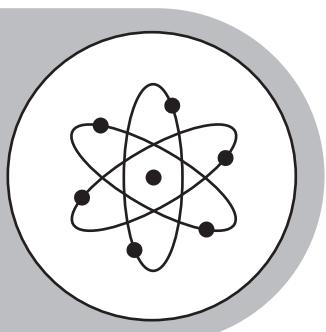
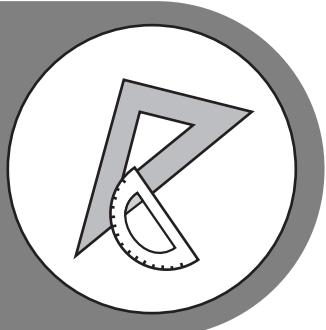
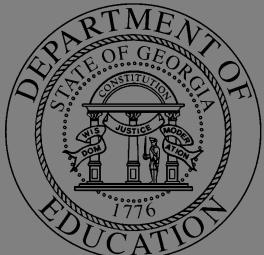


# PHYSICAL SCIENCE

# Study Guide

**Georgia End-Of-Course Tests**





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## **INTRODUCTION**

This study guide is designed to help students prepare to take the Georgia End-of-Course Test (EOCT) for ***Physical Science***. The guide provides information about the EOCT, tips on how to prepare for it, and some suggested strategies students can use to perform their best.

**What is the EOCT?** The EOCT program was created to improve student achievement through effective instruction and assessment of the Georgia Performance Standards specific to the eight EOCT core high school courses. The EOCT program also helps to ensure that all Georgia students have access to a rigorous curriculum that meets high performance standards. The purpose of the EOCT is to provide diagnostic data that can be used to enhance the effectiveness of schools' instructional programs.

The Georgia End-of-Course Testing program is a result of the A+ Educational Reform Act of 2000, O.C.G.A. §20-2-281. This act requires that the Georgia Department of Education create end-of-course assessments for students in grades 9 through 12 for the following core high school subjects:

### **Mathematics**

- Mathematics I: Algebra/Geometry/Statistics
- Mathematics II: Geometry/Algebra II/Statistics

### **Social Studies**

- United States History
- Economics/Business/Free Enterprise

### **Science**

- Biology
- Physical Science

### **English Language Arts**

- Ninth Grade Literature and Composition
- American Literature and Composition

**Getting started:** The HOW TO USE THE STUDY GUIDE section on page 2 outlines the contents in each section, lists the materials you should have available as you study for the EOCT, and suggests some steps for preparing for the ***Physical Science*** EOCT.

## HOW TO USE THE STUDY GUIDE

This study guide is designed to help you prepare to take the **Physical Science EOCT**. It will give you valuable information about the EOCT, explain how to prepare to take the EOCT, and provide some opportunities to practice for the EOCT. The study guide is organized into three sections. Each section focuses on a different aspect of the EOCT.

The **OVERVIEW OF THE EOCT** section on page 4 gives information about the test: dates, time, question format, and number of questions that will be on the **Physical Science EOCT**. This information can help you better understand the testing situation and what you will be asked to do.

The **PREPARING FOR THE EOCT** section that begins on page 5 provides helpful information on study skills and general test-taking skills and strategies. It explains how to prepare before taking the test and what to do during the test to ensure the best test-taking situation possible.

The **TEST CONTENT** section that begins on page 11 explains more specifically what the **Physical Science EOCT** measures. When you know the test content and how you will be asked to demonstrate your knowledge, it will help you be better prepared for the EOCT. This section also contains some test-taking strategies for successfully answering questions on the EOCT.

With some time, determination, and guided preparation, you will be better prepared to take the **Physical Science EOCT**.

### GET IT TOGETHER

In order to make the most of this study guide, you should have the following:

#### Materials:

- \* This study guide
- \* Pen or pencil
- \* Paper
- \* Highlighter

#### Resources:

- \* Dictionary
- \* Science textbook(s)
- \* A teacher or other adult

#### Study Space:

- \* Comfortable (but not too comfortable)
- \* Good lighting
- \* Minimal distractions
- \* Enough work space

#### Time Commitment:

- \* When are you going to study?
- \* How long are you going to study?

#### Determination:

- \* Willingness to improve
- \* Plan for meeting goals



**SUGGESTED STEPS FOR USING THIS STUDY GUIDE**

- 1** Familiarize yourself with the structure and purpose of the study guide.  
(You should have already read the INTRODUCTION and HOW TO USE THE STUDY GUIDE. Take a few minutes to look through the rest of the study guide to become familiar with how it is arranged.)
  
