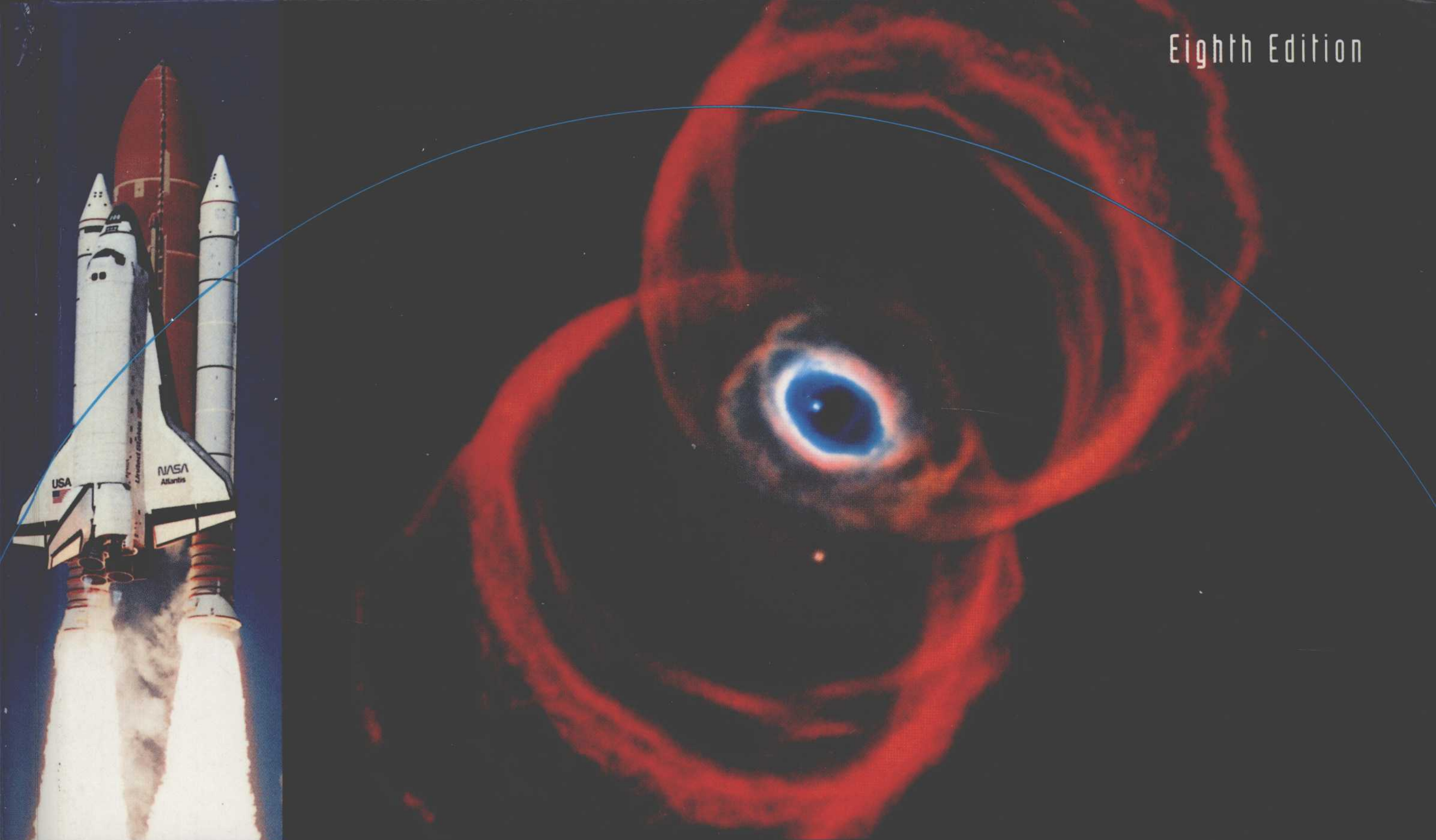
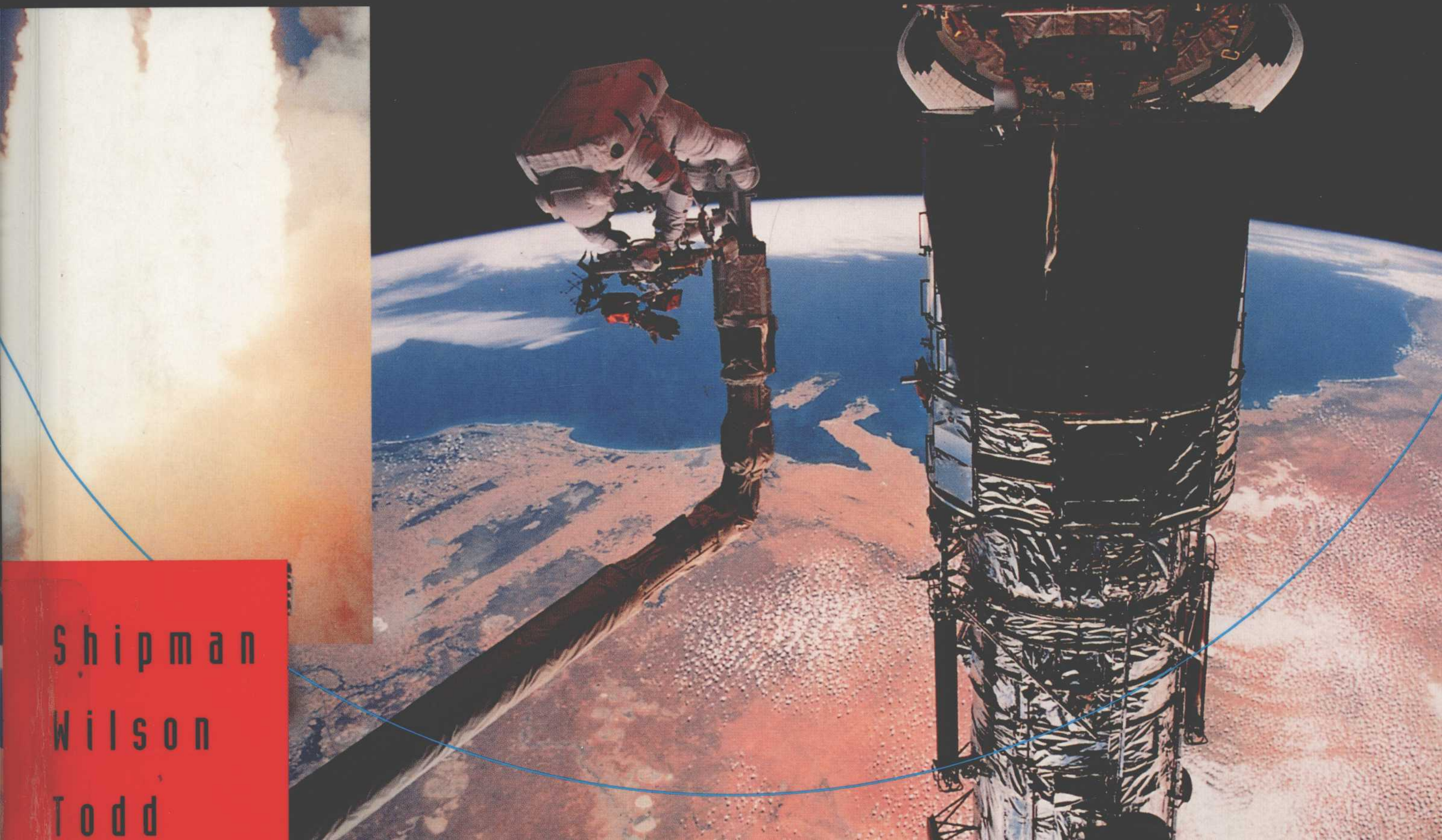
Eighth Edition



