped digit is 4 or less, round down
  - 2. If leftmost dropped digit is 5 or higher, round up
- C. Addition and Subtraction
  - 1. Result carries as many decimal places as the quantity with the fewest decimal places
- D. Calculations Involving Both Multiplication/Division and Addition/Subtraction
  - 1. Do steps in parentheses first
  - 2. Determine the number of significant figures in intermediate answer
  - 3. Do remaining steps

2.5 The Basic Units of Measurement

Learning Objective: Recognize and work with the SI base units of measurement, prefix multipliers, and derived units.

- A. English, metric, SI
- B. SI Units
  - 1. Length – m
  - 2. Mass – kg
  - 3. Time – s
- C. Prefix Multipliers
  - 1. milli (m) 0.001
  - 2. centi (c) 0.01
  - 3. kilo (k) 1000
  - 4. Mega (M) 1,000,000
- D. Derived Units
  - 1. Area – cm^2
  - 2. Volume – cm^3 or L

2.6 Problem Solving and Unit Conversions

Learning Objective: Convert between units.

- A. Units are important, most numbers have one
- B. Include units in all calculations
- C. Conversion factors change one unit to another, the value is unchanged
- D. General problem-solving strategy
  - 1. Sort
  - 2. Strategize
  - 3. Solve
  - 4. Check

2.7 Solving Multistep Conversion Problems

Learning Objective: Convert between units.

- A. Understand where you are going first
- B. Not all calculations can be done in one step

2.8 Unit Conversion in Both the Numerator and Denominator

Learning Objective: Convert units in a quantity that has units in the numerator and the denominator.

2.9 Units Raised to a Power

Learning Objective: Convert units raised to a power.

A. 1 inch = 2.54 cm, so 1 $inch^3 = (2.54)^3\ cm^3 = 16.4\ cm^3$

2.10 Density

Learning Objective: Calculate the density of a substance.

Learning Objective: Use density as a conversion factor.

A. Mass per unit volume

B. Derived unit

C. Can be used as a conversion factor between mass and volume

2.11 Numerical Problem-Solving Strategies and the Solution Map

A. Come up with a plan before you use your calculator

B. Use the units to guide your plan

Chemical Principle Teaching Ideas

Uncertainty

Students generally have a hard time understanding this concept. One method is to refer to everyday objects that they recognize. For example, you can talk about a coffee cup containing about 200 mL of coffee. You then ask the students what the new volume would be if you were to add a drop of water with a volume of 0.05 mL.

Units

Units are very important, and should always be used. Consider giving the students a measured value in many different units and having them guess what the unit is. Report the volume of your mug in barrels. What is the volume of the room measured in teaspoons?

Density

Most students understand the concept of density or how much stuff is packed into a particular volume. What they have a harder time recognizing is the fact that it is a conversion factor between mass and volume. This is the easiest example that is discussed and should be emphasized as this concept is used frequently throughout the course.

Skill Builder Solutions

2.1. Assuming all the trailing zeros are not significant, the decimal moves over 13 spaces to give $\$1.8416 \times 10^{13}$.

2.2. Not all the leading zeros are significant, so we move the decimal over 5 places to give 3.8×10^{-5}.

2.3. Each of the markings on the thermometer represents 1 degree Fahrenheit. We can therefore estimate one digit past the decimal place for a temperature of 103.4 degrees Fahrenheit.

2.4. a. 4
b. 3, as leading zeros do not count, but trailing zeros after the decimal do
c. 2
d. Unlimited significant figures
e. 3
f. Ambiguous, since you do not know if the last two zeros are significant

2.5. a. $\dfrac{1.10 \times 0.512 \times 1.301 \times 0.005}{3.4} = 0.001$ or 1×10^{-3}. There is only one significant digit in the final answer, as the 0.005 has only one significant digit in the numerator.

b. $\dfrac{4.562 \times 3.99870}{89.5} = 0.204$. The number 89.5 has the smallest number of significant digits, 3, so that is how many are quoted in the final answer.

2.6. a. $2.18 + 5.621 + 1.5870 - 1.8 = 7.6$. Only one digit past the decimal place is quoted because the least accurately known number (1.8) has one digit past the decimal.
b. $7.876 - 0.56 + 123.792 = 131.11$. Two digits past the decimal are quoted because 0.56 has two past the decimal and is the number with the fewest digits past the decimal.

2.7. a. $3.897 \times (782.3 - 451.88) = 3.897 \times 330.\underline{4}2 = 1288$. Four digits are quoted because the number in the second (multiplication) step with the fewest significant digits has four of them.

b. $\dfrac{4.58}{1.239} - 0.578 = 3.70 - 0.578 = 3.12$. Two digits past the decimal are quoted because the first part of the subtraction (3.70) has two digits past the decimal place.

2.8. $56.0\ \cancel{\text{cm}} \times \dfrac{1\ \text{inch}}{2.54\ \cancel{\text{cm}}} = 22.0\ \text{inch}$

2.9. $5{,}678\ \cancel{\text{m}} \times \dfrac{1\ \text{km}}{1000\ \cancel{\text{m}}} = 5.678\ \text{km}$

2.10. $1.2\ \cancel{\text{cu}} \times \dfrac{1\ \cancel{\text{qt}}}{4\ \cancel{\text{cu}}} \times \dfrac{1\ \text{L}}{1.057\ \cancel{\text{qt}}} = 0.28\ \text{L}$

2.11. $15.0\ \cancel{\text{km}} \times \dfrac{0.6214\ \cancel{\text{mi}}}{1\ \cancel{\text{km}}} \times \dfrac{5280\ \cancel{\text{ft}}}{1\ \cancel{\text{mi}}} \times \dfrac{1\ \text{lap}}{1056\ \cancel{\text{ft}}} = 46.6\ \text{laps}$

Plus. $5.72\ \cancel{\text{naut mi}} \times \dfrac{1.151\ \cancel{\text{mi}}}{1\ \cancel{\text{naut mi}}} \times \dfrac{1\ \cancel{\text{km}}}{0.6214\ \cancel{\text{mi}}} \times \dfrac{1000\ \text{m}}{1\ \cancel{\text{km}}} = 1.06 \times 10^4\ \text{m}$

2.12 $\dfrac{65\ \cancel{\text{km}}}{1\ \cancel{\text{hr}}} \times \dfrac{1\ \cancel{\text{hr}}}{60\ \cancel{\text{min}}} \times \dfrac{1\ \cancel{\text{min}}}{60\ \text{s}} \times \dfrac{1000\ \text{m}}{1\ \cancel{\text{km}}} = 18\ \text{m/s}$

2.13. $289.7\ \cancel{\text{in}^3} \times \dfrac{(2.54)^3\ \text{cm}^3}{1\ \cancel{\text{in}^3}} = 4747\ \text{cm}^3$

2.14. $3.25\ \cancel{\text{yd}^3} \times \dfrac{(36)^3\ \text{inch}^3}{1\ \cancel{\text{yd}^3}} = 1.52 \times 10^5\ \text{inch}^3$

2.15. $\dfrac{9.67\ \text{g}}{0.452\ \text{cm}^3} = 21.4\ \text{g/cm}^3$; Therefore, the ring is genuine platinum.

2.16. $35\ \cancel{\text{mg}} \times \dfrac{1\ \cancel{\text{g}}}{1000\ \cancel{\text{mg}}} \times \dfrac{1\ \text{cm}^3}{0.788\ \cancel{\text{g}}} = 4.4 \times 10^{-2}\ \text{cm}^3$

Plus. $246\ \cancel{\text{cm}^3} \times \dfrac{7.93\ \cancel{\text{g}}}{1\ \cancel{\text{cm}^3}} \times \dfrac{1\ \text{kg}}{1000\ \cancel{\text{g}}} = 1.95\ \text{kg}$

2.17. $0.82\ \cancel{\text{L}} \times \dfrac{1000\ \cancel{\text{mL}}}{1\ \cancel{\text{L}}} \times \dfrac{19.3\ \cancel{\text{g}}}{1\ \cancel{\text{mL}}} \times \dfrac{1\ \text{kg}}{1000\ \cancel{\text{g}}} = 16\ \text{kg}$

2.18. $\dfrac{23.2\ \cancel{\text{mg}} \times \dfrac{1\ \text{g}}{1000\ \cancel{\text{mg}}}}{1.20\ \cancel{\text{mm}^3} \times \dfrac{1\ \text{cm}^3}{(10)^3\ \cancel{\text{mm}^3}}} = \dfrac{2.32 \times 10^{-2}\ \text{g}}{1.20 \times 10^{-3}\ \text{cm}^3} = 19.3\ \text{g/cm}^3$

Yes, it is consistent with the density of gold.

Suggested Demonstrations

Density and Miscibility of Liquids, *Chemical Demonstrations* 3:233, Shakhashiri, B. Z. University of Wisconsin Press, 1989.

Guided Inquiry Ideas

Below are a few example questions that students answer in the guided inquiry activities provided in the Guided Activity Workbook.

How many significant figures are there in the number 0.0051? Underline it/them.

How many significant figures are there in the number 5.00? Underline it/them.

In a complete sentence or two, describe when you know a “trailing zero” is significant.

In a complete sentence, describe the significance of “leading zeros.”

Which of the following is a correct conversion factor from cm^3 to in^3? Circle all that apply.

$\left(\dfrac{1\ \text{in}^3}{2.54\ \text{cm}^3}\right) \qquad \left(\dfrac{1\ \text{in}}{2.54\ \text{cm}}\right)^3 \qquad \left(\dfrac{1\ \text{in}^3}{16.4\ \text{cm}^3}\right)$

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ChemActivity 1A: Atoms and Molecules

Answers to Critical Thinking Questions

1. 2
2. 2
3. Only one circle
4. More than one atom
5. They have different atoms, They have different numbers of atoms, etc.
6. A molecule is composed of two or more atoms.
7. An observation
8. No---laws are very general
9. Yes. One could observe something that contradicts a law and show that it is invalid.
10. A law summarizes a large number of observations.
11. Boyle's law
12. The law of conservation of mass
13. Theories explain why laws are true.
14. No. Laws summarize observations and theories explain laws.

ChemActivity 2A: Writing Numbers

Answers to Critical Thinking Questions

1. Statement 1
2. Statement 2
3. The one saying Statement 2. This scientist communicated more precision with more digits.
4. Statement 3
5. 0.6 °C
6. Their level of certainty. (The precision.)
7. 3
8. 10^3
9. 3
10. 10^{-3}
11. The number of factors of 10 or 1/10
12. In the boxes starting in the top left blank…
    a. 10·10·10·10·10·10
    b. 10^6
    c. (1/10)· (1/10)· (1/10)· (1/10)· (1/10)· (1/10)· (1/10)
    d. 10^{-7}
13. 5983
14. 5983 = 5.983 × 1000
15. 3
16. 0.00034 = **3.4** ÷ 10000 = **3.4** × (1/10) ×(1/10) ×(1/10) ×(1/10) = **3.4** × 10^{-4}
17.
    a. Write the number as a number between 1 and 10
    b. Determine how many factors of 10 or 1/10 are needed to make the number the same as the original
    c. Write those factors of 10 or 1/10 as the number 10 raised to an exponent
18. 1; 5
19. 3; 5.00
20. 1; 500
21. When a trailing zero is after a decimal point it is significant.
22. 2; 0.0051
23. Leading zeros are not significant
24. 4; 5.003
25. 1) after a decimal point, 2) between non-zero digits
26. Whether the zeros are significant or not
27. Scientific notation
28. (see answer in model)
29. (see table)

5.02	× 89.665	× 0.10	= 45.01183	= **45** (final answer)	
3	5	2		2	significant figures
2	3	2		0	# digits after dec. pt.

	s.f.	# digits after decimal pt.
1. 74	3	2
11. 8231	6	4
+ 12. 651	5	3
26. 2141		
Final Answer → **26. 21**	4	2

30. number of significant figures
31. number of decimal places

ChemActivity 2B: Units

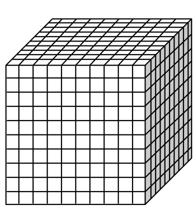
Answers to Critical Thinking Questions

1. m, kg, K
2. kg
3. False. kg is a base unit, and it has a prefix.
4. (answers will vary)
5. m; c; M; n; G
6. mg; nm; ps; dm; μK
7. 2.54
8. 1
9. 1 because the numerator and denominator are equal
10. 1
11. no
12. no; you are multiplying by 1
13. yes; 26.2 cm
14. We wanted to cancel in and keep cm
15. 1) The top and bottom are equal; 2) The units you want are on the top and the units you want to cancel are on the bottom.

ChemActivity 2C: More with Conversions

Answers to Critical Thinking Questions

1. 1
2. No
3. $$5.4 \text{ ft} \times \left(\frac{12 \text{ in}}{\mathbf{1\ ft}}\right) \times \left(\frac{\mathbf{2.54\ cm}}{1 \text{ in}}\right) = \mathbf{160} \quad \text{cm}$$
4. in ; m
5. 3 ft/1 yd; 12 in/1 ft; 2.54 cm/1 in; 0.01 m/1 cm; 1 km/1000m
6. 100 yd×(3 ft/1 yd)×(12 in/1 ft)×(2.54 cm/1 in)×(0.01 m/1 cm)×(1 km/1000m)=0.0914 km
7. A solution map shows the order in which units will be changed, starting with the units given and ending with the desired units.
8. yes; no
9. m^3
10. m/s
11. kg/m^3
12. 0.1 m
13. 0.001
14. no
15. no; 4.5 g = 1 cm^3
16. (1 cm^3/4.5 g) and (4.5 g/1 cm^3)
17. 1590 g × (1 cm^3/4.5 g) = 350 cm^3
18. 1.00
19. 1.00 in^3
20. 2.54 cm
21. 2.54 cm
22. $(2.54 \text{ cm})^3 = 16.4 \text{ cm}^3$
23. 16.4
24. Circle both: $\left(\frac{1 \text{ in}}{2.54 \text{ cm}}\right)^3$ $\left(\frac{1 \text{ in}^3}{16.4 \text{ cm}^3}\right)$
25. 10
26.



27. $(1 \text{ m}/10 \text{ dm})^3$ = 1 m^3/1000 dm = 1 m^3/1000 L
28. 5 m × 8 m × 3 m = 120 m^3
29. 120 m^3 × (1000 L/1 m^3) = 1.2×10^5 L

ChemActivity 3A: Classifying Matter

Answers to Critical Thinking Questions

1. No
2. No
3. Yes (a little)
4. gas
5. Something is compressible if it can be made smaller by squeezing it.
6. stay about the same
7. a lot bigger
8. gas
9. Solid and liquid. Because the gas is much bigger but the same amount of solid and liquid are about the same size.
10. liquid and gas
11. Because solids don't flow, the molecules must not be free to move around each other.
12. Similar to Fig. 3.4 in *Introductory Chemistry*
13. copper pipe
14. copper pipe, sugar
15. copper pipe, sugar
16. No. Sugar has more than one element, but they are all in one molecule.
17. sugar; yes, in the tea contents, etc.
18. tea and vinaigrette dressing
19. Answers will vary. (E.g. *The vinaigrette dressing has oil on top and water on the bottom. It also has other stuff in it.*)
20. tea; dressing
21. Answers will vary

ChemActivity 3B: Chemical Change

Answers to Critical Thinking Questions

1. physical
2. physical
3. physical; melting point is listed in the table as physical, and boiling is a similar process
4. chemical
5. Chemical properties refer to reactivity, while physical properties do not.
6. physical
7. no
8. chemical
9. yes
10. In chemical change a new compound is formed.
11. chemical; a new compound is formed
12. 58 g butane, 208 g oxygen
13. 176 g carbon dioxide; 90 g water
14. 266 g
15. 266 g
16. the compounds present
17. the mass
18. 4.184
19. 4184
20. 3.60×10^{6}
21. J < cal < Cal < kWh
22. (4.184 J/1 cal)
23. 115 Cal × (1000 cal/1 Cal) × (4.184 J/1 cal) = 4.31×10^{5} J
24. Energy moves from the car to the air as heat.
25. reactants
26. given off
27. given off
28. absorbing
29. the product it goes uphill by absorbing energy
30. Similar to the second part of figure 3.16 in *Introductory Chemistry*

ChemActivity 3C: Temperature and Heat

Answers to Critical Thinking Questions

1. 180 °
2. 100 °
3. 100 °
4. Celsius and Kelvin
5. A degree Celsius because there are fewer of them between freezing and boiling, so each one must be bigger
6. Yes, they are just shifted by 273
7. K = °C + 273.15 = 100 + 273.15 = 373.15 °C. Yes, it is consistent.
8. °C = (°F-32)/1.8
9. (212 °F-32)/1.8 = 100 °C
10. (70 °F -32)/1.8 = 21.1 °C
11. °F = 1.8 ×°C + 32
12. (1.8)(21.1) + 32 = 69.98 °F
13. Twice as much material should take twice as much heat. 4.184 × 2 = 8.368 J
14. Temperature change is 17 times greater, so it should take 17 times as much heat 4.184 × 17 = 71.13 J
15. Both have doubled so it should take four times as much heat 4.184 × 2 × 2 = 16.74 J
16. 37 times the temperature and 250 times the amount… 4.184 × 37 × 250 = 38.7 kJ
17. *q*; *m*; *C*; Δ*T*
18. 4.184 J/g °C
19. q = (2 g)(4.184 J/g °C)(2 °C) = 16.74 J
20. yes
21. yes
22. q = (2 g)(0.903 J/g °C)(2 °C) = 3.612 J
23. aluminium; it takes less heat to warm it by 1 °C, so the same amount of heat will warm it more
24. It is the ability of a substance to absorb heat without changing temperature.