- 2** Learn about the test and expectations of performance.  
(Read OVERVIEW OF THE EOCT.)
  
- 3** Improve your study skills and test-taking strategies.  
(Read PREPARING FOR THE EOCT.)
  
- 4** Learn what the test will assess by studying the standards in each domain.  
Also, study the strategies for answering questions that assess the standards in the domain.  
(Read TEST CONTENT.)
  
- 5** Answer the sample questions at the end of each domain section. Check your answers against the annotated answers to see how well you did.  
(See TEST CONTENT.)

## OVERVIEW OF THE EOCT

Good test takers understand the importance of knowing as much about a test as possible. This information can help you determine how to study and prepare for the EOCT and how to pace yourself during the test. The box below gives you a snapshot of the *Physical Science EOCT*.



### THE EOCT AT A GLANCE

#### **Administration Dates:**

The EOCT has three primary annual testing dates: once in the spring, once in the summer, and once in the winter. There are also mid-month, online tests given in August, September, October, November, February, and March.

#### **Administration Time:**

Each EOCT is composed of two sections, and students are given 60 minutes to complete each section. There is also a short stretch break between the two sections of the test.

#### **Question Format:**

All the questions on the EOCT are multiple choice.

#### **Number of Questions:**

Each section of the **Physical Science EOCT** contains 40 questions; there are a total of 80 questions on the **Physical Science EOCT**.

#### **Impact on Course Grade:**

A student's EOCT score is averaged in as 15% of his/her final course grade.

If you have additional administrative questions regarding the EOCT, please visit the Georgia Department of Education Web site at [www.doe.k12.ga.us](http://www.doe.k12.ga.us), see your teacher, or see your school test coordinator.



## PREPARING FOR THE EOCT

### WARNING!

You cannot prepare for this kind of test in one night. Questions will ask you to apply your knowledge, not list specific facts. Preparing for the EOCT will take time, effort, and practice.

In order to do your best on the **Physical Science EOCT**, it is important that you take the time necessary to prepare for this test and develop those skills that will help you take the EOCT.

First, you need to make the most of your classroom experiences and test preparation time by using good **study skills**. Second, it is helpful to know general **test-taking strategies** to ensure that you will achieve your best score.

### Study Skills



#### A LOOK AT YOUR STUDY SKILLS

Before you begin preparing for this test, you might want to consider your answers to the following questions. You may write your answers here or on a separate piece of paper.

1. How would you describe yourself as a student?  
Response: \_\_\_\_\_
2. What are your study skills strengths and/or weaknesses as a student?  
Response: \_\_\_\_\_
3. How do you typically prepare for a physical science test?  
Response: \_\_\_\_\_
4. Are there study methods you find particularly helpful? If so, what are they?  
Response: \_\_\_\_\_
5. Describe an ideal study situation (environment).  
Response: \_\_\_\_\_
6. Describe your actual study environment.  
Response: \_\_\_\_\_
7. What can you change about the way you study to make your study time more productive?  
Response: \_\_\_\_\_

Effective study skills for preparing for the EOCT can be divided into three categories.

- ◆ Time Management
- ◆ Organization
- ◆ Active Participation



## Time Management

Do you have a plan for preparing for the EOCT? Often students have good intentions for studying and preparing for a test, but without a plan, many students fall short of their goals. Here are some strategies to consider when developing your study plan:

- ◆ Set realistic goals for what you want to accomplish during each study session and chart your progress.
- ◆ Study during your most productive time of the day.
- ◆ Study for reasonable amounts of time. Marathon studying is not productive.
- ◆ Take frequent breaks. Breaks can help you stay focused. Doing some quick exercises (e.g., sit-ups or jumping jacks) can help you stay alert.
- ◆ Be consistent. Establish a routine and stick to it.
- ◆ Study the most challenging test content first.
- ◆ For each study session, build in time to review what you learned in your last study session.
- ◆ Evaluate your accomplishments at the end of each study session.
- ◆ Reward yourself for a job well done.

## Organization

You don't want to waste your study time. Searching for materials, trying to find a place to study, and debating what and how to study can all keep you from having a productive study session. Get organized and be prepared.

Here are a few organizational strategies to consider.



- ◆ Establish a study area that has minimal distractions.
- ◆ Gather your materials in advance.
- ◆ Develop and implement your study plan (See Appendices A–D for sample study plan sheets.)