# AN INTRODUCTION TO PHYSICAL SCIENCE



Shipman
Wilson
Todd

# An Introduction to Physical Science

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Eighth Edition

Houghton Mifflin Company Boston New York

To

*Students who desire to explore the universe in which they exist*
—J. T. S.

*People of D. C. Heath for twenty-five years of support*
—J. D. W.

*Clara Todd, for her patience and support*
—A. W. T.

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# Preface

Science and technology are the driving forces of change in our modern, technological society. Because of this, it is important that today's students be motivated to gain a broader understanding and knowledge of science. Equipped with this knowledge, they can thrive in our changing world and make informed decisions that ultimately affect their lives and the lives of others. Our primary goals in producing this revision are to stimulate students' interest in and knowledge of the physical sciences and to contribute to the development of their skills in critical reasoning and problem solving needed to cope in our modern world.

*An Introduction to Physical Science,* Eighth Edition, is intended for the first-year college nonscience major. The five divisions of physical science—physics, chemistry, astronomy, geology, and meteorology—are emphasized. Each division of physical science is defined and explained in the context of examples relating to the physical world. The textbook is readily adaptable to either a one- or a two-semester course, as its past success has demonstrated.

One of the outstanding features of this textbook is its emphasis on fundamental concepts. We build on the basic concepts as we progress through the textbook. For example, Chapter 1, which introduces the concepts of measurement, is followed by chapters on the basic topics of physics: motion, force, energy, heat, wave motion, electricity, magnetism, and modern physics. This foundation in physics is useful in developing the principles of chemistry, astronomy, geology, and meteorology that follow.

In this edition, physical concepts in the five divisions, or disciplines, of physical science are made *accessible* by developing them in a logical rather than a chronological fashion. Concepts are made *interesting* by discussing them in the context of everyday experience. Real-world examples throughout the text enhance the students' understanding of the world around them.

Each discipline is treated both descriptively and quantitatively. Mathematical assistance is provided for students who may need it, but the relative emphasis, whether descriptive or quantitative, is left to the discretion of the instructor. To those who wish to emphasize the descriptive approach in teaching physical science, we recommend using only the Review Questions and the Critical Thinking Questions at the end of each chapter and omitting the Exercises.

## Changes in This Edition

Following suggestions from our users, we made several additions and modifications to the Eighth Edition.

### *Enhanced Pedagogy*

- Each section begins with Learning Goals that provide the student with a focus for the text that follows.