ChemActivity 4A: Atoms and Elements (I)

Answers to Critical Thinking Questions

1. It seems continuous. No matter how small of a drop, it is still water.
2. Greek philosophers
3. atoms
4. John Dalton
5. Atoms are indivisible. There is no such thing as "half an oxygen atom".
6. Water is formed when one oxygen atom combines with two hydrogen atoms.
7. No. It will go through the paper.
8. It will go out the back of the room.
9. There must be a wooden rod in that room.
10. Throw lots of balls into each room. If any come back, that room must be the one with the wooden rods.
11. evenly distributed
12. More like tissue paper because it is evenly distributed across the room.
13. alpha particles
14. Most pass through with no deflection
15. No. A few are deflected at large angles.
16. More like wooden rods because some particles bounced back.
17. Rutherford proposed a model for the atom in which the matter is distributed in a few small concentrated locations.
18. proton and neutron
19. electron
20. 1.0073 amu/0.00055 amu= 1831 (electrons per proton are the actual units for this)
21. proton and electron
22. one
23. They are the same because the cancel each other out
24. protons and neutrons

ChemActivity 4B: Atoms and Elements (II)

Answers to Critical Thinking Questions

1. Si
2. P
3. K
4. Some symbols are clearly abbreviations, but not all.
5. No. They are not capitalized in CTQ 1-3 above.
6. The first letter in a symbol is capitalized. If there is another letter, it is not capitalized.
7. Antimony
8. 14; 79
9. The number of protons is in the periodic table above the symbol.
10. 19; 51
11. oxygen
12. proton
13. This must be nitrogen, not carbon, because the number of protons determines the identity of the element.
14. See Fig. 4.12 in Introductory Chemistry
15. Metals. See Fig. 4.12 in Introductory Chemistry
16. See Fig. 4.12 in Introductory Chemistry
17. See Fig. 4.12 in Introductory Chemistry
18. See the figure on p. 104 of Introductory Chemistry
19.
    a. rubidium: alkali metals
    b. vanadium: transition metal
    c. bromine: halogen
    d. neon: noble gas
    e. strontium: alkaline earth metal

ChemActivity 4C: Ions, Isotopes, and Atomic Mass

Answers to Critical Thinking Questions

1. 12; 12
2. +12
3. -10
4. There are two more protons than electrons, so the total charge is 2+.
5. 9
6. It must have the same number of electrons as protons: 9.
7. 9
8. It must have one more electron than protons: 10.
9. Neutral atoms have the same number of protons and electrons. Ions have unequal number.
10. An ion is an atom with an unequal number of protons and electrons, and therefore a non-zero charge.
11. A superscript to the right of the symbol.
12. Ion charge = $N_P - N_e$
13. The charge is 1+. The symbol is Na^+.
14. Li^+
15. K^+
16. Na^+
17. O^{2-}, F^-, Mg^{2+}
18. (add Ne to the right of F)
19. 10
20. 10
21. They are the same
22. 10
23. They are the same
24. Ions have the charges they do because atoms tend to form ions with the same number of electrons as the nearest noble gas.
25. 6
26. 1 amu
27. If it had more protons, it would not be carbon but some other element.
28. Electrons have so little mass that more electrons would not make a significant difference.
29. the neutron!
30. 6 amu
31. 6
32. 7
33. 1,000
34. 11,868 amu

35. 143 amu
36. 12,011 amu
37. 12.011 amu
38. Yes. It is under the symbol for carbon.
39. It means that the average of all the atoms is 35.45 amu. It may be that no atoms weigh exactly this amount.

ChemActivity 5A: Combining Elements

Answers to Critical Thinking Questions

1. (answers in table)
2. Total = 4.5; Ratios both = 8.0
3. mass of H, mass of O, total mass
4. The ratio mass O/mass H
5. 80 g
6. 2 Hs, 1 O
7. H_2O
8. No. The 2 should be subscript.
9. hydrogen peroxide, H_2O_2
10. Hydrogen peroxide has two atoms of oxygen and water has only one.
11. 1
12. Yes. One of each and no subscripts.
13. CO_2
14. 12 Cs, 22 Hs, 11 Os
15. 1
16. 2
17. subscript 2
18. 2
19. subscript 2
20. O and H are in parentheses. The 2 applies to both.
21. 2
22. 6
23. 2
24. Yes. The subscript on the parentheses.
25. Parentheses indicate a group of atoms that can all be multiplied by a subscript.
26. 8 Two NH_4 units with four H atoms in each unit. 2x4=8.
27. 500: one for each H
28. Only the ratio of atoms
29. H_2O_2
30. 2 Hs, 2 Os
31. Yes. There is one H for each O in the compound.
32. HO correctly communicates the ratio of atoms in the compound, but it does not communicate the actual number of atoms in one molecule. H_2O_2 also says how many atoms are in one molecule.
33. CH_2O

ChemActivity 5B: Types of Compounds

Answers to Critical Thinking Questions

1. He, Ar, O_2, N_2
2. H_2O, $C_6H_{12}O_6$, NaCl, $Mg(OH)_2$
3. No
4. Elements have only one kind of atom. Compounds are composed of more than one element.
5. atomic and molecular
6. Atomic elements have one atom. Molecular elements are composed of two of the same kind of atom bonded together.
7. left
8. right
9. Hydrogen is on the left, but it is a nonmetal
10. (circle Na and Mg)
11. No
12. Molecular compounds are composed only of nonmetals.
13. Ionic compounds all have a metal combined with a (some) nonmetal(s).
14. Yes
15. If a compound has only nonmetals, it is molecular. If it has a metal and nonmetals, it is ionic.
16. The metallic element
17. molecular: CH_4, CCl_4; ionic: KBr, Na_2CO_3
18. 2+
19. 2-
20. 3+
21. 3-
22. They are the same.
23. Yes
24. Al_2O_3
25. Yes

ChemActivity 5C: Naming Compounds

Answers to Critical Thinking Questions

1. Cations are positive, anions are negative.
2. Na, Al, Mg
3. sodium, aluminum, magnesium
4. If an atom always forms an ion with the same charge, the name of the ion is the same as the name of the atom.
5. calcium
6. Fe
7. iron(II), iron (III)
8. It always forms the same ion.
9. If an atom forms an ion with a fixed charge, the name of the ion is the same as the name of the atom. If an atom can form multiple ions, the name of the ion is the name of the atom followed by the charge in roman numerals in parentheses.
10. chloride, bromide, iodide
11. The name of an ion is the name of the atom with –ide added in place of the previous ending.
12. oxide
13. It has a metal and a nonmetal.
14. sodium
15. chloride
16. The name for the compound is the name of the cation followed by the name of the anion.
17. sodium chloride
18. To name an ionic compound, first name each of the ions. The name of the compound is the name of the cation followed by the name of the anion.
19. iron (II) chloride
20. They contain only nonmetals.
21. one; two
22. 1, 2, 3, 4, 5
23. No
24. Yes
25. The atom that appears to the left on the periodic table. (The more metallic element.)
26. It is the same
27. The name of the second atom is the name of the atom with –ide added in place of the previous ending.
28. The name of the first atom in the formula (the more metallic element) is written first, including a prefix indicating the number of atoms if the number is more than one. The name of the second atom is written next, with a prefix indicating the number and with the suffix –ide in place of the previous ending.

29. 1; 12.01 amu
30. 2; 32.00 amu
31. 44.01 amu
32. Formula mass
33. 2×(1.01 amu) + 16.00 amu = 18.02 amu
34. 1; 16.00 amu; 16.00 amu; 4; 1.01 amu; 4.04 amu; 32.05 amu

ChemActivity 6A: Counting by Weighing

Answers to Critical Thinking Questions

1. 0.150 lb
2. 0.150 lb
3. 0.150 lb/1 doz nails   1doz nails/0.150 lb
4. 3 doz nails x 0.150 lb/1 doz nails = 0.450 lb; yes
5. 2.60 lb x 1 doz nails/0.150 lb = 17.3 doz nails
6. If you know how much a certain number weighs, you can use that as a conversion factor to convert from weight to number.
7. 12
8. 12
9. 6.02×10^{23}; 602,000,000,000,000,000,000,000
10. 6.02×10^{23}
11. 3.5 doz nails x 12 nails/1 doz nails = 42 nails
12. 3.5 mol He x 6.02×10^{23} He/1 mol He = 2.11×20^{24}
13. A mole is similar to a dozen in that it specifies a particular number of objects. It is different in that it is much bigger!
14. 12.01 g
15. 32.07 g
16. Each atom weighs more. One mole always has the same number.
17. 6.94 g
18. 1 mol Li/6.94 g Li; 6.94 g Li/1 mol Li
19. 0.58 g C x 1 mol C/12.01 g C = 0.048 mol C
20. No. Knowing the molar mass lets you count atoms by weighing them.
21. A balance.

ChemActivity 6B: Counting by Weighing, Cont.

Answers to Critical Thinking Questions

1. 12.01 g
2. 32.00 g
3. 1 mol of CO_2
4. 44.01 g. It is the sum of the two masses of the atoms before the reaction.
5. The mass after a chemical reaction is the same as the mass before the chemical reaction.
6. The molar mass of a compound is the sum of all the molar masses of the atoms that make up the compound.
7. 44.01 g CO_2/1 mol CO_2 and 1 mol CO_2/44.01 g CO_2
8. 22.5 g CO_2 x 1 mol CO_2/44.01 g CO_2 = 0.511 mol CO_2
9. 32.00 g / 2 mol O atoms = 16.00 g/1 O atom
10. 16.00 g/mol
11. 16.00 g/mol + 1.01 g/mol + 1.01 g/mol = 18.02 g/mol
12. 32.00 g O_2/mol O_2
13. 8; 1; 4; 1; 4; 1
14. 32; 4; 4 doz; 1 doz; 4 mol; 1 mol
15. 5 chairs x 4 legs/chair = 20 legs
16. 1 mol CCl_4/4 mol Cl atoms; 4 mol Cl atoms/1 mol CCl_4
17. 2.6 mol CCl_4 x 4 mol Cl atoms/1 mol CCl_4 = 10.4 mol Cl atoms
18. 58.4 g/mol
19. 0.5; 50%
20.
    a. 2.3 g x 1 mol NaCl/58.4 g NaCl = 0.0394 mol NaCl
    b. 0.0394 mol NaCl x 1 mol Na/1 mol NaCl = 0.0394 mol Na
    c. 0.0394 mol Na x 23.0 g Na/1 mol Na = 0.906 g Na
21. $2.3 \text{ g NaCl} \times \frac{1 \text{ mol NaCl}}{58.4 \text{ g NaCl}} \times \frac{1 \text{ mol Na}}{1 \text{ mol NaCl}} \times \frac{23.0 \text{ g Na}}{1 \text{ mol Na}} = 0.91 \text{ g Na}$
22. 1490 mg
23. 0.394; 39.4%

ChemActivity 6C: Mass Percent and Empirical Formula

Answers to Critical Thinking Questions

1. a) 121 g; b) 70.9 g; c) 0.827 g; d) 1.65 mol; e) 58.6 g
2. 0.5864
3. 58.64%
4. Yes. The grams of Cl in 100 g.
5. 1) Multiply the atomic mass by the number of that atom and divide by the molar mass.
   2) Find the mass of that atom in 100 g.
6. (answers may vary)
7. 27 g
8. 11.1%; 88.9 %
9. 2.97 mol H; 1.5 mol O
10. H_2O
11. Yes. All we know from the data is that there are twice as many H atoms as O atoms.
12. CH_2O; 53.3; CH_2O; 40.0; 6.7
13. Divide each subscript by the smallest number
14. Yes. The mass percents can be turned into mole ratios.
15. No. Many different compounds will have the same mass percent.
16. 30.03 g
17. No.
18. The molar mass is a multiple of this weight.
19. H_2O_2. HO has a molar mass of 17.01 g, so there must be two of these fragments in the molecule.

ChemActivity 7A: Chemical Equations

Answers to Critical Thinking Questions

1. CO_2
2. CO_2
3. No
4. C and O_2
5. CO_2
6. Yes
7. …the compounds present after the reaction are different from the compounds present before the reaction.
8. A chemical reaction that produces light occurs when the glass capsule breaks.
9. Yes. A gas is formed.
10. Sublimation of carbon dioxide.
11. No. Sometimes a gas forms when there is no reaction.
12. Burning gas on the stove produces heat. Vegetables turn from bright to pale green when cooked. Etc.
13. oxygen; hydrogen
14. 1; 1
15. 4; 2
16. 2; 3
17. Carbon is balanced, hydrogen and oxygen are not.
18. Balanced means that there is the same number of each atom present before and after the reaction.
19. No.
20. No. Hydrogen atoms are disappearing and oxygen atoms are appearing.
21. They are the same.
22. How many of that molecule are in the reaction.
23. 1; 1
24. 4; 4
25. 4; 4
26. Yes. There is the same number of every atom before and after the reaction.
27. coefficients
28. No. The compounds would be different.
29. You can change the coefficients. You cannot change the subscripts.
30. $C_8H_{18} + O_2 \rightarrow CO_2 + H_2O$
31. No. Different amounts of C, O, and H.
32. C and H first, then O.
33. $C_8H_{18} + O_2 \rightarrow \mathbf{8}CO_2 + \mathbf{9}H_2O$
34. 8; 18
35. 16 + 9 = 25; 25/2 (or 12 ½)

36. $C_8H_{18} + 25/2\ O_2 \rightarrow 8CO_2 + 9H_2O$
37. $2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$
38. 16; 50; 36

ChemActivity 7B: Solution Chemistry

Answers to Critical Thinking Questions

1. Na^+, Cl^-, (and water)
2. Ag^+, NO_3^-, (and water)
3. No; AgCl
4. No
5. No; NH_4^+ and Cl^-, (and water)
6. soluble; soluble; insoluble; soluble; insoluble
7. Li^+; no exceptions
8. NO_3^-; no exceptions
9. usually soluble; AgCl is an exception
10. usually insoluble; LiOH is an exception
11. K^+ and I^-, (and water)
12. Pb^{2+} and NO_3^-, (and water)
13. yes
14. no
15. Pb^{2+} and I^-; PbI_2
16. K^+ and NO_3^-
17. **2** KI(*aq*) + $Pb(NO_3)_2$(*aq*) → **PbI_2**(*s*) + **2**KNO_3(*aq*)
18. K^+ and NO_3^-
19. $2I^-$(*aq*) + Pb^{2+}(*aq*) → PbI_2(*s*)
20. yes; yes
21. KCl and NaI
22. No
23. KI(*aq*) + NaCl(*aq*) → NO REACTION
24. no
25. A precipitation reaction will occur when two ionic solutions are mixed that contain ions that can form an insoluble compound.

26. Recap:
    a. **soluble** capable of dissolving
    b. **dissolves** forms a solution
    c. **solution** homogeneous liquid mixture
    d. **insoluble** incapable of dissolving
    e. **aqueous solution** homogeneous mixture in water
    f. **strong electrolyte solution** solution which conducts electricity
    g. **precipitate** solid formed when mixing solutions
    h. **molecular equation** equation for a precipitation reaction that includes formulas for entire compounds
    i. **precipitation reaction** reaction of two solutions to form a solid
    j. **spectator ion** an ion that does not participate in a precipitation reaction
    k. **net ionic equation** equation for a precipitation reaction that excludes spectator ions

ChemActivity 7C: Classes of Chemical Reactions

Answers to Critical Thinking Questions

1. $HCl(aq) + NaOH(aq) \rightarrow H_2O(l) + NaCl(aq)$
2. $H_2SO_4(aq) + 2LiOH(aq) \rightarrow 2H_2O(l) + Li_2SO_4(aq)$
3. (Underline Cl and Na in CTQ 1; underline SO_4 and Li in CTQ 2.)
4. $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$
5. water
6. an ionic compound
7. The cation comes from the base. The anion comes from the acid.
8. $HNO_3(aq) + LiOH(aq) \rightarrow H_2O(l) + LiNO_3(aq)$
9. H_2CO_3
10. CO_2
11. $H_2CO_3(aq) \rightarrow H_2O(l) + CO_2(g)$
12. $HNO_3(aq) + NaHSO_3(aq) \rightarrow H_2SO_3(aq) + NaNO_3(aq) \rightarrow H_2O(aq) + SO_2(g) + NaNO_3(aq)$
13. $2HCl(aq) + K_2S(aq) \rightarrow H_2S(g) + 2KCl$
14. Cl^-
15. $Zn(s) + Fe^{2+}(aq) \rightarrow Zn^{2+}(aq) + Fe(s)$
16. electrons
17. From Zn to Fe
18. oxidized
19. reduced
20. A compound reacting with molecular oxygen
21. Example Group C
22. Example Group B
23. Is a compound reacting with molecular oxygen? Is a metal reacting with a nonmetal? Are electrons being transferred?
24. displacement; synthesis; double-displacement; decomposition
25. synthesis; A: Mg; B: O_2; C: MgO
26. displacement; A: Zn; B: Cu; C: Cl

ChemActivity 8A: Pancakes and Molecules

Answers to Critical Thinking Questions

1. 5
2. 20. Every two eggs makes five pancakes. We can make four batches.
3. pancakes; 2; 20
4. tsp baking powder; 1; 1 ½
5. (there are several correct possibilities)
6. white; gray
7. 2 moles. The ratio is 2:3 in the equation.
8. 6 moles. Each N_2 makes 2 NH_3. We can make 3 batches.
9. NH_3; 1; 6
10. mol N_2; 3; 4
11. numbers (mol)
12. no
13. (there are several correct possibilities)
14. no
15. moles to moles
16. no; a balance
17. 2.02 g; 28.02 g; 17.04 g
18. 12.8 g NH_3x(1 mol NH_3/17.04 g NH_3) = 0.751 mol NH_3
19. mol H_2; 2; 1.13
20. g H_2; 1; 2.28
21. mol H_2; 2.02; 1; 3; 28.02; mol N_2; 43.23
27. $215.3 \text{ g NH}_3 \times \left(\frac{1 \text{ mol NH}_3}{17.04 \text{ g NH}_3}\right) \times \left(\frac{1 \text{ mol N}_2}{2 \text{ mol NH}_3}\right) \times \left(\frac{28.02 \text{ g N}_2}{1 \text{ mol N}_2}\right) = 177.0 \text{ g N}_2$

ChemActivity 8B: How Much Can We Make?