## Active Participation



Students who actively study will learn and retain information longer. Active studying also helps you stay more alert and be more productive while learning new information. What is active studying? It can be anything that gets you to interact with the material you are studying. Here are a few suggestions:

- ◆ Carefully read the information and then DO something with it. Mark the important points with a highlighter, circle them with a pen, write notes on them, or summarize the information in your own words.
- ◆ Ask questions. As you study, questions often come into your mind. Write them down and actively seek the answers.
- ◆ Create sample test questions and answer them.
- ◆ Find a friend who is also planning to take the test and quiz each other.

## Test-taking Strategies

There are many test-taking strategies that you can use before and during a test to help you have the most successful testing situation possible. Below are a few questions to help you take a look at your test-taking skills.



### A LOOK AT YOUR TEST-TAKING SKILLS

As you prepare to take the EOCT, you might want to consider your answers to the following questions. You may write your answers here or on your own paper.

1. How would you describe your test-taking skills?  
Response: \_\_\_\_\_
2. How do you feel when you are taking a test?  
Response: \_\_\_\_\_
3. List the strategies that you already know and use when you are taking a test.  
Response: \_\_\_\_\_
4. List test-taking behaviors you use when preparing for and taking a test that contribute to your success.  
Response: \_\_\_\_\_
5. What would you like to learn about taking tests?  
Response: \_\_\_\_\_

## Suggested Strategies to Prepare for the EOCT



**Learn from the past.** Think about your daily/weekly grades in your science classes (past and present) to answer the following questions.

- In which specific areas of science have you been successful?

Response: \_\_\_\_\_

---

- Is there anything that has kept you from achieving higher scores?

Response: \_\_\_\_\_

---

- What changes should you implement to achieve higher scores?

Response: \_\_\_\_\_

---

Before taking the EOCT, work toward removing or minimizing any obstacles that might stand in the way of performing your best. The test preparation ideas and test-taking strategies in this section are designed to help you accomplish this.



**Be prepared.** The best way to perform well on the EOCT is to be prepared. In order to do this, it is important that you know what knowledge or skills will be measured on the **Physical Science EOCT** and then practice understanding and using those skills. The standards that will be measured in this EOCT are located in the **Georgia Performance Standards** (GPS). The TEST CONTENT section of this study guide is designed to help you understand which specific standards are on the **Physical Science EOCT** and give you suggestions for how to study the standards that will be assessed. Take the time to read through this material and follow the study suggestions. You can also ask your science teacher for any suggestions he or she might offer on preparing for the EOCT.



**Start now.** Don't wait until the last minute to start preparing. Begin early and pace yourself. By preparing a little bit each day, you will retain the information longer and increase your confidence level. Find out when the EOCT will be administered so you can allocate your time appropriately.

## Suggested Strategies the Day before the EOCT



- ✓ **Review what you learned from this study guide.**
  1. Review the general test-taking strategies discussed in TOP 10 SUGGESTED STRATEGIES DURING THE EOCT on page 10.
  2. Review the content domain-specific information discussed in the section TEST CONTENT, beginning on page 11.
  3. Focus your attention on the domain or domains that you are most in need of improving.
  
- ✓ **Take care of yourself.**
  1. Try to get a good night's sleep. Most people need an average of eight hours, but everyone's sleep needs are different.
  2. Don't drastically alter your routine. If you go to bed too early, you might lie in bed thinking about the test. You want to get enough sleep so you can do your best.

## Suggested Strategies the Morning of the EOCT



**Eat a good breakfast.** Eat some food that has protein in it for breakfast (and for lunch if the test is given in the afternoon). Some examples of foods high in protein are peanut butter, meat, and eggs. Protein gives you long-lasting, consistent energy that will stay with you through the test to help you concentrate better. Don't eat too much. A heavy meal can make you feel tired. So think about what you eat before the test.



**Dress appropriately.** If you are too hot or too cold during the test, it can affect your performance. It is a good idea to dress in layers so you can stay comfortable regardless of the room temperature and keep your mind on the EOCT.



**Arrive for the test on time.** Racing late into the testing room can cause you to start the test feeling anxious. You want to be on time and prepared.

# TOP 10

## Suggested Strategies during the EOCT

These general test-taking strategies can help you do your best during the EOCT.