- We continue to integrate examples with step-by-step solutions throughout each chapter. In this edition, however, *after* each worked example, a Confidence Exercise gives the student further practice, if needed, in solving that specific type of problem.
- All end-of-chapter exercises have been paired. Each odd-numbered exercise has an even-numbered exercise that is similar in content to provide further practice. Answers are provided for the odd-numbered exercises only, allowing instructors to assign the even-numbered ones as homework.
- Relevance Questions that are thought provoking and relate to the material just covered appear at the end of many sections. These are intended to develop students' critical reasoning skills.
- To the Review Questions at the end of each chapter we added multiple-choice questions that are keyed to the appropriate section of the text, allowing students to quiz their knowledge of material just covered. Answers to the multiple-choice review questions are provided at the end of each chapter so that students can get quick feedback on their understanding of the material.

### *Updating, Rewriting, and Reorganizing*

- In the physics chapters on mechanics (Chapters 2, 3, and 4), several new Highlights were added to provide connections between the principles of physics and the real world (e.g., Impulse and the Automobile Air Bag).
- Chapter 9 (Atomic Physics) and Chapter 10 (Nuclear Physics) were completely rewritten to clarify concepts, simplify the exercises, and provide more exercises for student practice.
- In the chemistry section, Chapter 14 was renamed to better reflect the subject matter (Moles, Solutions, and Gases), and Chapter 15 on Organic Chemistry was condensed.
- Chapter 16 (The Solar System) was rewritten to place greater emphasis on comparative planetology. The latest information on the reporting of newly discovered planets beyond our solar system is included in the chapter. Currently, four planetary systems have been reported and comparisons are shown illustratively with respect to our solar system.
- New information collected by the Clementine space mission to the Moon was added to Chapter 18.
- The coverage of meteorology (Chapters 25 and 26) was condensed in this edition and now follows the coverage of geology.
- To underscore the relevance of the environment to physical science, we provided more examples of real-world environmental issues in this edition.

### *New Design, Improved Photo Program*

The inviting new design will be evident to those of you who have taught from previous versions of this textbook. Our goal was to make the presentation appealing and nonthreatening to students taking this course, since many students view this, and most science courses, as a less than welcoming proposition.

New photos were added to improve upon previous ones, where needed, and to provide more current information when appropriate. For example, the latest Hubble photograph of deep-space galaxies is included in Chapter 19. This photo, which required ten consecutive days for exposure, is a look back through space and eons of time at galaxies as they appeared before our solar system even existed.

## Supplements

- The *Study Guide* is by Clyde D. Baker of Ohio University, Aaron W. Todd of Middle Tennessee State University, and James T. Shipman, also of Ohio University. It features study goals for each chapter, a revised discussion that summarizes the textbook chapter, and a short explanation for each section; review questions, each with an essay answer; solved problems, including a third paired exercise with solution; multiple-choice questions, some with explanations; and a quiz, half multiple-choice and half short-answer.
- The *Instructor's Guide,* by James T. Shipman, Jerry D. Wilson, and Aaron W. Todd, includes Teaching Aids and audiovisual resources for each of the five sciences. Each chapter includes a brief discussion, suggested demonstrations, answers to review and critical thinking questions, solutions for exercises, answers to the Relevance Questions, and answers to the *Study Guide* quizzes.
- The *Laboratory Guide,* by James T. Shipman and Clyde D. Baker, contains 53 experiments. Each experiment includes an introduction, learning objectives, a list of required apparatus, a detailed procedure for collecting data (requiring students to generate tables and graphs and to perform calculations), and questions about the experiment.
- The *Instructor's Resource Manual for the Laboratory Guide,* by James T. Shipman and Clyde D. Baker, includes an integrated equipment list to assist instructors in planning experiments. Additional data and calculations are provided for most experiments, as well as answers to the *Lab Guide* questions, a discussion of each experiment, and additional questions.
- The *Instructor's Test Bank,* available to adopters, offers a printed version of more than 2000 questions in completion, multiple-choice, and short-answer formats. About 500 new questions were added to the Eighth Edition.
- The *Test Bank* questions are also available in a computerized testing program. Instructors can produce chapter tests, midterms, and final exams—with graphics—easily. Instructors may edit existing questions or add new ones as desired and preview questions on-screen. The computerized testing program is available for IBM, Macintosh, and Apple computers.
- The *Transparencies*—more than 100 in one, two, or four colors—illustrate important concepts from the textbook and are available to adopters of the Eighth Edition. Many of the transparencies from the physics and chemistry chapters are completely new.

## Acknowledgments

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J. T. S.
J. D. W.
A. W. T.

# An Illustrated Guide to the New Edition

The Eighth Edition of the best-selling *Introduction to Physical Science* continues to offer the clearest introduction to the five major areas of physical science: physics, chemistry, astronomy, geology, and meteorology.

This edition, which is three chapters shorter than previous editions, features a reorganization of chapters, a more colorful design, and stronger pedagogy designed to further enhance student learning. The following pages illustrate these new features in action.

**Balanced Organization**
The five divisions of physical science are represented in this textbook. Each division is defined and explained in the context of real-world examples.

## Brief Contents

**Relevance Questions**
New thought-provoking Relevance Questions at the end of many sections relate to the material just covered. These are intended to develop students' critical thinking skills.



bowstring bend and acquire potential energy. This potential energy is capable of doing work on an arrow, thus producing motion or kinetic energy. Note how work is a process of transferring energy.