Answers to Critical Thinking Questions

1. 3 cups
2. pancakes; 1; 15
3. 10; 25 pancakes
4. 4 tsp; 40 pancakes
5. 15; this is the lesser amount
6. flour
7. Determine how many pancakes you can make from each ingredient. The lesser amount is the amount you can make.
8. 11/15; 73%
9. mol $TiCl_4$; 1; 1.8
10. $3.2 \text{ mol Cl}_2 \times \left(\frac{1 \text{ mol TiCl}_4}{2 \text{ mol Cl}_2}\right) \times = 1.6 \text{ mol TiCl}_4$
11. 1.6 moles; this is less than 1.8 moles
12. Cl_2
13. No. Find the limiting reactant by calculating the amount of product that can be made from each reactant and choosing the reactant that produces the least product.
14. $53.2 \text{ g Na} \times \left(\frac{1 \text{ mol Na}}{22.99 \text{ g Na}}\right) \times \left(\frac{2 \text{ mol NaCl}}{2 \text{ mol Na}}\right) \times \left(\frac{58.44 \text{ g NaCl}}{1 \text{ mol NaCl}}\right) = 135 \text{ g NaCl}$
15. $65.8 \text{ g Cl}_2 \times \left(\frac{1 \textbf{ mol} \text{ Cl}_2}{\textbf{70.90} \text{ g Cl}_2}\right) \times \left(\frac{2 \text{ mol NaCl}}{1 \text{ mol Cl}_2}\right) \times \left(\frac{58.44 \text{ g NaCl}}{1 \text{ mol NaCl}}\right) = 108 \text{ g NaCl}$
16. 65.8 g Cl_2 in CTQ 15
17. Cl_2; 108 g NaCl
18. 79.7%
19. percent yield = (actual yield/theoretical yield)×100%
20. Use grams-to-moles-to-moles-to-grams with each reactant to predict how much product that would make. The one that makes the lesser amount of product is the limiting reactant, and the amount it makes is the theoretical yield.

ChemActivity 8C: Heat In or Heat Out?

Answers to Critical Thinking Questions

1. absorbed
2. lower
3. -802.3 kJ; negative
4. release; it can make things hot
5. exothermic; heat is coming out
6. negative; combustion of methane is exothermic and has negative ΔH_{rxn}
7. +182.6 kJ; positive
8. endothermic
9. If ΔH_{rxn} is negative the reaction is exothermic. If ΔH_{rxn} is positive the reaction is endothermic.
10. endothermic; ΔH_{rxn} is positive
11. exothermic
12. -2044 kJ
13. -2044 kJ
14. -2044; 3
15. $2.5 \text{ mol } C_3H_8 \times \frac{-2044 \text{ kJ}}{1 \text{ mol } C_3H_8} = -5100 \text{ kJ}$
16. $11.8 \times 10^3 \text{ g } C_3H_8 \times \frac{1 \text{ mol } C_3H_8}{44.11 \text{ g } C_3H_8} \times \frac{-2044 \text{ kJ}}{1 \text{ mol } C_3H_8} = -5.47 \times 10^5 \text{ kJ}$

CHEMACTIVITY 9A: WAVES AND LIGHT

ANSWERS TO CRITICAL THINKING QUESTIONS

1. A; the peaks are farther apart
2. B; more peaks will go by in a certain amount of time
3. The longer the wavelength, the lower the frequency.
4. Blue; the shorter the wavelength, the higher the frequency
5. Label Wave A "red" and Wave B "blue".
6. No.
7. $1.5\times10^{11}\ \text{m}\times \frac{1\ \text{s}}{3.0\times10^{8}\ \text{m}} = 500\ \text{s} \quad \times \frac{1\ \text{min}}{60\ \text{s}} = 8\tfrac{1}{3}\ \text{min}$
8. (Arrival should be 8 min and 20 s after departure.)
9. λ; nm
10. ν
11. red
12. blue
13. blue
14. Highest energy on the right, lowest on left
15. Longest wavelength on the left; shortest on the right
16. Highest frequency on the right; lowest on the left
17. (answers will vary)
18. short wavelength; High energy on the right; low energy on the left
19. see Fig. 9.4 in *Introductory Chemistry*
20. see Fig. 9.4 in *Introductory Chemistry*
21. radio (almost microwave)
22. No; visible radiation is harmless

ChemActivity 9B: Orbits and Orbitals

Answers to Critical Thinking Questions

1. In the center
2. *n*
3. attracted
4. *n*=1
5. n=1 because it can be closer to the nucleus
6. excited state because *n*=1 is the lowest energy
7. higher to lower
8. just individual narrow lines
9. They appear to be restricted. Narrow lines imply specific energies.
10. 1; 2; 3; 4; 5 from inner to outer
11. violet light
12. 5→2; violet; shortest to red, middle to blue, longest to violet
13. 6→2 (Answers ending at 1 might be suggested as well. Those lines happen to be in the UV.)
14. At the nucleus
15. no
16. it decreases
17. above or below the nucleus
18. on the horizontal line
19. it decreases
20. It is not correct. The radius varies.
21. 1; 4
22. *s*, *p*, *d*, *f*
23. excited state; 1*s*
24. 1; 3; 5
25. 4; 9

ChemActivity 9C: Electron Configurations

Answers to Critical Thinking Questions

1. 1; 5
2. 1; 5
3. electrons
4. there is a superscript 2
5. 6
6. 2
7. Yes; $1s^2 2s^2$
8. 7
9. 4
10. 3; $1s^2 2s^2 2p^3$
11. 1*s* is lower in energy
12. 2*s* is lower than 2*p*
13. $1s^2 2s^2$; $1s^2 2s^2 2p^6$
14. The *p* subshell can hold a maximum of six electrons.
15. 4*s* is lower than 3*d*
16. [Ar] $4s^2$ $3d^2$
17. [Ar] $4s^2$ $3d^{10}$ $4p^2$
18. ↑↓ (1s) ↑↓ (2s) ↑ ↑ _ (2p)
19. Different orbitals. The two electrons went into different *p* orbitals in carbon.
20. Same spin. In carbon they are both spin up.
21. ↑↓ (1s) ↑↓ (2s) ↑ ↑ ↑ (2p)
22. ↑↓ (4s) ↑ ↑ ↑ ↑ ↑ (3d)

ChemActivity 9D: The Periodic Table

Answers to Critical Thinking Questions

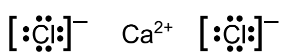
1. S: $3s^2 3p^4$; Sr: $5s^2$; Hg: $6s^2 5d^{10}$
2. The electron configuration of an element is generally the same as the element above it with the exception that the principle quantum numbers are increased by one.
3. The electron configuration of an element has one more electron than the element to its left, generally in the highest energy orbital.
4. *s* orbitals are being filled
5. *d* orbitals are being filled
6. *p* block; *f* block
7. Knowing which blocks are being filled for each section of the periodic table makes it easy to write the electron configuration for any element.
8. 3
9. 4
10. 4
11. 10
12. They are all ns^1
13. They are all ns^2 np^6 (full shell)
14. They are particularly stable and chemically inert.
15. F: $2s^2 2p^5$; F^-: $2s^2 2p^6$
16. Ne
17. It has a full outer shell.
18. It looses one electron to result in a full outer shell.
19. Many elements give up or take exactly enough electrons to form an ion with a full outer shell.
20. Li; K
21. smaller
22. bigger
23. F; Li
24. increase
25. decrease

ChemActivity 10A: Introduction to Bonding

Answers to Critical Thinking Questions

1. 3; 1
2. 10; 8
3. valence electrons
4. 5
5. 2
6. 2*s* and 2*p*; 8 electrons
7. Compounds typically form in which all atoms have a full outer shell
8. Yes; Potassium is a metal and chlorine is a nonmetal
9. 1; 7
10. 1
11. they are the same
12.

13. 2
14. $CaCl_2$;



15. covalent; They are both nonmetals.
16. 2
17. 8
18. (circles should include electrons!)
19. (circles should include electrons!)
20. sharing
21. two
22. two
23. a shared pair of electrons
24. 2
25. 2
26. 6
27. (they do)

ChemActivity 10B: Drawing Lewis Structures

Answers to Critical Thinking Questions

1. a) hydrogen; b) electron(s); c) octet; d) double
2. 6
3. 1
4. 8
5. 8; it is the same
6. 9
7. 8
8. Ammonium is a cation, so it has one fewer electron than the neutral atoms.
9. Carbon. There are multiple oxygen atoms, so they are likely terminal (Rule 1b).
10. O–C–O
11. 4
12. 12
13. no
14. 16
15. 4; 12
16. (three nonbonding pairs on each O)
17. yes
18. no
19. move nonbonding pairs to make double bonds
20. $:\ddot{O}=C=\ddot{O}:$
21. check
22. check
23. odd
24. No. An integer times eight will always be even.
25. B
26. P, S
27. No
28. yes
29. yes
30. yes; the double and single bonds have switched places
31. Circle "SO_2 has one long weak bond and one short strong bond."
32. No
33. No
34. An average. Each bond seems to be 1 ½ of a bond.

ChemActivity 10C: Molecular Shape and Polarity

Answers to Critical Thinking Questions

1. 180°
2. 120°
3. The more three dimensional arrangement. In the flat arrangement, they are only 90° apart, but in the 3D arrangement, they are slightly more than 90°.
4. The electron groups are as far apart as possible at 180°.
5. 3
6. No. The three groups got as far away as possible, and that is 120° if they are all the same.
7. 4
8. No. 109.5°.
9. tetrahedron
10. No. The Lewis structure is a flat representation of a 3D object. Methane looks like 90° in the Lewis structure, but is tetrahedral in real life.
11. up
12. No. Two bonding pairs to hydrogen atoms and two nonbonding pairs.
13. They are getting as far apart as possible.
14. 109.5°
15. Bent. The H atoms are at the corners of a tetrahedron and the O is in the middle.
16. F; Na
17. more
18. less
19. the larger electronegativity minus the smaller electronegativity. CH is 0.4. HF is 1.9.
20. 0.4
21. no
22. 2.0
23. a polar bond; toward the more electronegative atom
24. (Answers will vary. Electronegativity difference must be between 0.5 and 1.9.)
25. The electronegativity must be between 0.5 and 1.9
26. methane
27. no
28. it has no polar bonds
29. no; CO_2 and CCl_4 are not polar
30. The polar bonds cancel.
31. no; tetrahedral
32. For a molecule to be polar it must contain polar bonds that do not cancel.

ChemActivity 11A: Pressure

Answers to Critical Thinking Questions

1. The one on the left
2. The one on the right
3. The one in the middle
4. No. 10.3 m. The straw on the left has zero pressure in the top of the straw, and the water only goes up 10.3 m.
5. Pushed. Atmospheric pressure pushes liquid up the straw when the pressure inside the straw is less than the pressure on the liquid.
6. No.
7. "particle(s)"
8. Yes. A given volume of solid is heavier than the same volume of gas. (Alternatively, the fact that solids "sink" when dropped into a container containing gas demonstrates greater density.)
9. "Gases typically have…" **Observation**; "The hotter the gas…" **Theoretical Assumption**
10. Pushing them closer together
11. "The space between particles is much greater than the size of the particles themselves."
12. "Gases assume the shape of their container."; Because there are no forces between them, gas molecules move freely and fill their container.
13. August; August is hotter than January (in the Northern hemisphere, at least) and molecules move faster when it is hot.
14. "Gas *particles* do not attract or repel each other. They bounce off walls like billiard balls." This assumption is the only one that describes what happens at the walls.
15. Pa
16. 101,325
17. mmHg
18. tor
19. psi
20. 14.7
21. Pa
22. Force/Area
23. 760
24. 1 atm/760 mmHg; 760 mmHg/1 atm
25. $\mathbf{0.843}\ \text{atm} \times \frac{\mathbf{760}\ \text{mmHg}}{1\ \textbf{atm}} = \mathbf{641}\text{mmHg}$

ChemActivity 11B: Gas Laws

Answers to Critical Thinking Questions

1. No
2. No
3. (they are correct)
4. 0.245; 24.5; 97.8; 24.5
5. product of *P* and *V*
6. (the first)
7. (the first)
8. any two
9. $P_1V_1 = P_4V_4$
10. $P_4 = P_1V_1/V_4$
11. 5.76 atm
12. amount of nitrogen and temperature
13. no
14. no
15. The temperature in Kelvin is the temperature in Celsius plus 273.
16. 273 K
17. No. Compare Experiments 2 and 3. *T* doubles and *V* goes up about 10%.
18. Yes. Compare Experiments 1 and 2.
19. (the first)
20. (the second); If *V* doubles and *T* doubles *V*/*T* will stay the same.
21. (the one on the right)
22. 22.4 L
23. Charles's Law says that *V* is proportional to *T*.
24. Boyle's Law says that *V* is indirectly proportional to *P*.
25. Divide both sides by *T* and multiply by *P*.
26. (the second); If *PV*/*T* is constant, this quantity will be the same even after a change in some variable.
27. 5
28.

P_1 = 755 mmHg	P_2 = 687 mmHg
V_1 = 3.65 L	V_2 = unknown
T_1 = 302 K	T_2 = 291 K

29. $V_2 = \frac{P_1V_1T_2}{T_1P_2}$
30. 3.87 L
31. L; yes
32. Convert from °C to K.

ChemActivity 11C: Moles of Gas

Answers to Critical Thinking Questions

1. 25 L
2. increase
3. $V \propto n$; As *n* increases, *V* increases.
4. $\frac{V_1}{n_1} = \frac{V_2}{n_2}$; $V \propto n$, so $V = n \cdot \text{constant}$. Therefore $V/n = \text{constant}$.
5. $V \propto \frac{nT}{P}$
6. $V = nRT/P$
7. $PV = nRT$
8. You need any three to determine the fourth.
9. $V = nRT/P$ $P = nRT/V$ $T = PV/nR$ $n = PV/RT$
10. $V = (nR/P) \cdot T$, so if *n* and *P* are constant, this becomes Charles's Law.
11. L, atm, K
12. $V = nRT/P = 22.4\ \text{L}$
13. This can be used to convert from moles of gas when the pressure is 1 atm and the temperature is 0 °C.
14. You can calculate the molar mass by first finding *n* from *V*, *P*, and *T*. Dividing mass by moles gives molar mass.
15. 1 atm
16. oxygen, nitrogen, argon
17. 0.78, 0.21, 0.01
18. atm
19. (1 atm)·(0.78) = 0.78 atm
20. This is the contribution to the pressure from just the nitrogen
21. 0.21 atm; 0.01 atm
22. 1 atm
23. The total pressure of a gas is the sum of the partial pressures of all the components in the mixture.
24. P_a, P_b, P_c, and P_d
25. $P_{tot} = P_a + P_b + P_c + P_d$
26. The partial pressure of a gas is the contribution that gas makes to the total pressure.

ChemActivity 12A: Solids, Liquids, and Gases

Answers to Critical Thinking Questions

1. between states
2. within universities
3. *inter* means between; *intra* means within
4. An intermolecular force is a force between molecules.
5. dashed lines
6. No. It is within a molecule, not between molecules.
7. solid and liquid
8. liquid and gas
9. solid and liquid
10. crystalline
11. no regular repeating structure
12. They tend to minimize their surface because of surface tension.
13. Water has a higher surface tension.
14. Water has stronger intermolecular forces.
15. motor oil
16. motor oil has stronger intermolecular forces
17. 0 Torr
18. evaporation
19. it stops
20. 760 Torr; 1 atm
21. no
22. It does not. The increase from evaporation is canceled by the decrease from condensation.
23. All the liquid would evaporate because the partial pressure of water could never reach the vapor pressure.
24. yes
25. 100 °C, the boiling point
26. The boiling point is the temperature at which the vapor pressure equals atmospheric pressure.