- 1 Focus on the test.** Try to block out whatever is going on around you. Take your time and think about what you are asked to do. Listen carefully to all the directions.
- 2 Budget your time.** Be sure that you allocate an appropriate amount of time to work on each question on the test.
- 3 Take a quick break if you begin to feel tired.** To do this, put your pencil down, relax in your chair, and take a few deep breaths. Then, sit up straight, pick up your pencil, and begin to concentrate on the test again. Remember that each test section is only 60 minutes.
- 4 Use positive self-talk.** If you find yourself saying negative things to yourself, such as “I can’t pass this test,” it is important to recognize that you are doing this. Stop and think positive thoughts, such as “I prepared for this test, and I am going to do my best.” Letting the negative thoughts take over can affect how you take the test and what your test score will be.
- 5 Mark in your test booklet.** Mark key ideas or things you want to come back to in your test booklet. Remember that only the answers marked on your answer sheet will be scored.
- 6 Read the entire question and the possible answer choices.** It is important to read the entire question so you know what it is asking. Read each possible answer choice. Do not mark the first one that “looks good.”
- 7 Use what you know.** Draw on what you have learned in class, from this study guide, and during your study sessions to help you answer the questions.
- 8 Use content domain-specific strategies to answer the questions.** In the TEST CONTENT section, there are a number of specific strategies that you can use to help improve your test performance. Spend time learning these helpful strategies so you can use them while taking the test.
- 9 Think logically.** If you have tried your best to answer a question but you just aren’t sure, use the process of elimination. Look at each possible answer choice. If it doesn’t seem like a logical response, eliminate it. Do this until you’ve narrowed down your choices. If this doesn’t work, take your best educated guess. It is better to mark something down than to leave it blank.
- 10 Check your answers.** When you have finished the test, go back and check your work.

### A WORD ON TEST ANXIETY

It is normal to have some stress when preparing for and taking a test. It is what helps motivate us to study and try our best. Some students, however, experience anxiety that goes beyond normal test “jitters.” If you feel you are suffering from test anxiety that is keeping you from performing at your best, please speak to your school counselor, who can direct you to resources to help you address this problem.

## TEST CONTENT

Up to this point in this study guide, you have been learning various strategies on how to prepare for and take the EOCT. This section focuses on what will be tested. It also includes a section of sample questions that will let you apply what you have learned in your classes and from this study guide.

The Georgia End-of-Course Test (EOCT) for **Physical Science** is designed to test four major areas of knowledge, called **content domains**. The content domains are broad categories. Each of the content domains is broken down into smaller ideas. These smaller ideas are called **standards**. Each content domain contains standards that cover different ideas related to its content domain. Each question on the EOCT measures an individual standard within a content domain.

The four content domains for the **Physical Science EOCT** are important for several reasons. Together they represent the ability to understand what you read and communicate with others regarding physical science concepts. Another, more immediate reason that the content domains are important has to do with test preparation. The best way to prepare for any test is to study and know the material measured on the test. Since the **Physical Science EOCT** covers the four content domains and nothing else, isn't it a good idea to learn as much about these domains as you can? The more you understand about these domains, the greater your chances are of getting a good score on the EOCT.

The chart below lists the four content domains for the **Physical Science EOCT**.

### CONTENT DOMAINS

- I. Atomic and Nuclear Theory and the Periodic Table
- II. Chemical Reactions and Properties of Matter
- III. Energy, Force, and Motion
- IV. Waves, Electricity, and Magnetism



### UNDERSTANDING THE STANDARDS

One way to think about **content domains** and **standards** is to think about a supermarket. Supermarkets often group similar foods in the same aisles or areas of the store. For example, the section of the store marked "Fresh Fruits" will be a section filled with apples, oranges, and bananas, to name just a few. So the part of the store called "Fresh Fruits" is like the domain name, and all the various items—apples, oranges, bananas—are the standards that fall under that domain.

## **Studying the Content Domains**

You should plan to study/review the standards for ALL the content domains. To learn what the EOCT will cover, work through this TEST CONTENT section. It is organized by the content domains into the following areas:

- **A Look at the Content Domain:** an overview of what will be assessed in the content domain.
- **Spotlight on the Standards:** information about the specific standards that will be assessed. (Note: The names of the standards may not be the exact names used by the Georgia Department of Education. Some of the names in this study guide may have been modified to reflect the fact that this book is designed for students and not for professional educators.)
- **Sample Questions:** sample questions *similar* to those that appear on the EOCT.
- **Answers to the Sample Questions:** in-depth explanations of the answers to the sample questions.

### **Read All About It**

Physical science is a very broad subject. To provide you with most of the information related to physical science would take hundreds of pages. Instead, this guide will provide you with some specific information that you will need to know for the **Physical Science EOCT**, and it will help to direct your study efforts. Your physical science textbook will be your best source of additional information.