RELEVANCE QUESTION

- **A fellow student tells you that he has both zero kinetic energy and zero potential energy. Is this possible? Explain.**

## 4.3 Conservation of Energy

LEARNING GOALS

- Explain the difference between the conservation of *total* energy and the conservation of *mechanical* energy.
- Give examples of the conservation of energy.

As we have seen, energy changes from one form to another, and it does so without a net loss or net gain. That is to say, energy is *conserved*—the amount remains constant. The study of energy transformations has led to one of the most basic scientific principles—the law of conservation of energy. Although the meaning is the same, the law of conservation of energy (or, simply, the conservation of energy) can be stated in many different ways. For example, *Energy can neither be created nor destroyed; In changing from one form to another, energy is always conserved.*

Our formal definition of the **conservation of total energy** will be:

**The total energy of an isolated system remains constant.**

Thus, although energy may be changed from one form to another, energy is not lost from the system. A *system* is something enclosed within boundaries, which may be real or imaginary, and *isolated* means that nothing from the outside affects the system (and vice versa).

For example, the students in a classroom might … a system. They may move around in … if no one leaves or enters, then the …ents is conserved ("law of conserva-…). We sometimes say that the total en-…erse is conserved. This is true, since …e largest system we can think of, and since all the energy in the universe is in it somewhere in some form.

In equation form, we may write the conservation of energy as

$$(\text{total energy})_{\text{time }1} = (\text{total energy})_{\text{time }2}$$

That is to say, the total energy does not change with time.

To simplify the understanding of the conservation of energy, we often use *ideal* systems in which the energy is only in two forms—kinetic and potential. In this case we talk about the **conservation of mechanical energy,** which may be written in equation form as

$$(E_k + E_p)_{t_1} = (E_k + E_p)_{t_2}$$

$$(\tfrac{1}{2}mv^2 + mgh)_{t_1} = (\tfrac{1}{2}mv^2 + mgh)_{t_2}$$

where $t_1$ and $t_2$ indicate the energy at different times, that is, initial and final. Here we assume that no energy is lost in the form of heat because of frictional effects (or any other cause). It is an ideal, but instructive, situation in helping to understand the conservation of energy.

**Example 4.2**
**Finding Kinetic and Potential Energies**

A 0.10-kg stone is dropped from a height of 10 m. What will the kinetic and potential energies of the stone be at the heights indicated in Fig. 4.10? (Neglect air resistance.)

cont. →

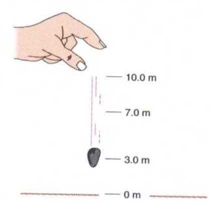



Figure 4.10
**Changing kinetic and potential energies.**
(See Example 4.2.)



Figure 21.15
**The JOIDES *Resolution*.**
This modern oceanographic research vessel drills for sample sediments beneath the ocean floor.

Scientists have studied the remanent magnetism of rocks of various ages and have found evidence of such changes of alignment. Moreover, they have found that rock of the same age on a continent has the same misalignment, but that the misalignment is different for different continents. This suggests that the entire continent must have moved as a unit and that each continent moved or "drifted" in its own separate direction.

In recent years investigative drilling into the ocean floor has been done by scientists from the oceanographic research vessel JOIDES (Joint Oceanographic Institutions for Deep Earth Sampling) *Resolution* (Fig. 21.15). These drillings have shown that the ocean floor between Africa and South America is covered by relatively young sediment strata. Also, drilling has revealed that the strata thicknesses increase away from the Mid-Atlantic Ridge, which implies that the older part of the ocean floor is farther away from the ridge. The older parts would be covered by a greater thickness of sediment because there would have been a longer time for the sediment to accumulate.

These observations support the idea of seafloor spreading as a mechanism for the theory of continental drift, which has culminated in the modern theory of plate tectonics.

RELEVANCE QUESTION

- **Of the evidence that seems to support continental drift, which seems the most logical to you and why?**

## 21.3 Plate Tectonics

LEARNING GOALS

- Describe the theory of plate tectonics.
- List the general relative motions of plates and the resulting geologic implications.

The view of ocean basins in a process of continual self-renewal has led to the acceptance of the theory of **plate tectonics.*** We now view the lithosphere not as one solid rock but as a series of solid sections or segments called plates, which are constantly in very slow motion and interacting with one another. There are about 20 plates over the surface of the globe. Some are very large, and some are small. The major plates are illustrated in Fig. 21.16, on the following page.

The most active, restless parts of Earth's crust are located at the plate boundaries. Along the ridges where one plate is pulling away from another (**divergent boundary**), new oceanic rock is formed. Where plates are driven together (**convergent boundary**), rock is consumed. In still other parts of Earth's surface, one plate slides along one side of another (**transform boundary**), and rock is neither produced nor destroyed. These boundary types are illustrated in Fig. 21.17.

Figure 21.18, on page 627, illustrates the structure of the lithosphere and asthenosphere. The interface between these two structures is significant in terms of internal geologic processes. The asthenosphere, which lies beneath the lithosphere, is essentially solid rock, but it is so close to its melting temperature that it contains pockets of molten

*Tectonics (from the Greek *tekto,* "builder") is the study of Earth's general structural features and their changes.