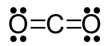
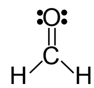
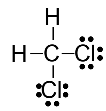
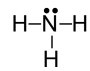
ChemActivity 12B: Energetics of Boiling and Freezing

Answers to Critical Thinking Questions

1. 20 °C (circle lower left corner)
2. liquid
3. temperature increases
4. 100 °C
5. overcoming intermolecular forces (boiling!)
6. combination of liquid and gas
7. 40 kJ
8. endothermic; heat must go in
9. This is the amount of heat required to vaporize (or boil) one mole of water.
10. Vaporization is endothermic.
11. amount of material and heat required to boil it
12. $255\text{ g} \times \frac{1\text{ mol water}}{18.02\text{ g water}} \times \frac{40.7\text{ kJ}}{1\text{ mol water}} = 576\text{ kJ}$
13. gas
14. left part: liquid only; middle part: liquid and gas; right part: gas only
15. circle lower left corner; left part: solid only; middle part: solid and liquid; right part: liquid only
16. about 2 kJ
17. about 6 kJ
18. melting
19. endothermic; energy must be put in
20. exothermic; opposite of melting -or- energy must be removed
21. 6.02 kJ; ΔH=-6.02 kJ
22. $3.79\text{ kg} \times \frac{1000\text{ g}}{1\text{ kg}} \times \frac{1\text{ mol water}}{18.02\text{ g water}} \times \frac{6.02\text{ kJ}}{1\text{ mol water}} = 1270\text{ kJ}$

ChemActivity 12C: Types of Intermolecular Forces

Answers to Critical Thinking Questions

1.  nonpolar;  polar;  polar;  polar
2. dispersion
3. It must be polar.
4. N, O, or F
5. The hydrogen is not bonded to the oxygen.
6. (similar to figure 12.18)
7. attractive; opposite charges attract
8. neon
9. neon; It has the higher boiling point, and higher boiling points indicate stronger intermolecular forces.
10. Dispersion increases with increasing molar mass.
11. octane; Because octane is a liquid at room temperature, and propane is a gas, octane must have the higher boiling point and therefore the stronger intermolecular forces.
12. (all of them)
13. formaldehyde and methanol
14. only methanol
15. Methanol has the highest boiling point because it has the strongest intermolecuar forces.
16. dispersion only < dipole-dipole < hydrogen bonding
17. So that the dispersion force is comparable in all the compounds.
18. ice: hydrogen bonding; xenon: dispersion; NaCl: attraction between + and –; graphite: covalent
19. xenon < ice < NaCl < graphite
20.
    a. ice: composed of molecules
    b. NaCl: composed of ions
    c. graphite: composed of atoms covalently bonded
    d. xenon: composed of atoms not covalently bonded

ChemActivity 13A: Solutions

Answers to Critical Thinking Questions

1. salt
2. water
3. liquid solution; the solvent is a liquid
4. brass
5. yes; gaseous solution
6. soda water
7. soda water, vodka, seawater
8. all of them
9. all of them
10. A solution must be a homogeneous mixture.
11. it dissolved into the water
12. separated Na^+ and Cl^-
13. 100 g – 64 g = 36 g
14. No. Only 36 g will dissolve and 2 g will remain as solid.
15. More soluble. More dissolves at 100 °C than at room temperature.
16. Some (2 g) will come out of solution.
17. hot water
18. about twice as much
19. cold water
20. As the cold tap water warms up, dissolved air is less soluble and comes out of solution as bubbles.
21. Solids are more soluble in hot water, but gases are more soluble in cold water.
22. about 3 atm
23. When the pressure decreases, the gas is not as soluble, so it comes out as bubbles.
24. The partial pressure of CO_2 in the air is very small, so the solubility of CO_2 exposed to air is almost zero.

ChemActivity 13B: Concentration

Answers to Critical Thinking Questions

1. salt
2. water
3. liquid solution; the solvent is a liquid
4. brass
5. yes; gaseous solution
6. soda water
7. soda water, vodka, seawater
8. all of them
9. all of them
10. A solution must be a homogeneous mixture.
11. it dissolved into the water
12. separated Na^+ and Cl^-
13. 100 g – 64 g = 36 g
14. No. Only 36 g will dissolve and 2 g will remain as solid.
15. More soluble. More dissolves at 100 °C than at room temperature.
16. Some (2 g) will come out of solution.
17. hot water
18. about twice as much
19. cold water
20. As the cold tap water warms up, dissolved air is less soluble and comes out of solution as bubbles.
21. Solids are more soluble in hot water, but gases are more soluble in cold water.
22. about 3 atm
23. When the pressure decreases, the gas is not as soluble, so it comes out as bubbles.
24. The partial pressure of CO_2 in the air is very small, so the solubility of CO_2 exposed to air is almost zero.

ChemActivity 13C: How is a Solution Different?

Answers to Critical Thinking Questions

1. 0.250 mol sucrose
2. 0.500 mol sucrose/kg water
3. something else; Mass percent is g/g×100% and molarity is moles/L **solution**.
4. 0 °C; 100 °C
5. –1 °C; 101°C
6. –0.93 °C; 100.26 °C
7. (not bad, if I do say so myself)
8. down
9. up
10. 0 °C→100 °C
11. –0.93 °C → 100.26 °C
12. A solute extends the range of temperatures over which a substance is a liquid.
13. freezing; boiling
14. $1.86\,\frac{°\text{C}\cdot\text{kg solvent}}{\text{mol solute}}$ and $0.512\,\frac{°\text{C}\cdot\text{kg solvent}}{\text{mol solute}}$
15. 1.5 mol sucrose/kg water
16. about 101 °C
17. 100.77 °C
18. fine (many groups may now realize that they forgot to add ΔT to 100 °C)
19. change in…
20. 100.77 °C
21. yes; The more solute, the higher the boiling point.
22. no; Whether it is 1.5 glucose or 1.5 sucrose, the boiling point is the same.
23. allows solvent to pass through but not solute
24. solution on the left, solvent on the right
25. no; The concentration on the left is something. The concentration on the right is zero.
26. yes; Solvent can move through the membrane and dilute the solution.
27. (drawing should have a higher level of liquid on the left and lower on the right)

ChemActivity 14A: Acids and Bases

Answers to Critical Thinking Questions

1. They end in "acid."
2. They all have at least one H atom.
3. They are all bases.
4. No. NH_3 is not a base.
5. sodium bicarbonate; $NaHCO_3$
6. acetic acid; $HC_2H_3O_2$; acid
7. It is sour.
8. (answers will vary); bitter
9. more sour foods; acidic
10. acid; It produces H^+ in aqueous solution.
11. base; It produces OH^- in aqueous solution.
12. $KOH(aq) \rightarrow K^+(aq) + OH^-(aq)$
13. base; It produces OH^- in aqueous solution.
14. $\underline{H}C_2H_3O_2$
15. $HC_2H_3O_2(aq) \rightarrow H^+(aq) + C_2H_3O_2(aq)$
16. as hydronium; H_3O^+
17. a base
18. $NH_3(aq) \rightarrow$???; there is no hydroxide to dissociate
19. No. Everything is aqueous.
20. 1) Not all bases have hydroxide; 2) It can't address non-aqueous solutions.
21. HCl donates a proton to water.
22. HCl is the acid (underline HCl, write acid)
23. H_2O (underline H_2O, write base)
24. Water donates a proton to ammonia. (H_2O is the acid. NH_3 is the base.)
25. yes; HCl is an acid and NH_3 is a base in Model 1.
26. Cl^- (underline, write conjugate base)
27. H_3O^+ (underline, write conjugate acid)
28. NH_4^+ is the conjugate acid. OH^- is the conjugate base.
29. $H_3O^+(aq) + Cl^-(aq) \rightarrow HCl(aq) + H_2O(l)$
30. H_3O^+ acid; Cl^- base; HCl conjugate acid; H_2O conjugate base
31. NH_4^+/NH_3; H_2O/OH^-; H_3O^+/H_2O
32. NO_3^-; H_2SO_4
33. The conjugate base of a compound is what is left after a proton has been removed.
34. The conjugate acid of a compound is what you get after adding a proton.

ChemActivity 14B: Chemistry of Acids and Bases

Answers to Critical Thinking Questions

1. acids: HCl, HNO_3, and HCl; bases: KOH, NaOH, and $NaHCO_3$
2. water
3. H from the acid, O and the other H from the base
4. $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$
5. $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$
6. $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$
7. An ionic compound; (label KCl, $NaNO_3$, and NaCl "salt")
8. The cation comes from the base. The anion comes from the salt.
9. $CO_2(g)$; HCO_3^- (bicarbonate)
10. acids: HCl and HI; metals: Mg, K
11. hydrogen
12. both come from the acid
13. an ionic compound; (label $MgCl_2$ and KI "salt")
14. yes; the metal
15. no
16. Solid metal becomes an aqueous solution.
17. When dissolving compounds, they remain the same compound. When dissolving metal, it changes from the pure metal to a new compound.
18. $HCl(aq) + NaOH(aq) \rightarrow H_2O(l) + NaCl(aq)$; a neutralization
19. (label the buret "0.100 NaOH" and the flask "25.00 mL HCl"
20. acidic; HCl is an acid
21. basic; all the acid has been neutralized and extra base was still added
22. 35.27 mL; the solution was neither acidic nor basic
23. 0.100 mol NaOH/L
24. 0.03527 L × 0.100 mol NaOH/L = 0.00353 mol NaOH
25. 0.00353 mol HCl; the same as the number of moles as NaOH because they exactly neutralize each other without there being extra of either one
26. 25.00 mL
27. 0.00353 mol HCl/0.02500 L = 0.141 M
28. You can determine the concentration of the unknown by reacting the two together until the solution is neither acidic nor basic (as seen by the indicator). The volume of the solution of known concentration can be used to determine the moles of the unknown.

ChemActivity 14C: Strong and Weak Acids and Bases

Answers to Critical Thinking Questions

1. strong; weak
2. all of them
3. one
4. 0 M; 0.15 M; 0.15 M. They all ionize, and each HCl produces one H^+ and one Cl^-.
5. 0.15 M; 0 M; 0 M. Only one in 1000 ionize, so they are almost all still HF.
6. HCl ionizes completely, but HF ionizes only partially.
7. Strong acids ionize completely. Weak acids ionize very little.
8. HCl; ions in solution are required to conduct electricity
9. No. Strong and weak refer to the degree of ionization. Concentrated weak acids exist but do not ionize very much.
10. strong; weak
11. No. Na^+ and OH^-
12. from a water molecule
13. It is what is left of the water after the ammonia accepts a proton.
14. $NH_4^+(aq) + OH^-(aq)$
15. just a little bit
16. Strong bases complete dissociate into OH^- in solution. Weak bases only partially accept a proton from water to produce OH^-.
17. NaOH; It has a significant number of ions in solution.
18. They are different. Strong bases ionize completely. Weak bases only ionize partially, no matter how concentrated.
19. Cl^-
20. a proton, H^+
21. weaker
22. stronger
23. The stronger an acid is the weaker its conjugate base will be.

ChemActivity 14D: pH and Buffers

Answers to Critical Thinking Questions

1. H_3O^+
2. OH^-
3. No. There are small amounts of H_3O^+ and OH^- from water reacting with itself.
4. 1.0×10^{-7} ; 1.0×10^{-7}
5. 1.0×10^{-14}
6. 0.1 M; HCl completely ionizes
7. 1.0×10^{-14}; This is true for any solution containing water.
8. $1.0\times10^{-14}/0.1 = 1.0\times10^{-13}$
9. 0.1 M; NaOH completely dissociates in solution.
10. 1.0×10^{-14} ; This is true for any solution containing water.
11. $1.0\times10^{-14}/0.1 = 1.0\times10^{-13}$
12. bigger
13. no; smaller
14. 2; 7
15. The pH is the opposite of the exponent on the 10.
16. 9
17. log
18. Take the log and then change the sign.
19. 10^x
20. Change the sign and raise 10 to that power.
21. acidic; 5
22. neutral; 7
23. The pH of an acidic solution will be less than 7. The pH of an acidic solution will be greater than seven.
24. up; Hydroxide is added making hydronium smaller, resulting in smaller pH.
25. down; Hydronium is added, making pH smaller.
26. one or two
27. B
28. B
29. A buffer is a solution that resists change in pH.
30. The pH changes very little when strong acid or base are added.
31. B
32. (circle HCl)
33. (circle NaOH)
34. Add a few drops of strong acid and base, and see if the pH changes much.
35. (exp. 1, 2, and 4)
36. (exp. 1, 2, and 5)
37. (exp. 1 and 2)

38. It must contain both a weak acid and a weak base.
39. $HCl + C_2H_3O_2^- \rightarrow Cl^- + HC_2H_3O_2$
40. $NaOH + HC_2H_3O_2 \rightarrow H_2O + NaC_2H_3O_2$
41. HCl will be neutralized by the weak base. NaOH will be neutralized by the weak acid.

ChemActivity 15A: Dynamic Equilibrium

Answers to Critical Thinking Questions

1. 14 mol/L·s
2. 359
3. The more concentrated reactants are, the faster the rate.
4. 0.0133 mol/L·s
5. 442.68 mol/L·s
6. The higher the temperature, the faster the rate.
7. Temperature. Increasing concentrations by 10X increases the rate by 100X. Increasing the Temperature by 2X increases the rate by 10^{12}!
8. 0.1 M; 0.1 M; 0 M
9. 0.0417 M; 0.0417 M; 0.1170 M
10. H_2 and I_2 have decreased. HI has increased.
11. Slows down. There are less reactants.
12. 0; There is no HI present.
13. Speeds up. There is more HI as time goes on.
14. no; no
15. no; Reactants are turning to products at the same rate that products are turning to reactants.
16. 70 ms
17. Concentrations are staying the same. Reactions are still occurring.
18. no; The rates of the forward and reverse reactions may be very different.
19. no; The reverse reaction is replacing reactants.
20. (they are correct)
21.

43	50
53	50

22. circle $\frac{[HI]^2}{[H_2][I_2]}$; 50
23. $x^2=1.3^2/50$; $x=0.18$ M
24. products
25. reactants
26. an exponent on that concentration
27. It does not go in. C(*s*) is not included in Rxn 3.
28. It does not go in. $H_2O(l)$ is not included in Rxn 4.
29. circle (*g*), (*aq*); X (*s*), (*l*)
30. circle (*g*), (*aq*); X (*s*), (*l*)
31. Gases and aqueous things are included because they change during a reaction.
32. $H_2 + I_2 \rightarrow 2HI$ $K=[HI]^2/[H_2][I_2]$

33. top
34. products; Products are on top. If the fraction is big, the top is big.
35. big
36. more HBr; It is a product and on the top of the fraction which is a big number.
37. reactants; K is a small number, so products are small and reactants are big.

ChemActivity 15B: Le Châtelier's Principle

Answers to Critical Thinking Questions

1. no; The concentration of white was increased, but the concentration of black stayed the same.
2. no; Solids have the same concentration all the time, regardless of how much you have.
3. forward; Reaction rates increase with concentration. Higher white concentration would result in a faster forward reaction.
4. Whites need to turn into blacks. This will slow down the forward reaction and speed up the reverse reaction to reestablish equilibrium.
5. shifts to remove what you added
6. forward; In that case the reverse reaction would be slower than the forward reaction.
7. The reaction shifts to replace what you removed.
8. 8 white circles; 8 black circles; 16 total
9. 10 white circles; 4 black circles; 14 total
10. fewer
11. The reaction shifted backwards (turning blacks into whites) in order to reduce the number of particles.
12. fewer gas particles
13. The reaction would have shifted to the right to produce more black circles.
14. reactant
15. white circles turn into black circles
16. away
17. product
18. lower the temperature; The reaction will shift toward the side with heat.