## Content Domain I: Atomic and Nuclear Theory and the Periodic Table

### A LOOK AT CONTENT DOMAIN I



**Look** Test questions in this content domain will measure your ability to understand the structure and properties of atoms. Your answers to the questions will help show how well you can perform on the following standards:

- Investigate our current understanding of the atom
- Distinguish the characteristics and components of radioactivity
- Investigate the arrangement of the Periodic Table
- Compare and contrast the phases of matter as they relate to atomic and molecular motion



### Spotlight on the Standards

#### ★Investigate our current understanding of the atom★

As far as scientists can tell, the universe we live in is composed of many tiny particles called atoms. The concept of the atom began with the ancient Greeks, but this concept did not fully develop until after A.D. 1700. Today scientists know that atoms contain even tinier particles. These particles are the **proton**, **neutron**, and the **electron**. The proton and neutron are located in the **nucleus**, or center, of the atom. The proton has a single positive (+) charge, while the neutron has a zero (0), or neutral, charge. The proton and neutron have approximately the same mass. The electron has a single negative (–) charge and is about 2000 times lighter than the proton or neutron.

Electrons, unlike the proton and neutron, are found outside the nucleus in a region called the **electron cloud**. The electron cloud is divided into **energy levels**, which are sometimes referred to as **electron shells**. Each energy level can hold a certain number of electrons. The first energy level, which is closest to the nucleus and has the lowest amount of energy, can hold only two electrons (see the box up and to the right). Electrons with higher energy are found in energy levels farther from the nucleus. Electrons in the outermost energy level, or **valence shell**, are called **valence electrons**. The outermost

### Energy Levels

Maximum number of electrons for each energy level:

Energy Level	No. of Electrons
1	2
2	8
3	18
4	32

electrons determine how the element will react chemically with other elements. A question for this standard might look like this:

**Use the periodic table to answer the question.**

**Which group of elements has six valence electrons?**

- A Group I A (1)
- B Group II A (2)
- C Group V A (15)
- D Group VI A (16)

The correct answer is choice **D**. Group VI A, or 16, has six electrons in the outermost energy level. Choice **A** is incorrect. Group I A, or 1, has one valence electron in the outermost energy level. Choice **B** is incorrect. There are two valence electrons in the outermost energy level. Choice **C** is incorrect. Group V A, or 15, has five valence electrons.

There are many ways to describe the atom. One way is to use the **atomic number**. It tells how many protons reside in the nucleus and identifies the element. For example, an element with an atomic number of 6 (an atom with six protons) is a carbon atom with the chemical symbol C. All atoms with the same number of protons are of the same element, no matter how many electrons or neutrons they might have.

**Isotopes** are atoms that have the same number of protons but different numbers of neutrons. As a result, a single element may contain atoms that have different masses. The **atomic mass** is the average mass of all the different isotopes that make up the element.

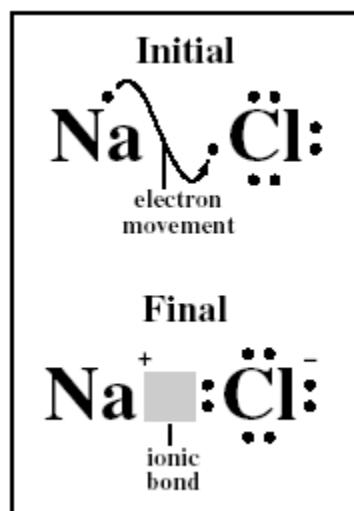
Atoms have the capacity for combining together by forming **chemical bonds**. These bonds involve the movement of valence electrons from one atom to another. Some electrons are completely transferred from one atom to another in an **ionic bond**. An ionic bond usually forms between metal and nonmetal atoms. For example, a sodium (Na) atom, a metal, combines with a chlorine (Cl) atom, a nonmetal, to form an ionic bond. The process is shown in the diagram on the following page. Both atoms are most stable when they have eight electrons in their outermost energy levels. Sodium has one electron in the outermost energy level, while chlorine has seven electrons. Chlorine accepts one electron from the sodium atom, giving it eight electrons in the outermost energy level. This leaves sodium with its lower energy level of eight electrons. This level forms a new, stable valence shell (not shown in the diagram). After the electrons have been transferred, the two atoms now have unbalanced charges, forming ions. The sodium has a positive charge and the chlorine has a negative charge. The attraction from these opposite charges creates the ionic bond. A **formula unit** of sodium chloride (NaCl)

**Look It Up**

Use the periodic table to locate the following information about the first 20 elements:

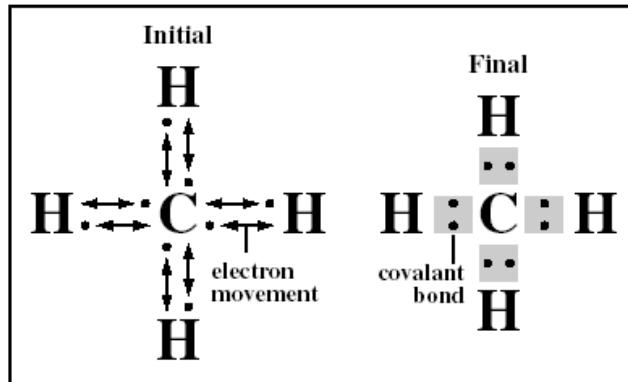
- Element Name
- Symbol
- Atomic Number
- Atomic Mass

results from the bonding of these two atoms. A formula unit is the smallest unit of a substance that retains the properties of the substance and the simplest way to write a chemical formula of a substance.



How can you find the charge on an ion such as sodium? The charge is simply the atomic number (number of protons) minus the number of electrons surrounding the nucleus. The atomic number of chlorine is 17. If a chlorine atom has 18 electrons, the charge is  $17 - 18 = -1$ . The atomic number of sodium is 11. If a sodium atom has only 10 electrons around the nucleus, it has a charge of  $11 - 10 = +1$ .

A **covalent bond** is usually formed between two nonmetal atoms. Unlike ionic bonds, the nonmetal atoms share their valence electrons usually in such a way that each atom has eight valence electrons surrounding it. Hydrogen is an exception; it needs only two valence electrons. The example below shows four hydrogen atoms (nonmetal atoms) reacting with a single carbon atom (another nonmetal atom) to form four covalent bonds. Each hydrogen atom shares an electron with the carbon atom. The carbon atom in turn shares its four electrons, one with each hydrogen atom. These electrons are shared back and forth. In this way, both the carbon atom and hydrogen atoms have the maximum number of electrons in their outermost energy levels. Together they form a **molecule** of methane, CH<sub>4</sub>.



**STRATEGY BOX—Analyze the Word by Its Parts**

When faced with an unknown term in physical science, look for familiar prefixes, suffixes, and word roots. Knowing the meaning of these word parts will help you determine the meaning of the unknown word. For example, *atom* can be broken down into the following word parts:

a- means “not”      -*tomos* means “cutting”

Therefore, an atom is a particle that cannot be cut (separated) any further and still retains the properties of the particular element. When the atom was named, it was thought that it could not be divided further. We now know this is not true.

**Spotlight on the Standards****★ *Distinguish the characteristics and components of radioactivity*★**

Sometimes very heavy elements have unstable nuclei. Atoms of these elements are radioactive. A radioactive element may decay and give off three types of radiation.

- **Alpha ( $\alpha$ )** radiation or particles. These particles consist of helium (He) nuclei, which are very large. Usually a sheet of paper can stop them.
- **Beta ( $\beta$ )** radiation or particles. These particles consist of electrons ( $e^-$ ), which are much smaller and lighter than alpha particles. They have much more penetrating power, and a thick wooden board is required to stop them.
- **Gamma ( $\gamma$ )** rays. This radiation is an extremely energetic form of light. Usually several inches of lead or a few feet of concrete are required to shield people from the damaging effects of gamma radiation.

Every radioactive element has a distinctive rate of decay. This rate is measured by the **half-life** ( $t_{1/2}$ ). The half-life is the time required for one-half of the atoms to undergo decay to isotopes of other atoms. Radon, a radioactive gas, has a half-life of 3.8 days. That means after 3.8 days, only one-half of the original radon atoms are left. After 7.6 days, only one-fourth are left and so on.

A question for this standard might look like this:

**A radioactive substance has a half-life of 10 years. What fraction of a sample of the substance would be left after 30 years?**

- A  $\frac{1}{2}$
- B  $\frac{1}{3}$
- C  $\frac{1}{8}$
- D  $\frac{1}{9}$

The correct answer is choice C. The half-life is the time it takes for half the atoms in a sample of a radioactive element to decay into other elements. For the above substance, one-half of the sample would remain after 10 years. After another 10 years (20 years total), one-half of that amount would remain, which means one-fourth of the sample remains. After another 10 years (30 years total), one-half of the last amount would remain, which would leave one-eighth of the sample remaining. Therefore, choice C is the correct answer. Choices A, B, and D are incorrect.

**Fission** occurs when some atomic nuclei decay spontaneously or when bombarded by neutrons. This results in the production of lighter elements and radiation. On the beneficial side, fission provides a significant amount of electrical energy for the United States and other developed nations. Compared to coal or oil, fission provides about a million times more energy per pound of fuel. It also eliminates air pollutants. On the other hand, nuclear waste from fission creates disposal problems. Improper disposal of radioactive wastes underground might lead to radioactive contamination of water supplies.