**Learning Goals**
Each section now begins with Learning Goals that provide a focus for the text that follows.


Figure 8.7
**Wattage (power) ratings.**
(a) A 60-W light bulb dissipates 60 J of electrical energy each second. (b) The curling iron uses 13 W at 120 V. Given the wattage and voltage ratings, you can find the current drawn by an appliance by using $I = P/V$.

have heating coils of low resistance so as to get a large current for large $I^2R$ losses. When a light bulb lights, much of the power goes to produce heat as well as light. The unit of power is the watt, and light bulbs are rated in watts (● Fig. 8.7).

**Example 8.2**
**Finding Current and Resistance**

Find the current and resistance of a 60-W, 120-V light bulb in operation.

**Solution**

**Step 1**

**Given:** $P = 60\text{ W}$ (power)

$V = 120\text{ V}$ (voltage)

**Step 2**

**Wanted:** $I$ (current)

$R$ (resistance)

The units are standard. Notice that the electrical units we commonly use are metric units.

**Step 3**

The current is obtained using Eq. 8.5, $P = IV$. Rearranging,

$$I = \frac{P}{V} = \frac{60\text{ W}}{120\text{ V}} = 0.50\text{ A}$$

We can rearrange Eq. 8.4 (Ohm's law) to solve for resistance,

$$R = \frac{V}{I} = \frac{120\text{ V}}{0.50\text{ A}} = 240\ \Omega$$

Notice we could also solve for $R$ from Eq. 8.6. Rearranging this equation we have,

$$R = \frac{P}{I^2} = \frac{60\text{ W}}{(0.50\text{ A})^2} = 240\ \Omega$$

**CONFIDENCE EXERCISE 8.2**

A coffeemaker draws 10 A of current operating at 120 V. How much electrical energy is used by the coffeemaker each second?

In metals, electrical resistance generally decreases with decreasing temperature. If you lowered the temperature enough, could you get rid of resistance completely? In some cases, the answer is yes. See the chapter Highlight on superconductivity.

**RELEVANCE QUESTION**

- **The heating element of a coffee pot is required to heat up quickly (joule heat). Should the element have a high or low resistance?**

## Step-by-Step Solutions

In-text examples are worked out with step-by-step solutions.



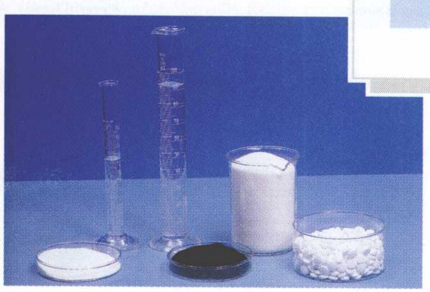


Figure 14.2
**A mole of six substances, each sample consisting of $6.02 \times 10^{23}$ FU.**
From left to right: 58.5 g NaCl, 18.0 g $H_2O$, 74.1 g 1-butanol ($C_4H_9OH$), 12.0 g carbon, 342 g cane sugar ($C_{12}H_{22}O_{11}$), and 180 g aspirin ($C_9H_8O_4$).

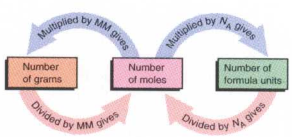



Figure 14.3
**Conversion problems.**
A schematic showing four types of conversion problems for number of moles, number of grams, and number of formula units.

moles, number of grams, and number of formula units. We will concentrate on the four problem types outlined in ● Fig. 14.3, namely, (1) converting moles to grams by multiplying by the molar mass, (2) converting grams to moles by dividing by the molar mass, (3) converting moles to formula units by multiplying by $N_A$, $6.02 \times 10^{23}$ FU/mol, and (4) converting formula units to moles by dividing by $N_A$, $6.02 \times 10^{23}$ FU/mol. In each of these types of problems, checking the units after the problem is set up will help avoid mistakes. (Note that dividing by MM or $N_A$ is the same as multiplying by $\frac{1}{MM}$ or $\frac{1}{N_A}$, respectively.)

**Example 14.1**
**Converting Moles to Grams**

How many grams is 4.00 mol of iron, Fe?

**Solution**

**Step 1**

**Given:** 4.00 moles of Fe

**Step 2**

**Wanted:** Number of grams of Fe

**Step 3**

The periodic table gives 55.8 u as the atomic mass of Fe. Therefore, the molar mass is 55.8 g/mol. We can set up the problem as follows, multiplying the number of moles by the molar mass:

$$4.00\text{ mol} \times 55.8\text{ g/mol} = 223\text{ g}$$

**CONFIDENCE EXERCISE 14.1**

How many grams is 3.00 mol of Na?

## Confidence Exercises

New Confidence Exercises appear after each worked-out example, giving students further practice in solving that type of problem.

**Highlights**

**Several new Highlights provide connections between the principles of physical science and real-world experience.**



HIGHLIGHT

## Air Bags

A car—out of control on a dark, rainy night—hits a huge oak tree head-on. The driver walks away with only minor injuries due to having worn his seat belt and having bought a car equipped with air bags.

Most experts agree that automobile air bags represent an application of chemistry that is saving thousands of lives. These bags, which are stored in the steering wheel and dashboard of many vehicles, are designed to inflate almost instantaneously (within about 40 ms) in the event of a front-end collision, cushioning the front-seat occupants against impact (Fig. 1).