ChemActivity 15C: Solubility Products and Catalysts

Answers to Critical Thinking Questions

1. Ca^{2+}(*aq*); SO_4^{2-}(*aq*)
2. reactants; coefficients; solids
3. $[Ca^{2+}][SO_4^{2-}]$
4. It is the product of the ions, it describes solubility, and it is a constant.
5. small; Calcium sulfate is only very slightly soluble in water.
6. (mine was!)
7. $CaSO_4$ is most soluble because it has the largest K. CuS is least soluble because it has the smallest K.
8. No, only incomplete. These are very slightly soluble, and you might not notice any dissolving.
9. they are the same
10. they are the same
11. they are all equal
12. $K_{sp} = 1.77\times10^{-10} = [Ag^+]\cdot[Cl^-] = S^2$; $S = sqrt(1.77\times10^{-10}) = 1.33\times10^{-5}$
13. no; the solubility is the square root of K_{sp}.
14. (circle products)
15. too slow; It is not at equilibrium because at equilibrium it would be almost all water.
16. lower
17. no; At first the energy goes up, then down as it becomes products.
18. (label the vertical double-headed arrow)
19. More molecules hit hard enough to get over the bump.
20. The activation energy is too high.
21. (circle faster)
22. lower; If less energy is required, more will react in the same time.
23. Lower the activation energy.
24. (should look like Fig. 15.17 in *Introductory Chemistry*)

ChemActivity 16A: Oxidation and Reduction

Answers to Critical Thinking Questions

1. oxygen
2. Because adding oxygen to a compound is usually oxidation.
3. no; Lithium plus chlorine is also oxidation.
4. ionic
5. Li^{+}; Cl^{-}
6. 0; 0
7. It looses an electron to chlorine. It changes from a charge of zero to a charge of +1, so it must have lost a negative charge.
8. losing electrons
9. gaining electrons
10. goes down
11. a charge goes down (is reduced) when an atom is reduced
12. chlorine
13. lithium
14. oxygen
15. covalent
16. apparently so…
17. to the right
18. up
19. oxygen
20. 2–
21. 2–
22. 2–
23. 4+; Each oxygen is 2– and the total must be zero.
24. 4–
25. goes up
26. oxidized; The oxidation state goes up, so it is loosing electrons. (Alternatively, the oxidation state is not being reduced, so carbon is not reduced.)
27. yes; It combines with oxygen, so it makes sense that it is being oxidized.
28. Rule 1; 0
29. directly below
30. 3a; $2\cdot(+1) + (-2) = 0$
31. The oxidation state applies to each atom. In the water example, we had to multiply the +1 oxidation state of H by the number of atoms.
32. 3b; $(+5) + 3\cdot(-2) = -1$
33. Rule 4 says Na is +1. Then applying Rule 3, Cl must be –1.
34. No. We just applied rule 4 before Rule 3. Rule 3 will probably come last frequently.

35. yes; Rule 2 was easier.
36. H: +1; N: –3; H is first because hydrogen is higher on the list in Rule 5 than nitrogen.

ChemActivity 16B: Balancing Redox Equations

Answers to Critical Thinking Questions

1. The first is balanced with respect to mass but not charge. The second is not balanced with respect to either.
2.

Al(*s*)	Ag^+(*aq*)	Al^{3+}(*s*)	Ag(*s*)	Fe^{2+}(*aq*)	MnO_4^-(*aq*)	Fe^{3+}(*aq*)	Mn^{2+}(*aq*)
0	+1	+3	0	+2	+7 –2	+3	+2

3. both; Oxidation states are changing so electrons are being transferred.
4. They add.; The first is oxidation, the second is reduction.
5. Al(*s*) → Al^{3+}(*s*) + 3e^-; Ag^+(*aq*) +e^- → Ag(*s*)
6. no; Al(*s*) → Al^{3+}(*s*) + 3e^-; 3Ag^+(*aq*) + 3e^- → 3Ag(*s*)
7. The electrons lost by the substance being oxidized are gained by the substance being reduced.
8. Al(*s*) + 3Ag^+(*aq*) → Al^{3+}(*s*) + 3Ag(*s*)
9. yes
10. yes
11. no; It contains oxygen atoms only on one side. It cannot be balanced by changing coefficients.
12.

Step	1	2	3	4	5	6	7
CTQ	2	4		5	6	8	10

13. step 3
14.

$(Fe^{2+} \rightarrow Fe^{3+} + e^-)\times 5$

$\underline{8H^+ + MnO_4^- + 5e^- \rightarrow Mn^{2+} + 4\ H_2O}$

$5Fe^{2+} + 8H^+ + MnO_4^- \rightarrow 5Fe^{3+} + Mn^{2+} + 4\ H_2O$

15. no; The protons must come from somewhere.
16. Cu^{2+}(*aq*) + Mg(*s*) → Cu(*s*) + Mg^{2+}(*aq*)
17. copper
18. reduced; Cu^{2+}(*aq*) + 2e^- → Cu(*s*)
19. oxidized; Mg(*s*) → Mg^{2+}(*aq*) + 2e^-
20. Mg. It is the one that loses an electron in the spontaneous reaction.
21. Mg.
22. The metals at the top have a greater tendency to be oxidized
23. Ca; Ca(*s*) + Mg^{2+}(*aq*) → Ca^{2+}(*aq*) + Mg(*s*)
24. Cu(*s*) + H^+(*aq*) $\nrightarrow$ Cu^{2+}(*aq*) + H_2(*g*) NO REACTION
25. Because they have a lesser tendency to lose electrons than hydrogen, so hydrogen cannot oxidize them.

26. A metal will dissolve in acid is it appears above H_2 in the activity series of metals.
27. It is a table that lists metals in order of decreasing tendency to lose electrons.

ChemActivity 16C: Electrochemical Cells

Answers to Critical Thinking Questions

1. $Cu^{2+}(aq) + Zn(s) \rightarrow Cu(s) + Zn^{2+}(aq)$
2. $Cu^{2+}(aq) + 2e^{-} \rightarrow Cu$; $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^{-}$
3. Not far. The reaction must occur when a copper ion collides with a zinc atom (or with a copper touching a zinc atom).
4. $Cu^{2+}(aq) + Zn(s) \rightarrow Cu(s) + Zn^{2+}(aq)$
5. No, the Cu^{2+} and Zn are in different beakers.
6. $Cu^{2+}(aq) + 2e^{-} \rightarrow Cu$; $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^{-}$
7. the beaker on the left
8. the beaker on the right
9. They must travel through the wire. (A few inches?)
10. (draw electrons on the wire moving from zinc electrode to copper electrode)
    $2H_2 + O_2 \rightarrow 2H_2O$
11. The one on the right. It is producing electricity.
12. no
13. water
14. the one on the left; It requires an external supply of electricity (the battery).
15. The electrolytic cell could be run by a solar panel, and the fuel cell could run a car.
16. We could generate hydrogen with electrolytic cells connected to solar panels and then use that hydrogen in a fuel-cell powered car.

ChemActivity 17A: Nuclear Reactions

Answers to Critical Thinking Questions

1. 6; 6
2. 6; yes, subscript on the left
3. 6; 7
4. 12; yes, superscript on the left
5. the number of protons
6. top left: mass; bottom left: charge; large box: symbol
7. yes (some students may need to change "protons" to "charge")
8. 30; +15
9. electron; It has a charge of –1 and almost no mass.
10. positron
11. gamma, beta, alpha
12. no
13. 238
14. 234 + 4 = 238
15. 92
16. 90 + 2 = 92
17. During a nuclear reaction neither the total mass nor the total charge change.
18. yes; (any reaction from the handout can be used)
19. ${}^{15}_{8}\mathrm{O} \rightarrow {}^{15}_{7}\mathrm{N} + {}^{0}_{+1}\mathrm{e}$

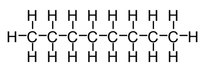
ChemActivity 17B: Decay and Time

Answers to Critical Thinking Questions

1. 1000000
2. 14 billion years
3. no; In 28 years ¾ of it has decayed away and ¼ is left.
4. Every 14 billion years, half of what was there at the beginning decays away.
5. 63 billion years is 14 more years after the last entry. Half of 88388, or 44194, will be left.
6. no; There is a wide range of half-lives from microseconds to billions of years!
7. ${}^{238}_{92}\mathrm{U} \longrightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$; 4.5×10^{9} years
8. no; It will undergo beta decay with a half-life of 24.1 days.
9. 100
10. still alive
11. 100
12. It does not.
13. 100 atoms per 100 trillion atoms
14. 100 atoms per 100 trillion atoms
15. It starts to decrease
16. ${}^{14}_{6}\mathrm{C} \longrightarrow {}^{14}_{7}\mathrm{C} + {}^{0}_{-1}\mathrm{e}$
17. 5730 years
18. 5730 years
19. By comparing the amount of carbon-14 in the artifact with the carbon-14 in living trees, you can determine how many half-lives have passed.
20. no; All the carbon-14 would be gone, and an accurate measurement would be impossible.
21. fission
22. fusion
23. three neutrons are produced
24. yes
25. yes
26. Each one could hit another U-235 and produce three more neutrons.

CHEMACTIVITY 18A: ALKANES

ANSWERS TO CRITICAL THINKING QUESTIONS

1. 5; 6; 8
2. 5; 6; 8
3. 1; 3; 4; 2
4. Which atoms are bonded together in a molecule.
5. No. CH_3 indicates that the three hydrogens are bonded to the carbon.
6. The more carbons, the higher the boiling point.
7. pentane and hexane
8. more atoms → stronger dispersion forces
9. C_8H_{18};  ; $CH_3CH_2CH_2CH_2$ $CH_2CH_2CH_2CH_3$
10. carbon and hydrogen
11. no
12. An alkane is a molecule containing only carbon and hydrogen with no double or triple bonds.
13. C_4H_{10}
14. C_4H_{10}
15. no
16. Isomers are molecules with the same atoms (and molecular formulas), but the atoms are connected in different ways.
17. methane
18. methyl
19. drop –ane and add –yl
20. (circle the six carbons in the horizontal chain)
21. (put a rectangle around the two carbons dropping from the straight chain)
22. It is the carbon with the ethyl group attached.
23. It is the end closest to the substituent.
24. Alphabetical order.
25. no; There is nothing.
26. a hyphen

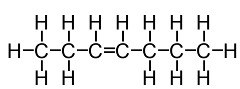
ChemActivity 18B: Alkenes and Alkynes

Answers to Critical Thinking Questions

1. a carbon-carbon double bond
2. end in -ene
3. a carbon-carbon triple bond
4. end in –yne
5. alkenes
6.

C_nH_{2n}	C_nH_{2n-2}	C_nH_{2n+2}
alkenes	alkynes	alkanes

7. the position of the double bond
8. the end closest to the double bond; In each example, the double bond is between the numbered carbon and the next higher numbered carbon. (In 2-octyne, numbering starts from the right.)
9.

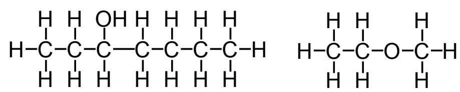
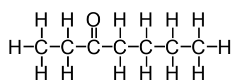
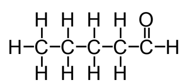
C_7H_{14} $CH_3CH_2CH{=}CHCH_2CH_2CH_3$ 

10. A hydrocarbon is a molecule with only carbon and hydrogen atoms.
11. ethane
12. chlorine
13. fluorine, bromine, iodine, astatine
14. H from ethane and Cl from chlorine
15. HCl
16. A chlorine atom is being substituted for a hydrogen atom.
17.
    a. methane and bromine (Br_2)
    b. with heat or light
    c. HBr
18. ethane
19. chlorine
20. yes
21. yes
22. One chlorine atom is on one side of the double bond and the other chlorine atom is on the other side of the double bond.
23. no
24. alkenes; Alkenes react with halogens without heat or light.
25. A halogen is being added to an alkene.
26. 2-pentene

27. hydrogen
28. hexane
29. two. After the first one adds, it will be an alkene. The second one adds to make it an alkane.
30. No. There is no double bond and all the carbons already have as many hydrogens as they can.
31. Alkanes are saturated. Alkenes and alkynes are undsaturated.
32. unsaturated fats
33. C_6H_6
34. 12
35. It has double bonds.
36. no
37. benzene. One would expect it to undergo an addition reaction with hydrogen because it has a carbon-carbon double bond. It does not, so it is surprisingly stable.

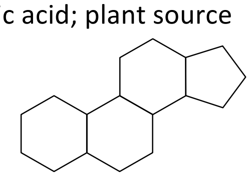
ChemActivity 18C: Functional Groups

Answers to Critical Thinking Questions

1. an –OH group connected to an alkyl group; (circle all the OHs in the alcohols)
2. They end in "-ol."
3. The carbon that the –OH is attached to.
4. an –O– between two alkyl groups
   alkyl groups and end in "ether"
5. 
6. a carbon-oxygen double bond
7. Aldehydes all have one H atom on the double-bonded carbon. Ketones have two alkyl groups on the double-bonded carbon.
8. aldehyde
9. –one
10. 
11. 
12. an OH bonded to a C which is bonded to an alkyl group and double bonded to an O atom
13. two alkyl groups bonded to a O-C=O group
14. (circle the proton on the OH)
15. (circle the CH_3)
16. (draw a box around the $CH_3CH_2CH_2COO$)
17. 4
18. yes
19. (circle the CH_2CH_3 on the right)
20. (draw a box around the CH_3CH_2COO)
21. CH_3CH_2COOH
22. an N with 1–3 alkyl groups
23. an ethyl and a methyl
24. benzaldehyde (almond flavoring); with a name like that, cadaverine must stink!

ChemActivity 19A: Carbohydrates and Lipids

Answers to Critical Thinking Questions

1. $C_6H_{12}O_6$; $C_6H_{12}O_6$; $C_6H_{12}O_6$
2. no
3. 6; 6
4. Its molecular formula can be written as carbon with water molecules.
5. aldehyde and alcohol
6. (circle CH_2 toward the bottom)
7. yes; (circle CH_2 group toward the top)
8. (see Figure 19.2 in *Introductory Chemistry*)
9. (glucose is top left; fructose is top right; sucrose is bottom)
10. (circle and label the O between the glucose and fructose portions of sucrose)
11. $C_{12}H_{22}O_{11}$; yes
12. no; 2Hs and an O are missing. They form water.
13. Disaccharides are formed of monosaccharides bonded together.
14. glycosidic linkage
15. glucose
16. yes; It is made of carbohydrate units, so it must also be $C_n(H_2O)_m$
17. polar
18. yes; They are polar and like dissolves like.
19. non-polar
20. no; They are non-polar and like dissolves like.
21. carboxylic acid
22. myristic acid; plant and animal source
23. oleic acid; plant source
24. 
25. fatty acids

ChemActivity 19B: Proteins and DNA

Answers to Critical Thinking Questions

1. (circle the H_2N- group and label "amine")
2. carboxylic acid; (draw a box around the COOH and label it "acid")
3. methyl
4. alcohol; carboxylic acid; amine
5. An amino acid has an NH_2 on one end, a carboxylic acid on the other, and an R-group bonded to the central carbon which can be a wide number of things.
6. alanine, serine, and aspartic acid. Only lysine is an essential amino acid.
7. lysine and serine; (Label the one on the left lysine and the one on the right serine.)
8. (circle the bond between C=O and N in the bottom structure and label it "peptide bond")
9. No. There OH from lysine and H from serine are missing. A water molecule is the missing product.
10. yes; additional amino acids could be added to the N on the left or the COOH on the right.
11. primary structure
12. secondary structure
13. pleated sheet, helix, random coil
14. tertiary structure
15. Quaternary structure is the coming together of two or more peptide chains to form a large three-dimensional structure.
16. deoxyribose
17. four; adenine, cytosine, thymine, guanine
18. three; (circle the three pentose rings in the structure)
19. (draw a box around each of the three ring structures to the upper right of each deoxyribose); from top to bottom: adenine, thymine, guanine
20. PO_4: phosphate
21. DNA is a long chain of deoxyribose units connected with phosphate. Each deoxyribose has a nucleoside base connected to it on the side opposite the phosphate.

Measurement and Problem Solving

2

Chapter Overview

Chapter 2 introduces the student to a cornerstone of the chemical sciences, the manipulation of numbers and their associated units. These concepts are very important for the rest of the course, and in order to be successful in this course, students must understand them well. Simple and complex unit conversions as well as problem-solving strategies will be covered and explained in detail.

Lecture Outline

2.1 Measuring Global Temperatures
- A. Units are important
- B. How many digits do I report?

2.2 Scientific Notation: Writing Large and Small Numbers
- Learning Objective: Express very large and very small numbers using scientific notation.
- A. Shorthand notation for numbers
- B. Two main pieces: decimal and power-of-10 exponent
- C. Measured value does not change, just how you report it

2.3 Scientific Figures: Writing Numbers to Reflect Precision
- Learning Objective: Report measured quantities to the right number of digits.
- A. How many digits can I report? How many should I report?
- B. Certain digits and estimated digits
- C. Counting significant figures
  1. All nonzero digits are significant
  2. Interior zeros are significant
  3. Trailing zeros after a decimal point are significant
  4. Trailing zeros before a decimal point are significant
  5. Leading zeros are not significant
  6. Zeros at the end of a number, but to the left of a decimal point, are ambiguous
- D. Exact numbers

2.4 Significant Figures in Calculations
- Learning Objective: Round numbers to the correct number of significant figures.
- Learning Objective: Determine the correct number of significant figures in the results of multiplication and division calculations.
- Learning Objective: Determine the correct number of significant figures in the results of addition and subtraction calculations.

Learning Objective: Determine the correct number of significant figures in the results of calculations involving both addition/subtraction and multiplication/division.

A. Multiplication and Division
   1. Result carries as many significant digits as the factor with the fewest significant digits.

B. Rounding
   1. If leftmost dropped digit is 4 or less, round down
   2. If leftmost dropped digit is 5 or higher, round up

C. Addition and Subtraction
   1. Result carries as many decimal places as the quantity with the fewest decimal places

D. Calculations Involving Both Multiplication/Division and Addition/Subtraction
   1. Do steps in parentheses first
   2. Determine the number of significant figures in intermediate answer
   3. Do remaining steps

2.5 The Basic Units of Measurement

Learning Objective: Recognize and work with the SI base units of measurement, prefix multipliers, and derived units.