**Fusion**, as a future energy source, might provide all the benefits of fission with few of its problems. Fusion occurs when two light nuclei, such as hydrogen, collide together and combine to form heavier nuclei. Fusion occurs in the sun, and is one of the most energetic processes in the universe.

#### STRATEGY BOX—Fission/Fusion Confusion

Here is a way to help remember the difference between fission and fusion. *Fission* is similar to *fissure*, the process of splitting. So fission happens when the nucleus splits in two. *Fusion* is like *fuse*, to unite two things. So fusion occurs when two nuclei join.

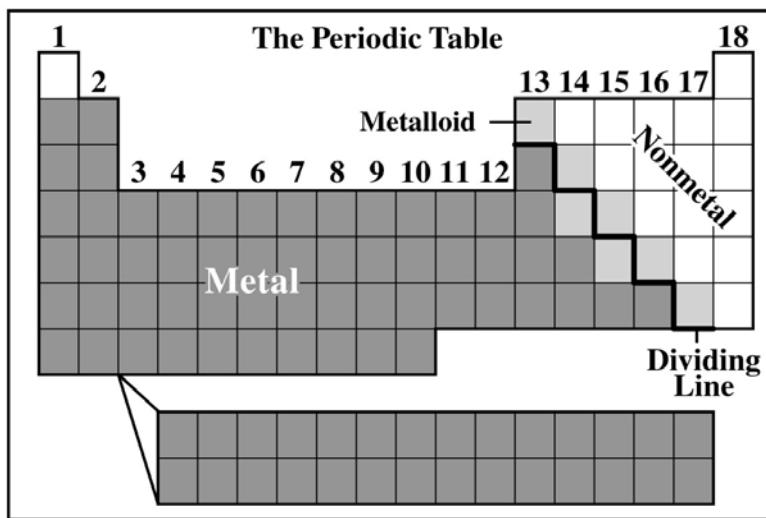


## Spotlight on the Standards

### ★Investigate the arrangement of the Periodic Table★

In the 19th century, chemists discovered that certain elements had similar properties. They found that when elements were arranged according to reactivity, a periodic pattern in the properties of the elements could be seen. The **periodic table** was then developed to organize and classify these elements and even predict the existence of elements that had not yet been discovered.

There are three major classifications for the elements. These can be seen in the periodic table below.



- The **metal** elements are located to the left of the dividing line. These elements are all solids at room temperature with the exception of mercury (Hg). Metals are notable for their shiny luster and ability to conduct electricity.
- The **nonmetal** elements are located to the right. Nitrogen (N), oxygen (O), fluorine (F), chlorine (Cl), and the noble gases (in the last column) are gases at room temperature. Bromine (Br) is a liquid, while all other nonmetals are solid. Nonmetals do not conduct electricity.
- **Metalloids** have both metallic and nonmetallic properties. These are solid at room temperature. They are located between the metals and nonmetals and straddle the diagonal dividing line. Metalloids are useful as part of electronic circuits.

Elements are also arranged by **group numbers**. These numbers may be seen at the top of each column in the periodic table above. The **representative elements** are those elements located in columns 1–2 and 13–18. Group 1 and 2 elements have the same number of valence electrons as their group number. The number of valence electrons for group 13–18 elements can be found by subtracting 10 from the group number. Valence electrons for non-representative elements (group 3–12) will not be covered on the test. It is important to

note that elements within the same group have the same number of valence electrons. Since they have the same number of valence electrons, they react with other elements in a very similar way. Elements in group 1, the **alkali metals**, and group 2, the **alkaline earth metals**, are the most reactive metals, while the **noble gases** (group 18) are the most nonreactive elements.

### STRATEGY BOX—Set the Table

On the EOCT, a question might refer you to a table of information. When working with tables carefully read the headings of the columns and rows. When you think you have the answer, double check the information given in the table.

When a metal and a nonmetal react with each other, the metal forms a positive ion (cation) and the nonmetal forms a negative ion (anion). Metals in group 1 lose one electron to form an ion with a charge or valence number of  $+1$ . Group 2 metals lose two electrons to form ions with a  $+2$  charge. Nonmetallic elements in groups 15, 16, and 17 gain electrons, forming ions with a  $-3$ ,  $-2$ , and  $-1$  charge, respectively.



### Spotlight on the Standards

**★Compare and contrast the phases of matter as they relate to atomic and molecular motion★**

Atoms and molecules are in constant motion. The type and degree of motion determine the phase or state of matter.