After the crash, the bags deflate immediately so that the occupants can see and move. Air bags are activated when the severe deceleration of the impact causes a steel ball to compress a spring and electrically ignite a detonator, which, in turn, causes about 100 g of sodium azide ($NaN_3$) to decompose explosively to form sodium and about 56 L of nitrogen gas inside the bag:

$$2\,NaN_3(s) \longrightarrow 2\,Na(s) + 3\,N_2(g)$$

Not only is sodium azide explosive, it is also almost as poisonous as sodium cyanide. Thus, to avoid pollution problems, the sodium azide present in the air bag activators must be properly disposed of when a vehicle is junked.

Some car manufacturers also provide air bags to protect passengers seated in the rear seats; and a well known foreign car maker has begun installing air bags in the front doors of some of its models to protect against side impacts. Unfortunately, the several-hundred-dollar cost of air bags has led to a lucrative market in stolen air bags.

## Heat Packs

A skier—trapped by a snowstorm—builds a snow cave for protection. Realizing her hands and feet are cold and in danger of frostbite, she removes four small heat packs from her pocket, strips the plastic cover from them to reveal four small paper packets, and places one in each mitten and boot. Soon her hands and feet are warm again.

These "magic" packets of energy contain powdered iron (and other components) moistened by a little water (Fig. 2). When the plastic cover is removed, air can penetrate the paper packet, producing a common exothermic reaction—the rusting of iron. In simplified form, the reaction can be written:

$$4\,Fe(s) + 3\,O_2(g) \longrightarrow 2\,Fe_2O_3(s) + \text{heat}$$

Of course, an iron (steel) surface exposed to air and moisture inevitably rusts, but this process is much too slow to be useful in heat packs. But recall the discussion in Section 13.4 about the effect of surface area on the rate of a chemical reaction. The iron in the heat packs is in the form of a fine powder! The large amount of surface area causes the reaction with oxygen to be fast enough to produce sufficient energy to keep our skier's hands and feet warm for up to six hours, giving her a good chance to be rescued.

Figure 1
**Testing an airbag.**


Figure 2
**A popular brand of portable hot pack.**



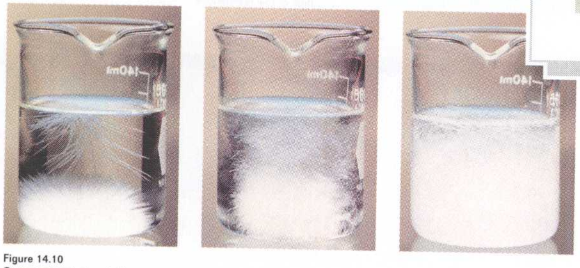


Figure 14.10
**Supersaturated solution.**
When a seed crystal is added to a supersaturated solution of sodium acetate, $NaC_2H_3O_2$, the excess solid instantly crystallizes, forming a saturated solution.

HIGHLIGHT

## The Lake Nyos Tragedy

Figure 1
**Lake Nyos in Cameroon, Africa.**

Nearly 2000 people were killed on August 21, 1986, when a cloud of gas suddenly erupted from Lake Nyos in Cameroon, Africa (Fig. 1). At first it was thought that the gas was hydrogen sulfide ($H_2S$), but it now seems clear that the huge, suffocating cloud was composed of the dense gas carbon dioxide ($CO_2$).

Why the cloud of $CO_2$ suddenly boiled from the lake may never be known for certain, but scientists think that the lake suddenly "turned over," bringing to the surface huge quantities of dissolved $CO_2$. Lake Nyos is deep, and layers of warm, less dense water near the surface float on the colder, denser water nearer the bottom of the lake. Normally, the lake remains this way, with little mixing among the layers.

Over hundreds or thousands of years, $CO_2$ must have seeped into the cold water at the bottom of the lake and dissolved in large amounts because of the great pressure present. On that fateful August day, wind or cooling of the lake's surface due to monsoon clouds must have caused the water that was supersaturated with $CO_2$ to reach the surface and release tremendous quantities of gaseous $CO_2$. Being dense, colorless, and odorless, the gas spread out along the ground and replaced the oxygen normally in the air. The people and animals nearby never knew what hit them.

**Multiple-Choice Review Questions**

New multiple-choice review questions at the end of each chapter are keyed to the appropriate section of the text, allowing students to test their knowledge of material just covered. Answers are provided at the end of each chapter, providing quick feedback.

716 *Chapter 25 The Atmosphere*

**Important Terms**

| | | | |
|---|---|---|---|
| atmospheric science | ionosphere | anemometer | convection cycle |
| meteorology | insolation | wind vane | sea breeze |
| troposphere | Rayleigh scattering | rain gauge | land breeze |
| weather | greenhouse effect | radar | Coriolis force |
| stratosphere | barometer | Doppler radar | friction (drag) |
| mesosphere | humidity | wind | jet streams |
| thermosphere | relative humidity | air currents | clouds |
| ozone ($O_3$) | dew point | isobar | lapse rate |
| ozonosphere | psychrometer | | |

**Important Equations**

**Relative Humidity:** (%) $RH = \frac{AC}{MC}(\times 100\%)$

**Review Questions**

**25.1 Composition and Structure**

1. Which is the third most abundant gas in the atmosphere?
(a) oxygen
(b) carbon dioxide
(c) nitrogen
(d) argon
2. The ozone layer lies in the
(a) thermosphere.
(b) troposphere.
(c) stratosphere.
(d) mesosphere.
3. What is the difference between atmospheric science and meteorology?
4. What is the composition of the air you breathe?
5. Humans inhale oxygen and exhale carbon dioxide. With our population, wouldn't this reduce the atmospheric oxygen level over a period of time? Explain.
6. Why is the plant pigment chlorophyll so important?
7. Describe how the temperature of the atmosphere varies in each of the following regions:
(a) the mesosphere
(b) the stratosphere
(c) the troposphere
(d) the thermosphere
8. Of what importance is the atmospheric ozone layer?
9. What is believed to cause the displays of lights called auroras?