A. English, metric, SI

B. SI Units
   1. Length – m
   2. Mass – kg
   3. Time – s

C. Prefix Multipliers
   1. milli (m) 0.001
   2. centi (c) 0.01
   3. kilo (k) 1000
   4. Mega (M) 1,000,000

D. Derived Units
   1. Area – cm^2
   2. Volume – cm^3 or L

2.6 Problem Solving and Unit Conversions

Learning Objective: Convert between units.

A. Units are important, most numbers have one

B. Include units in all calculations

C. Conversion factors change one unit to another, the value is unchanged

2.7 Solving Multistep Conversion Problems

Learning Objective: Convert between units.

A. Understand where you are going first

B. Not all calculations can be done in one step

2.8 Units Raised to a Power

Learning Objective: Convert units raised to a power.

A. 1 inch = 2.54 cm so 1 $inch^3 = (2.54)^3\ cm^3 = 16.4\ cm^3$

2.9 Density

Learning Objective: Calculate the density of a substance.

Learning Objective: Use density as a conversion factor.

A. Mass per unit volume
B. Derived unit
C. Can be used as a conversion factor between mass and volume

2.10 Numerical Problem-Solving Strategies and the Solution Map

A. Come up with a plan before you use your calculator
B. Use the units to guide your plan

Chemical Principle Teaching Ideas

Uncertainty

Students generally have a hard time understanding this concept. One method is to refer to everyday objects that they recognize. For example, you can talk about a coffee cup containing about 200 mL of coffee. You then ask the students what the new volume would be if you were to add a drop of water with a volume of 0.05 mL.

Units

Units are very important, and should always be used. Consider giving the students a measured value in many different units and having them guess what the unit is. Report the volume of your mug in barrels. What is the volume of the room measured in teaspoons?

Density

Most students understand the concept of density, or how much stuff is packed into a particular volume. What they have a harder time recognizing is the fact that it is a conversion factor between mass and volume. This is the easiest example that is discussed and should be emphasized as this concept is used frequently throughout the course.

Skill Builder Solutions

2.1. Assuming all the trailing zeros are not significant, the decimal moves over 13 spaces to give $1.6342 $\times 10^{13}$.

2.2. All the leading zeros are not significant, so we move the decimal over 5 places to give 3.8×10^{-5}.

2.3. Each of the markings on the thermometer represents 1 degree Fahrenheit. We can therefore estimate one digit past the decimal place for a temperature of 103.4 degrees Fahrenheit.

2.4. a. 4
b. 3, as leading zeros do not count, but trailing zeros after the decimal do
c. 2
d. Unlimited significant figures
e. 3
f. Ambiguous, since you do not know if the last 2 zeros are significant

2.5. a. $\dfrac{1.10 \times 0.512 \times 1.301 \times 0.005}{3.4} = 0.001$. There is only one significant digit in the final answer as the 0.005 has only one significant digit in the numerator.

b. $\dfrac{4.562 \times 3.99870}{89.5} = 0.204$. The number 89.5 has the fewest number of significant digits, 3, so that is how many quoted in the final answer.

2.6. a. 2.18 + 5.621 + 1.5870 – 1.8 = 7.6. Only one digit past the decimal place is quoted because the least accurately known number (1.8) has one digit past the decimal.

b. 7.876 – 0.56 + 123.792 = 131.11. Two digits past the decimal are quoted, because 0.56 has two past the decimal and is the number with the fewest digits past the decimal.

2.7. a. $3.897 \times (782.3 - 451.88) = 3.897 \times 330.\underline{4}2 = 1288$. Four digits are quoted because the number in the second (multiplication) step with the fewest significant digits has four of them.

b. $\dfrac{4.58}{1.239} - 0.578 = 3.70 - 0.578 = 3.12$. Two digits past the decimal are quoted because the first part of the subtraction (3.70) has two digits past the decimal place.

2.8. $56.0\ \cancel{\text{cm}} \times \dfrac{1\ \text{inch}}{2.54\ \cancel{\text{cm}}} = 22.0\ \text{inch}$

2.9. $5{,}678\ \cancel{\text{m}} \times \dfrac{1\ \text{km}}{1000\ \cancel{\text{m}}} = 5.678\ \text{km}$

2.10. $1.2\ \cancel{\text{cu}} \times \dfrac{1\ \cancel{\text{qt}}}{4\ \cancel{\text{cu}}} \times \dfrac{1\ \text{L}}{1.057\ \cancel{\text{qt}}} = 0.28\ \text{L}$

2.11. $15.0\ \cancel{\text{km}} \times \dfrac{0.6214\ \cancel{\text{mi}}}{1\ \cancel{\text{km}}} \times \dfrac{5280\ \cancel{\text{ft}}}{1\ \cancel{\text{mi}}} \times \dfrac{1\ \text{lap}}{1056\ \cancel{\text{ft}}} = 46.6\ \text{laps}$

Plus. $5.72\ \cancel{\text{naut mi}} \times \dfrac{1.151\ \cancel{\text{mi}}}{1\ \cancel{\text{naut mi}}} \times \dfrac{1\ \cancel{\text{km}}}{0.6214\ \cancel{\text{mi}}} \times \dfrac{1000\ \text{m}}{1\ \cancel{\text{km}}} = 1.06 \times 10^4\ \text{m}$

2.12. $289.7\ \cancel{\text{in}^3} \times \dfrac{(2.54)^3\ \text{cm}^3}{1\ \cancel{\text{in}^3}} = 4747\ \text{cm}^3$

2.13. $3.25\ \cancel{\text{yd}^3} \times \dfrac{(36)^3\ \text{inch}^3}{1\ \cancel{\text{yd}^3}} = 1.52 \times 10^5\ \text{inch}^3$

2.14. $\dfrac{9.67\ \text{g}}{0.452\ \text{cm}^3} = 21.4\ \text{g/cm}^3$; Therefore the ring is genuine platinum.

2.15. $35 \cancel{\text{mg}} \times \dfrac{1 \cancel{\text{g}}}{1000 \cancel{\text{mg}}} \times \dfrac{1 \text{ cm}^3}{0.788 \cancel{\text{g}}} = 4.4 \times 10^{-2} \text{ cm}^3$

Plus. $246 \cancel{\text{cm}^3} \times \dfrac{7.93 \cancel{\text{g}}}{1 \cancel{\text{cm}^3}} \times \dfrac{1 \text{ kg}}{1000 \cancel{\text{g}}} = 1.95 \text{ kg}$

2.16. $0.82 \cancel{\text{L}} \times \dfrac{1000 \cancel{\text{mL}}}{1 \cancel{\text{L}}} \times \dfrac{19.3 \cancel{\text{g}}}{1 \cancel{\text{mL}}} \times \dfrac{1 \text{ kg}}{1000 \cancel{\text{g}}} = 16 \text{ kg}$

2.17. $\dfrac{23.2 \cancel{\text{mg}} \times \dfrac{1 \text{ g}}{1000 \cancel{\text{mg}}}}{1.20 \cancel{\text{mm}^3} \times \dfrac{1 \text{ cm}^3}{(10)^3 \cancel{\text{mm}^3}}} = \dfrac{2.32 \times 10^{-2} \text{ g}}{1.20 \times 10^{-3} \text{ cm}^3} = 19.3 \text{ g/cm}^3$

Yes, it is consistent with the density of gold.

Suggested Demonstrations

Density and Miscibility of Liquids, *Chemical Demonstrations* 3:233, Shakhashiri, B.Z. University of Wisconsin Press, 1989.

Guided Inquiry Ideas

Below are a few example questions that students answer in the guided inquiry activities provided in the Guided Activity Workbook.

How many significant figures are there in the number 0.0051? Underline it/them.

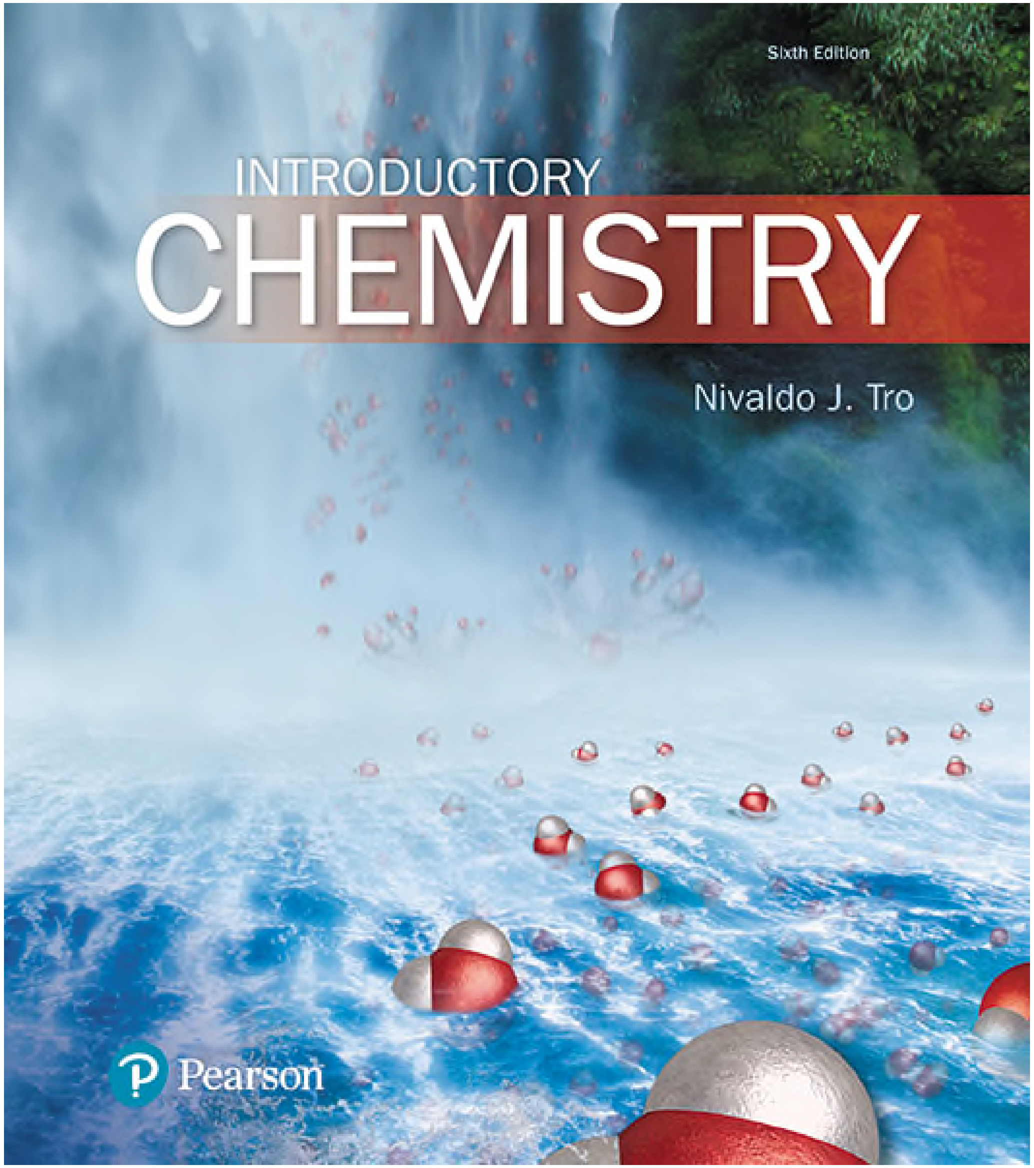
How many significant figures are there in the number 5.00? Underline it/them.

In a complete sentence or two describe when you know a "trailing zero" is significant.

In a complete sentence, describe the significance of "leading zeros".

Which of the following is a correct conversion factor from cm^3 to in^3? Circle all that apply.

$\left(\dfrac{1 \text{ in}^3}{2.54 \text{ cm}^3}\right)$ $\qquad \left(\dfrac{1 \text{ in}}{2.54 \text{ cm}}\right)^3$ $\qquad \left(\dfrac{1 \text{ in}^3}{16.4 \text{ cm}^3}\right)$



Lecture Presentation

Chapter 2

Measurement and Problem Solving

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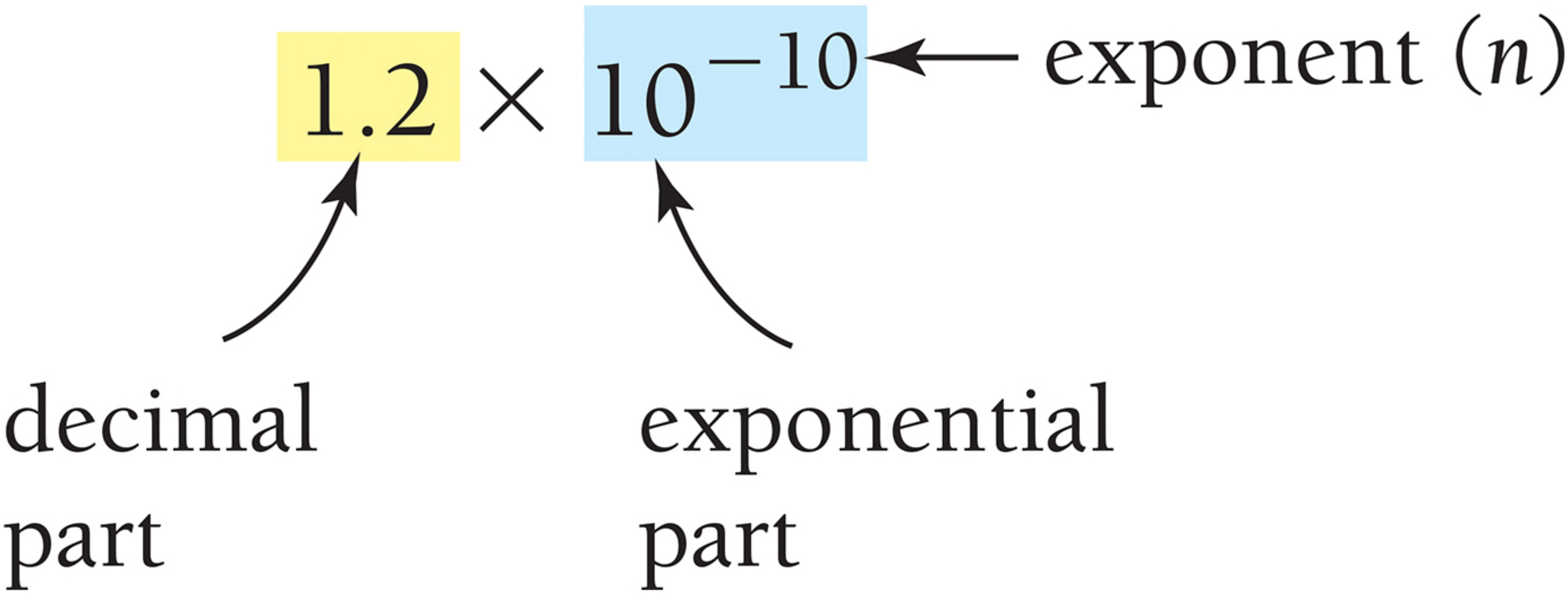
Uncertainty Indicated by Last Reported Digit

- **The uncertainty is indicated by the last reported digit.**
- Example: measuring global temperatures
- Average global temperatures have risen by 0.6 °C in the last century.
- By reporting a temperature increase of 0.6 °C, the scientists mean 0.6 +/– 0.1 °C.
- The temperature rise could be as much as 0.7 °C or as little as 0.5 °C, but it is not 1.0 °C.
- The degree of certainty in this particular measurement is critical, influencing political decisions that directly affect people's lives.

Scientific Notation Has Two Parts

- A number written in scientific notation has two parts.
- A **decimal part: a number that is between 1 and 10.**
- An **exponential part: 10 raised to an exponent, *n*.**



Writing Very Large and Very Small Numbers

- A positive exponent means 1 multiplied by 10 *n* times.
- A negative exponent (–*n*) means 1 divided by 10 *n* times.

$$10^0 = 1$$

$$10^1 = 1 \times 10 = 10$$

$$10^2 = 1 \times 10 \times 10 = 100$$

$$10^3 = 1 \times 10 \times 10 \times 10 = 1000$$

$$10^{-1} = \frac{1}{10} = 0.1$$

$$10^{-2} = \frac{1}{10 \times 10} = 0.01$$

$$10^{-3} = \frac{1}{10 \times 10 \times 10} = 0.001$$

To Convert a Number to Scientific Notation

- Find the decimal part. Find the exponent.
- Move the decimal point to obtain a number between 1 and 10.
- Multiply that number (the decimal part) by 10 raised to the power that reflects the movement of the decimal point.