**25.2 Atmospheric Energy Content**

10. Earth's average temperature is regulated by
(a) Rayleigh scattering.
(b) the greenhouse effect.
(c) atmospheric pressure.
(d) photosynthesis.
11. Approximately what percentage of insolation reaches Earth's surface: (a) 33%, (b) 40%, (c) 50%, (d) 75%?
12. What does the term insolation stand for?
13. From what source does the atmosphere receive most of its *direct* heating, and how is the overall heating accomplished?
14. The maximum insolation is received daily around noon. Why, then, is the hottest part of the day around 2:00 or 3:00 P.M.?
15. (a) Why is the sky blue? (b) In terms of Rayleigh scattering, why is it advantageous to have amber fog lights and red tail lights on cars?
16. (a) Explain what is meant by the "greenhouse effect." (b) How does the selective absorption of atmospheric gases provide a thermostatic effect for Earth?

**25.3 Atmospheric Measurements and Observations**

17. Pressure is measured with
(a) an anemometer.
(b) a barometer.
(c) a wind vane.
(d) a psychrometer.

98 *Chapter 4 Work and Energy*

**Critical Thinking Questions**

1. Suppose the professor asks you to go out and bring back a bucket of energy. Could you do it? Explain.
2. Can we detect energy with our senses? For example, can we smell energy?
3. Some factory workers are paid by the hour. Others may be paid on a piecework basis (paid according to the number of pieces or items they process or produce). Is there a power consideration involved in either of these methods of payment? Explain.
4. Someone tells you that the Sun is indir[...] of hydropower. Could this be true? Expl[...]
5. The efficiency of a machine may be defined [...] of the work output/work (energy) input, and is usually expressed as a percentage. A perpetual motion machine would have an efficiency of 100%. Explain why. What would it mean if a machine had an efficiency greater than 100%?

**Exercises**

**4.1 Work**

1. A horizontal force of 20 N moves a block 0.50 m on a level surface. How much work is done?
Answer: 10 J
2. While rearranging a dorm room, a student does 300 J of work in moving a desk 2.0 m. What was the magnitude of the applied horizontal force?
3. A 5.0-"kilo" bag of sugar is on a counter. How much work is required to put the bag on a shelf a distance of 0.45 m above the counter?
Answer: 22 J
4. How much work is required to lift a 4.0-kg concrete block a height of 2.0 m?
5. A man pushes a lawn mower on a level lawn with a force of 200 N. If 40% of this force is directed downward, how much work is done by the man in pushing the mower 6.0 m?
Answer: $7.2 \times 10^2$ J
6. A worker applies a force of 100 N to lift the handles of a wheelbarrow 0.50 m, and then pushes forward with a horizontal force of 75 N to move the wheelbarrow 4.0 m on a level surface. What is the total work done by the worker?

**4.2 Kinetic Energy and Potential Energy**

7. What is the kinetic energy in joules of a 1000-kg automobile traveling at 90 km/h?
Answer: $3.1 \times 10^5$ J
8. How much work would have to be done to bring a 1000-kg automobile traveling at 90 km/h to a stop?
9. What is the kinetic energy of a 20-kg dog that is running with a speed of 9.0 m/s (about 20 mi/h)?
Answer: $8.1 \times 10^2$ J
10. Which has more kinetic energy: a 0.0020-kg bullet traveling at 400 m/s or a $6.4 \times 10^4$-metric-ton ocean liner traveling at 10 m/s (20 knots)? Justify your answer.
11. A student wishes to calculate the work done in changing the speed of a 1.0-kg object from 2.0 m/s to 6.0 m/s. She first finds the difference in the speeds (4.0 m/s) and then uses this for $v$ in the kinetic energy equation $E = \frac{1}{2}mv^2$, to compute an *incorrect* answer of 8.0 J. Why is the answer incorrect, and what is the correct answer?
Answer: 16 J
12. How much work is done in slowing a 1000-kg automobile from 90 km/h to 30 km/h?
13. By what factor is the kinetic energy of an object increased when its speed increases (a) from 1.0 m/s to 3.0 m/s, and (b) from 2.0 m/s to 8.0 m/s?
Answer: (a) 9 (b) 16
14. (a)By what factor is the kinetic energy increased when the speed of a car is increased from 30 km/h to 40 km/h? (b) What is the factor of decrease in slowing from 40 km/h to 30 km/h?
15. What is the potential energy of a 3.00-kg object at the bottom of a well 10.0 m deep as measured from ground level? Explain the sign of the answer.
Answer: −294 J
16. How much work is required to lift a 3.00-kg object from the bottom of a 10.0-m-deep well?