To Convert a Number to Scientific Notation

$5983 = 5.983 \times 10^{3}$

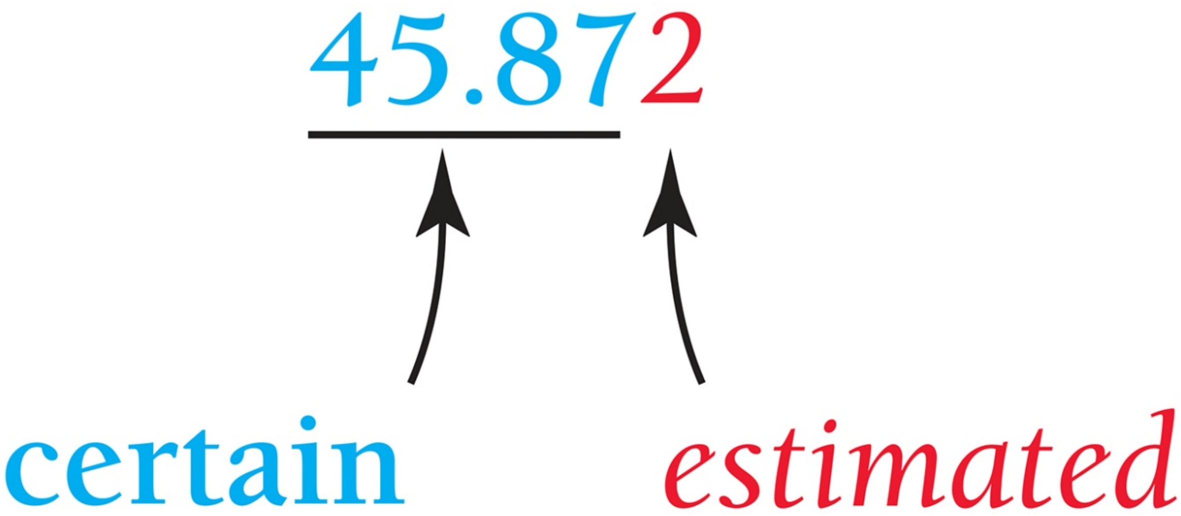
3 2 1

$0.00034 = 3.4 \times 10^{-4}$

1 2 3 4

- If the decimal point is moved to the left, the exponent is positive.
- If the decimal point is moved to the right, the exponent is negative.

Reporting Scientific Numbers



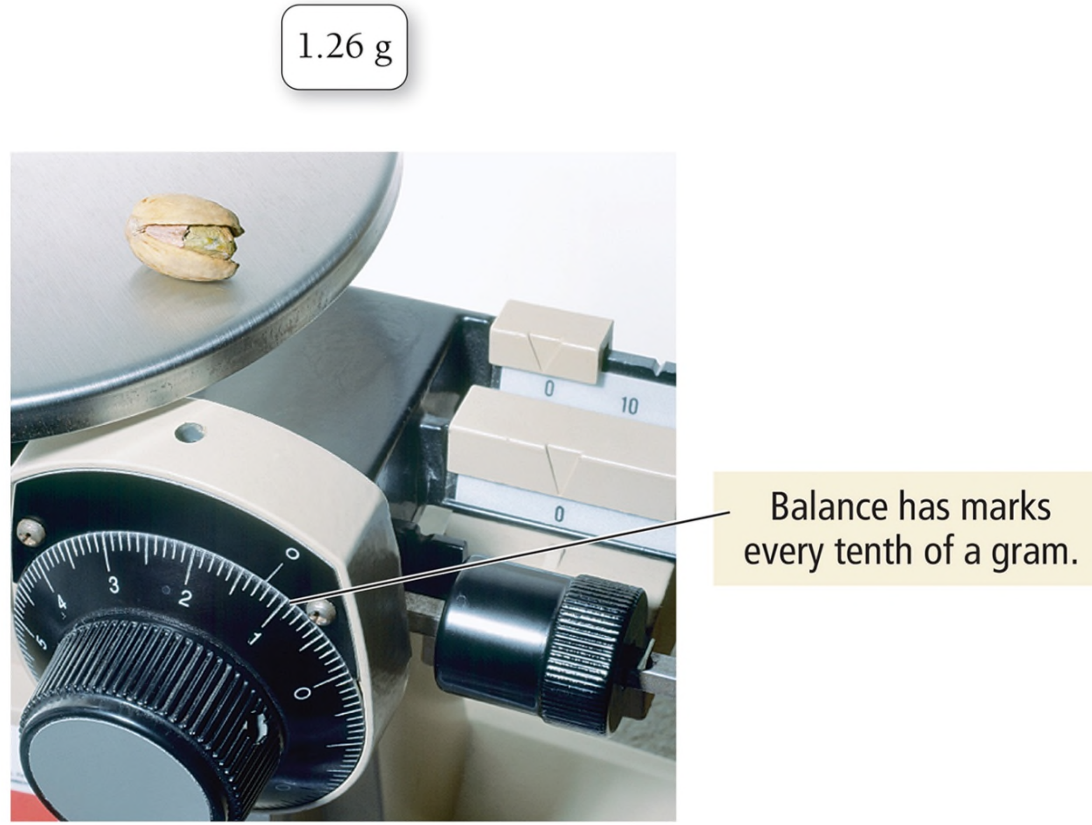
- The first four digits are certain; the last digit is estimated.
- The greater the precision of the measurement, the greater the number of significant figures.

Estimating Tenths of a Gram

- This balance has markings every 1 g.
- We estimate to the tenths place.
- To estimate between markings, mentally divide the space into 10 equal spaces and estimate the last digit.
- This reading is 1.2 g.

Estimating Hundredths of a Gram

- This scale has markings every 0.1 g.
- We estimate to the hundredths place.
- The correct reading is 1.26 g.



Significant Figures in a Correctly Reported Measurement

1. All **nonzero** digits **are significant.**
2. **Interior zeros** (zeros between two numbers) **are significant.**
3. **Trailing zeros** (zeros to the right of a nonzero number) that fall after a decimal point **are significant.**
4. **Trailing zeros** that fall before a decimal point **are significant.**
5. **Leading zeros** (zeros to the left of the first nonzero number) **are NOT significant.** They serve only to locate the decimal point.
6. **Trailing zeros at the end** of a number, but before an implied decimal point, **are ambiguous** and should be avoided.

Identifying Exact Numbers

- *Exact numbers have an unlimited number of significant figures.*
- Exact counting of discrete objects
- Integral numbers that are part of an equation
- Defined quantities
- *Some conversion factors are defined quantities, while others are not.*

1 in. = 2.54 cm exact

Counting Significant Figures

How many significant figures are in each number?

0.0035	**two significant figures**
1.080	**four significant figures**
2371	**four significant figures**
2.9×10^5	**three significant figures**
1 dozen = 12	**unlimited significant figures**
100.00	**five significant figures**
100,000	**ambiguous**

Significant Figures in Calculations

Rules for Rounding:

- When numbers are used in a calculation, the result is rounded to reflect the significant figures of the *data*.
- For calculations involving multiple steps, round only the final answer—*do not round off between steps*.
  - This practice prevents small rounding errors from affecting the final answer.

Significant Figures in Calculations

Rules for Rounding:

- Use only the *last (or leftmost) digit being dropped* to decide in which direction to round—ignore all digits to the right of it.
- Round down if the last digit dropped is 4 or less; round up if the last digit dropped is 5 or more.

Significant Figures in Calculations

Multiplication and Division Rule:

- The result of multiplication or division carries the same number of significant figures as the factor with the fewest significant figures.

Significant Figures in Calculations

Multiplication and Division Rule:

- The intermediate result (in blue) is rounded to two significant figures to reflect the least precisely known factor (0.10), which has two significant figures.

$$5.02 \times 89.665 \times 0.10 = 45.0118 = 45$$

5.02	89.665	0.10	45.0118	45
(3 sig. figures)	(5 sig. figures)	(2 sig. figures)		(2 sig. figures)

Significant Figures in Calculations

Multiplication and Division Rule:

- The intermediate result (in blue) is rounded to three significant figures to reflect the least precisely known factor (6.10), which has three significant figures.

$$5.892 \div 6.10 = 0.96590 = 0.966$$

(4 sig. figures) (3 sig. figures) (3 sig. figures)

Significant Figures in Calculations

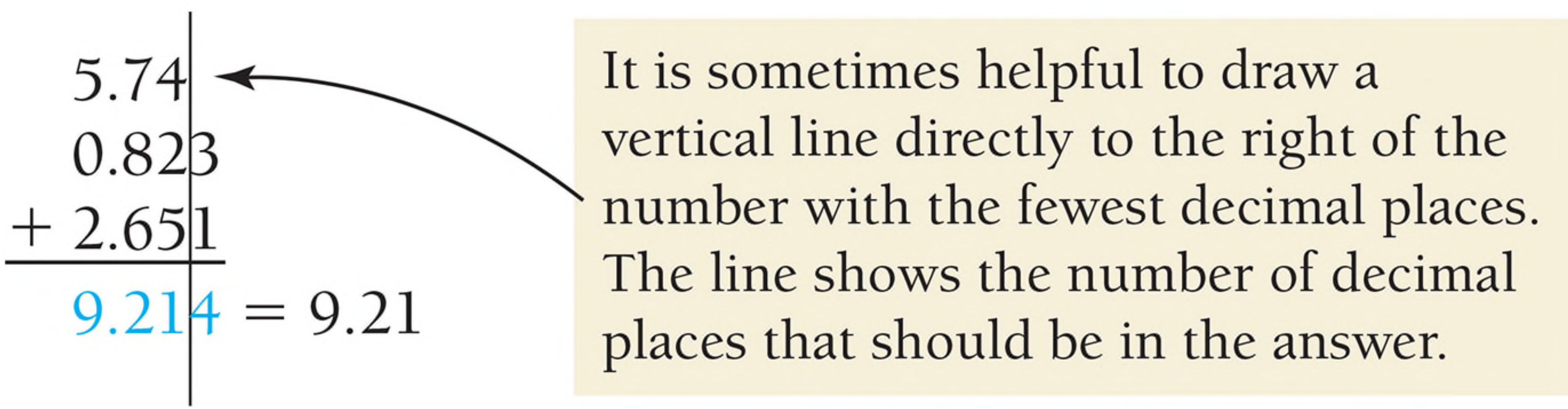
Addition and Subtraction Rule:

- In addition or subtraction calculations, the result carries the same number of decimal places as the quantity carrying the fewest decimal places.

Significant Figures in Calculations

Addition and Subtraction Rule:

- We round the intermediate answer (in blue) to two decimal places because the quantity with the fewest decimal places (5.74) has two decimal places.



Significant Figures in Calculations

Addition and Subtraction Rule:

- We round the intermediate answer (in blue) to one decimal place because the quantity with the fewest decimal places (4.8) has one decimal place.

$$\begin{array}{r} 4.8 \\ -\ 3.965 \\ \hline 0.835 \end{array} = 0.8$$

Both Multiplication/Division and Addition/Subtraction

In calculations involving both multiplication/division and addition/subtraction

- do the steps in parentheses first;
- determine the correct number of significant figures in the intermediate answer <u>without rounding</u>;
- then do the remaining steps.

Both Multiplication/Division and Addition/Subtraction

- In the calculation 3.489 × (5.67 – 2.3), do the step in parentheses first. 5.67 – 2.3 = $3.\underline{3}7$
- Use the subtraction rule to determine that the intermediate answer has only one significant decimal place.
- To avoid small errors, it is best not to round at this point; instead, underline the least significant figure as a reminder.

$$3.489 \times 3.\underline{3}7 = 1\underline{1}.758 = 12$$

- Use the multiplication rule to determine that the intermediate answer (11.758) rounds to two significant figures (12) because it is limited by the two significant figures in $3.\underline{3}7$.

The Basic Units of Measurement

- The unit system for science measurements, based on the metric system, is called the **International System of Units** (*Système International d'Unités*) or ***SI* units**.

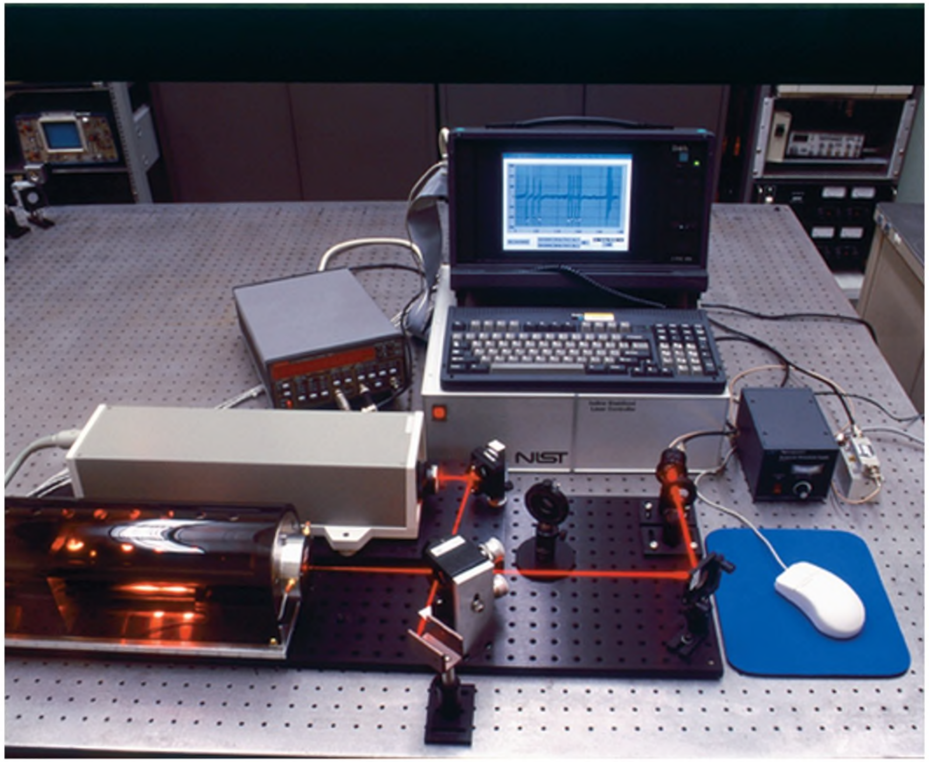
TABLE 2.1 Important SI Base Units

Quantity	Unit	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
temperature*	kelvin	K

*Temperature units are discussed in Chapter 3.

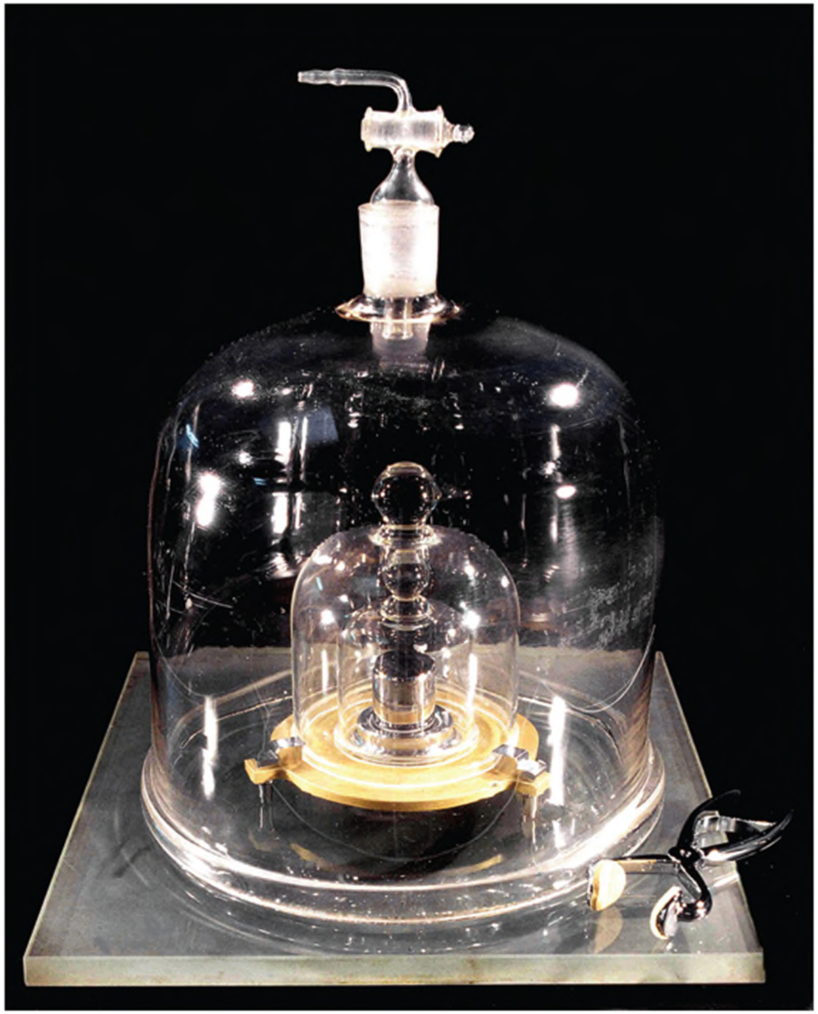
Basic Units of Measurement: Length

- **The standard of length:** The definition of a meter, established by international agreement in 1983, is the distance that light travels in vacuum in 1/299,792,458 s (The speed of light is 299,792,458 m/s.).



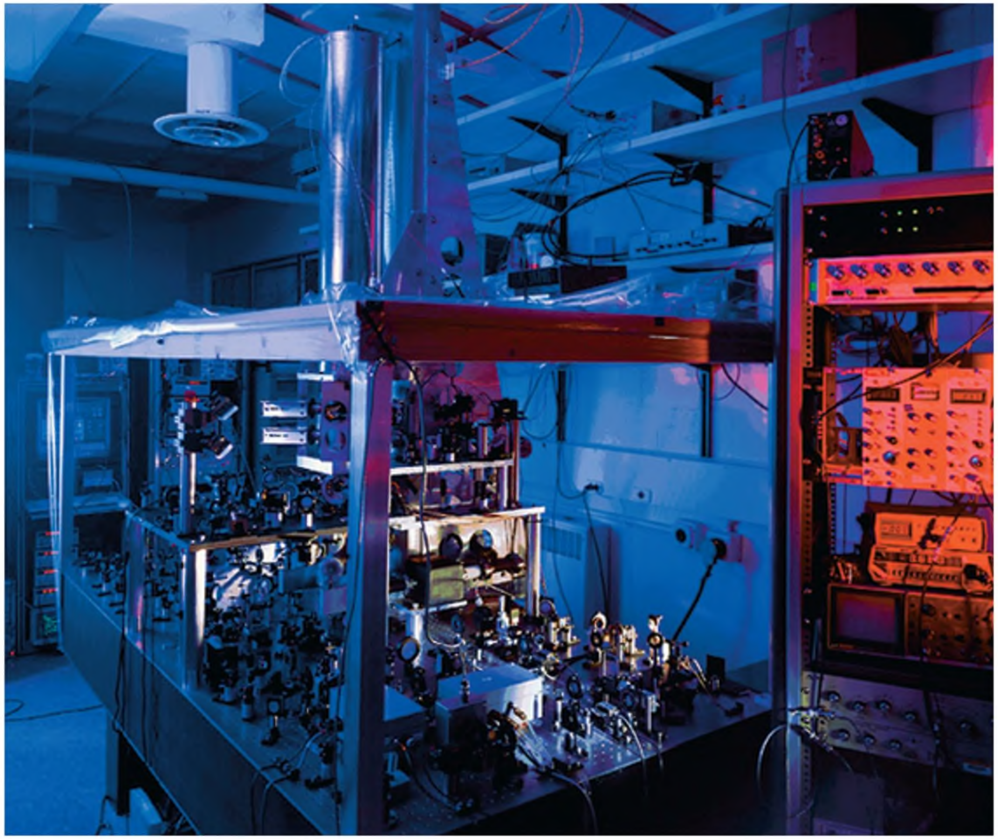
Basic Units of Measurement: Mass

- **The standard of mass:** The kilogram is defined as the mass of a block of metal kept at the International Bureau of Weights and Measures at Sèvres, France. A duplicate is kept at the National Institute of Standards and Technology near Washington, D.C.



Basic Units of Measurement: Time

- **The standard of time:** The second is defined, using an atomic clock, as the duration of 9,192,631,770 periods of the radiation emitted from a certain transition in a cesium-133 atom.



Weight vs. Mass

- The kilogram is a measure of mass, which is different from weight.
- The **mass** of an object is a measure of the quantity of **matter** within it.
- The weight of an object is a measure of the gravitational pull on that matter.
- Consequently, **weight** depends on **gravity** while mass does not.

SI Prefix Multipliers

TABLE 2.2 SI Prefix Multipliers

Prefix	Symbol	Meaning	Multiplier	
tera-	T	trillion	1,000,000,000,000	(10^{12})
giga-	G	billion	1,000,000,000	(10^{9})
mega-	M	million	1,000,000	(10^{6})
kilo-	k	thousand	1,000	(10^{3})
hecto-	h	hundred	100	10^{2}
deca-	da	ten	10	10^{1}
deci-	d	tenth	0.1	(10^{-1})
centi-	c	hundredth	0.01	(10^{-2})
milli-	m	thousandth	0.001	(10^{-3})
micro-	μ	millionth	0.000001	(10^{-6})
nano-	n	billionth	0.000000001	(10^{-9})
pico-	p	trillionth	0.000000000001	(10^{-12})
femto-	f	quadrillionth	0.000000000000001	(10^{-15})

Choosing Prefix Multipliers

- Choose the prefix multiplier that is most convenient for a particular measurement.
- Pick a unit similar in size to (or smaller than) the quantity you are measuring.
- A short chemical bond is about 1.2×10^{-10} m. Which prefix multiplier should you use?

  pico = 10^{-12}; nano = 10^{-9}
- The most convenient one is probably the picometer. Chemical bonds measure about 120 pm.

Volume as a Derived Unit

- A derived unit is formed from other units.
- Many units of **volume,** a measure of space, are derived units.
- Any unit of length, when cubed (raised to the third power), becomes a unit of volume.
- Cubic meters (m^3), cubic centimeters (cm^3), and cubic millimeters (mm^3) are all units of volume.

Problem-Solving and Unit Conversions

- Getting to an equation to solve from a problem statement requires *critical thinking.*
- No simple formula applies to every problem, yet you can learn problem-solving strategies and begin to develop some chemical intuition.

Unit conversion type:

- Many of the problems can be thought of as *unit conversion problems,* in which you are given one or more quantities and asked to convert them into different units.

Specific equation type:

- Other problems require the use of *specific equations* to get to the information you are trying to find.

Using Dimensional Analysis to Convert Between Units

- Units are multiplied, divided, and canceled like any other algebraic quantities.
- Using units as a guide to solving problems is called *dimensional analysis*.
- Always write every number with its associated unit.
- Always include units in your calculations, dividing them and multiplying them as if they were algebraic quantities.
- Do not let units appear or disappear in calculations. Units must flow logically from beginning to end.

Using Dimensional Analysis to Convert Between Units

- For most conversion problems, we are given a quantity in some units and asked to convert the quantity to another unit. These calculations take the form:

$$\text{information given} \times \text{conversion factor(s)} = \text{information sought}$$

$$\cancel{\text{given unit}} \times \frac{\text{desired unit}}{\cancel{\text{given unit}}} = \text{desired unit}$$

Converting Between Units

- Conversion factors are constructed from any two quantities known to be equivalent.
- We construct the conversion factor by dividing both sides of the equality by 1 in. and canceling the units.

$$2.54\text{ cm} = 1\text{ in.}$$

$$\frac{2.54\text{ cm}}{1\text{ in.}} = \frac{1\text{ in.}}{1\text{ in.}}$$

$$\frac{2.54\text{ cm}}{1\text{ in.}} = 1$$

The quantity $\frac{2.54\text{ cm}}{1\text{ in.}}$ is equal to 1 and can be used to convert between inches and centimeters.

Converting Between Units

- In solving problems, always check if the final units are correct, and consider whether or not the magnitude of the answer makes sense.

$$44.7\ \cancel{\text{cm}} \times \frac{1\ \text{in.}}{2.54\ \cancel{\text{cm}}} = 17.6\ \text{in.}$$

- Conversion factors can be inverted because they are equal to 1 and the inverse of 1 is 1.

Therefore,

$$\frac{1}{1} = 1$$

$$\frac{2.54\ \text{cm}}{1\ \text{in.}} = 1 = \frac{1\ \text{in.}}{2.54\ \text{cm}}$$

The Solution Map

- A solution map is a visual outline that shows the strategic route required to solve a problem.
- For unit conversion, the solution map focuses on units and how to convert from one unit to another.

Diagram Conversions Using a Solution Map

- The solution map for converting from inches to centimeters is as follows:

$$\frac{2.54\ \text{cm}}{1\ \text{in.}}$$

- The solution map for converting from centimeters to inches is as follows:

$$\frac{1\ \text{in.}}{2.54\ \text{cm}}$$

General Problem-Solving Strategy

- Identify the starting point (the ***given*** information).
- Identify the end point (what you must ***find***).
- Devise a way to get from the starting point to the end point using what is given as well as what you already know or can look up.
- You can use a *solution map* to diagram the steps required to get from the starting point to the end point.
- In graphic form, we can represent this progression as

Given → Solution Map → Find

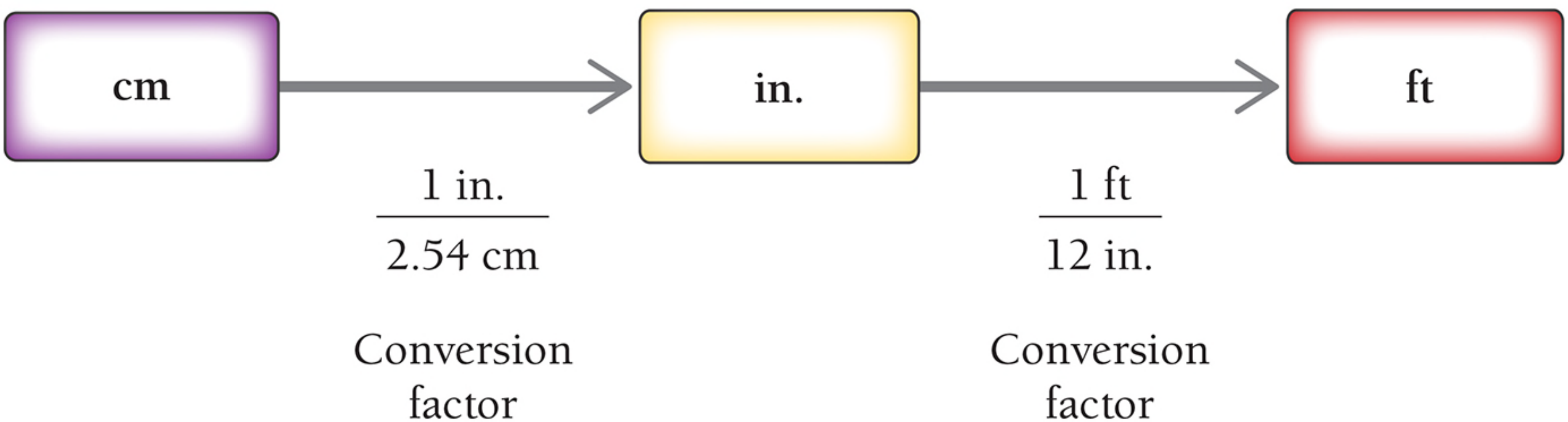
General Problem-Solving Strategy

- **Sort.** Begin by sorting the information in the problem.
- **Strategize.** Create a solution map—the series of steps that will get you from the given information to the information you are trying to find.
- **Solve.** Carry out mathematical operations (paying attention to the rules for significant figures in calculations) and cancel units as needed.
- **Check.** Does this answer make physical sense? Are the units correct?

Solving Multistep Unit Conversion Problems

- Each step in the solution map should have a conversion factor with the units of the previous step in the denominator and the units of the following step in the numerator.

SOLUTION MAP



Follow the Solution Map to Solve the Problem

SOLUTION MAP

$$194\ \cancel{\text{cm}} \times \frac{1\ \cancel{\text{in.}}}{2.54\ \cancel{\text{cm}}} \times \frac{1\ \text{ft}}{12\ \cancel{\text{in.}}} = 6.3648\ \text{ft}$$

Unit Conversion in Both the Numerator and Denominator

SOLUTION MAP

$$48.0\frac{\cancel{\text{mi}}}{\cancel{\text{gal}}} \times \frac{1.609\ \text{km}}{\cancel{\text{mi}}} \times \frac{1\ \cancel{\text{gal}}}{3.785\ \text{L}} = 20.4\ \frac{\text{km}}{\text{L}}$$

Converting Units Raised to a Power

- *When converting quantities with units raised to a power, the conversion factor must also be raised to that power.*

Conversion with Units Raised to a Power

We cube both sides to obtain the proper conversion factor.

$$(2.54\ \text{cm})^3 = (1\ \text{in.})^3$$
$$(2.54)^3\ \text{cm}^3 = 1^3\ \text{in.}^3$$
$$16.387\ \text{cm}^3 = 1\ \text{in.}^3$$

We can do the same thing in fractional form.

$$1255\ \cancel{\text{cm}^3} \times \frac{1\ \text{in.}^3}{16.387\ \cancel{\text{cm}^3}} = 76.5851\ \text{in.}^3 = 76.59\ \text{in.}^3$$

Physical Property: Density

- Why do some people pay more than \$3000 for a bicycle made of titanium?
- For a given volume of metal, titanium has less mass than steel.
- We describe this property by saying that titanium (4.50 g/cm^3) is less dense than iron (7.86 g/cm^3).

Density

The density of a substance is the ratio of its mass to its volume.

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

Calculating Density

- *We calculate the density of a substance by dividing the mass of a given amount of the substance by its volume.*
- For example, a sample of liquid has a volume of 22.5 mL and a mass of 27.2 g.
- To find its density, we use the equation *d* = *m*/*V*.

$$d = \frac{m}{V} = \frac{27.2\ \text{g}}{22.5\ \text{mL}} = 1.21\ \text{g/mL}$$

A Solution Map Involving the Equation for Density

- In a problem involving an equation, the solution map shows how the *equation* takes you from the *given* quantities to the *find* quantity.

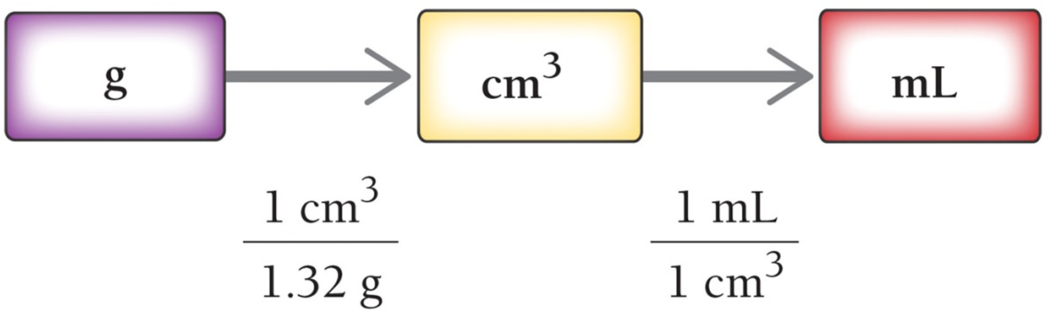
$$d = \frac{m}{V}$$

Density as a Conversion Factor

- We can use the density of a substance as a conversion factor between the mass of the substance and its volume.
  - For a liquid substance with a density of 1.32 g/cm^3, what volume should be measured to deliver a mass of 68.4 g?

Density as a Conversion Factor

SOLUTION MAP



SOLUTION

$$68.4\ \cancel{\text{g}} \times \frac{1\ \cancel{\text{cm}^3}}{1.32\ \cancel{\text{g}}} \times \frac{1\ \text{mL}}{1\ \cancel{\text{cm}^3}} = 51.8\ \text{mL}$$

Measure 51.8 mL to obtain 68.4 g of the liquid.

Densities of Some Common Substances

- Table 2.4 provides a list of the densities of some common substances.
- This data is needed when solving homework problems.

TABLE 2.4 Densities of Some Common Substances

Substance	Density (g/cm^3)
charcoal, oak	0.57
ethanol	0.789
ice	0.92
water	1.0
glass	2.6
aluminum	2.7
titanium	4.50
iron	7.86
copper	8.96
lead	11.4
gold	19.3
platinum	21.4

Chapter 2 in Review

Uncertainty:

- Scientists report measured quantities so that the number of digits reflects the certainty in the measurement.
- Write measured quantities so that every digit is certain except the last, which is estimated.

Chapter 2 in Review

Units:

- Measured quantities usually have units associated with them.
- The SI units:

  length: meter, mass: kilogram, time: second
- Prefix multipliers such as *kilo*- or *milli*- are often used in combination with these basic units.
- The SI units of volume are units of length raised to the third power; liters or milliliters are often used as well.

Chapter 2 in Review

Density:

- The density of a substance is its mass divided by its volume, $d = m/V$, and is usually reported in units of grams per cubic centimeter or grams per milliliter.
- Density is a fundamental property of all substances and generally differs from one substance to another.

Chemical Skills Learning Objectives

1. LO: Express very large and very small numbers using scientific notation.
2. LO: Report measured quantities to the right number of digits.
3. LO: Determine which digits in a number are significant.
4. LO: Round numbers to the correct number of significant figures.

Chemical Skills Learning Objectives

5. LO: Determine the correct number of significant figures in the results of multiplication and division calculations.
6. LO: Determine the correct number of significant figures in the results of addition and subtraction calculations.
7. LO: Determine the correct number of significant figures in the results of calculations involving both addition/subtraction and multiplication/division.

Chemical Skills Learning Objectives

8. LO: Convert between units.
9. LO: Convert units in a quantity that has units in the numerator and the denominator.
10. LO: Convert units raised to a power.
11. LO: Calculate the density of a substance.
12. LO: Use density as a conversion factor.

Highlight Problem Involving Units

- In 1999, NASA lost a $94 million orbiter because two groups of engineers failed to communicate to each other the units that they used in their calculations. Consequently, the orbiter descended too far into the Martian atmosphere and burned up.

Highlight Problem Involving Units

- Suppose that the Mars orbiter was to have established orbit at 155 km and that one group of engineers specified this distance as 1.55×10^5 m.
- Suppose further that a second group of engineers programmed the orbiter to go to 1.55×10^5 ft.
- What was the difference in kilometers between the two altitudes?
- How low did the probe go?