**Paired Exercises**

Each odd numbered end-of-chapter exercise has an even-numbered exercise that is similar in content. Answers are provided for odd-numbered exercises only, allowing instructors to assign the even-numbered ones as homework.

**Math Level**

By using simpler numbers, the math in this edition has been made more accessible. Each discipline is treated both descriptively and quantitatively, but the relative emphasis is left to the discretion of the instructor.

## New design

A new design, including an improved photo program, makes the presentation more visually appealing and nonthreatening to students.



**CHAPTER OUTLINE**



Motion is everywhere. We walk to class. We drive to the store. Birds fly. The wind blows the trees. The rivers flow. Even the continents drift. In the larger environment, Earth rotates on its axis, the Moon revolves around Earth, Earth revolves around the Sun, the Sun moves in the galaxy, and the galaxies move with respect to one another.

This chapter focuses on the description of motion, with definitions and discussion of terms such as *speed, velocity,* and *acceleration.* We will study these concepts without considering the forces involved, reserving that discussion for Chapter 3.

Two basic kinds of motion are straight-line motion and circular motion. We experience examples of these each day. For instance, we know that driving around a curve feels different than driving in a straight line. Understanding acceleration is the key to understanding these basic kinds of motion.

### 2.1 Defining Motion

**LEARNING GOAL**

- Define motion.

The term **position** refers to the location of an object. To designate the position of an object, we must give or imply a reference point. For example, the entrance to campus is 1.6 km (1 mi) from the intersection with the traffic light. The book is on the table. Atlanta is in Georgia. The Cartesian coordinates of the point on the graph are $(x, y) = (2.0\ \text{cm}, 3.0\ \text{cm})$.

If an object changes its position, we say that motion has occurred. When an object is undergoing a continuous change in position, we say the object is moving or is in **motion.**

Consider an automobile traveling on a straight highway. The motion of the automobile may or may not be at a constant rate. In either case, the motion is described by using the fundamental units of length and time.

That length and time describe motion is evident in running. For example, as shown in ● Fig. 2.1, the cheetah runs a certain length in the shortest possible time. Combining length and time to give the *time rate of change of position* is the basis of describing motion in terms of speed and velocity, as discussed in the following section.

**RELEVANCE QUESTION**

- In coming to physical science class, how would you describe your motion?

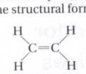
Figure 2.1
**Motion.**
We describe motion in terms of distance and time. Here, a running cheetah appears to be trying to run a distance in the shortest possible time. The cheetah is the fastest of all land animals, capable of attaining speeds up 113 km/h or 70 mi/h. (The slowest creature is the snail, 0.05 km/h or 0.03 mi/h.)



Table 15.4 **Some Members of the Alkene Series**

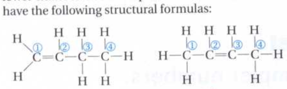
| Name | Molecular Formula | Condensed Structural Formula |
|---|---|---|
| Ethene (ethylene) | $C_2H_4$ | $CH_2{=}CH_2$ |
| Propene | $C_3H_6$ | $CH_3CH{=}CH_2$ |
| 1-Butene | $C_4H_8$ | $CH_3CH_2CH{=}CH_2$ |
| 2-Butene | $C_4H_8$ | $CH_3CH{=}CHCH_3$ |
| 1-Pentene | $C_5H_{10}$ | $CH_3(CH_2)_2CH{=}CH_2$ |

ethene, $C_2H_4$ (also known by the common name ethylene), shown by the structural formula



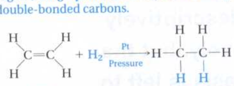
Ethene (ethylene)

Some of the simpler alkenes are listed in Table 15.4. Note that the *-ane* suffix for alkane names is changed to *-ene* for alkenes. A number preceding the name indicates the carbon atom on which the double bond starts. The carbons in the chain are numbered starting at the end that gives the double bond the lower number. For example, 1-butene and 2-butene have the following structural formulas:



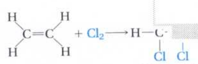
1-Butene 2-Butene

Alkenes are termed *unsaturated* hydrocarbons because under proper conditions additional hydrogen can be added to them. Alkenes are very reactive, and two characteristic reactions are the *addition* of hydrogen (using a platinum catalyst) and halogens to the double-bonded carbons.



Ethene Ethane

Addition of hydrogen



Ethene 1,2-Dichloroethane

Addition of halogens

Alkene molecules can also bond to one another in long chains and sheets by using the double bonds, as we will see in Section 15.5.

**Alkynes**

Hydrocarbons that have a triple bond between two carbon atoms are called **alkynes.** Imagine that two hydrogen atoms have been removed from each of two adjacent carbon atoms in an alkane, allowing the two C atoms to form two additional bonds between them.

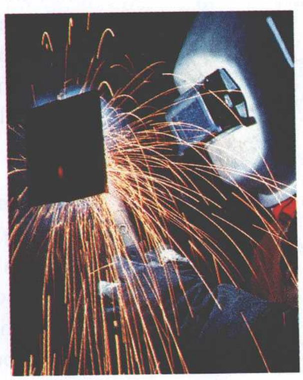


Figure 15.6
**An ironworker cutting steel with an oxyacetylene torch.**
The combustion of acetylene (ethyne) produces the intense heat needed to fuse metals.

# Contents