- In the **solid phase**, atoms or molecules are held in a rigid structure. They are free to vibrate but cannot move around. As a result, solids have a definite volume and shape.
- The **liquid phase** is intermediate between solid and gas. Intermolecular forces hold these atoms or molecules loosely together but do not force them into a rigid structure. Liquid molecules are free to move about to a certain degree, so they have a definite volume. However, liquids conform to the shape of their container.

States of Matter		
	Shape	Volume
Solids	Definite	Definite
Liquids	Not definite	Definite
Gases	Not definite	Not definite

- In the **gas phase**, atoms and molecules experience their greatest freedom. The forces attracting gas molecules are almost nonexistent. As a result, gas molecules are much farther apart and can move freely about. The molecules take on the shape of their container but do not possess a definite volume.
- Finally, **plasmas** are gases that have been so energized that their atoms have been stripped of some or all electrons. Solar flares are great examples of plasmas. Solar flares eject extremely hot hydrogen ions ( $H^+$ ) away from the Sun toward Earth.

The **pressure (P)**, **volume (V)**, and the **absolute temperature (T)** are usually used to describe the condition of a gas. Pressure is the force exerted on a surface per unit area. To understand how the above variables are related, consider air in a variable-volume container. When the temperature of a gas is increased, the atoms or molecules move faster since they have more energy. If the volume remains the same, the force pushing on the walls of the container increases, resulting in a rise in pressure. Conversely, if a gas is cooled at constant volume, the pressure decreases. When a gas is compressed into a smaller volume, the surface area of the walls decreases, leading to an increase in pressure. When the converse is true, the pressure decreases. Chemists have summarized these relationships mathematically with the following laws:

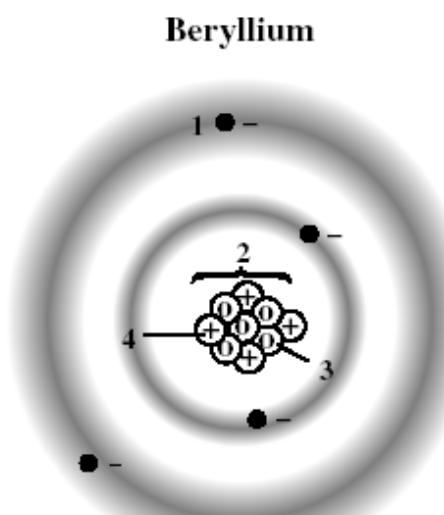
**PV = a constant when the temperature is constant**  
**V is directly proportional to T when the pressure is constant**

These laws can prove very useful when trying to describe the properties of a gas under changing conditions.

## Sample Questions for Content Domain I

This section has some sample questions for you to try. After you have answered all the questions, check your answers in the “Answers to the Content Domain I Sample Questions” section that follows. That section will give you the correct answer to each question and will explain why the other answer choices are incorrect.

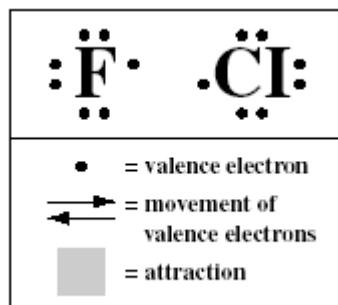
- 1** The following diagram shows a model of a beryllium atom.



Which of the marked particles represents a proton?

- A 1
- B 2
- C 3
- D 4

- 2** Use the key to answer the question.



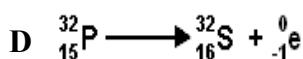
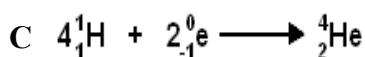
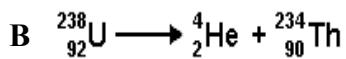
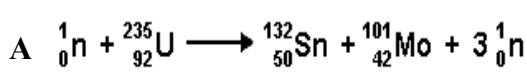
Whenever ionic or covalent bonds form there is a movement of electrons. Which of the following reaction pictures best shows what happens when a covalent bond forms between fluorine and chlorine?

- A  $\begin{array}{c} \ddot{\bullet} \\ | \\ \bullet - \end{array} \rightarrow \begin{array}{c} \ddot{\bullet} \\ | \\ \cdot \ddot{\bullet} - \end{array} \rightarrow F^+ \boxed{\bullet} :\ddot{\bullet}Cl^-$
- B  $\begin{array}{c} \ddot{\bullet} \\ | \\ \bullet - \end{array} \leftarrow \begin{array}{c} \ddot{\bullet} \\ | \\ \cdot \ddot{\bullet} - \end{array} \rightarrow F^- \boxed{\bullet} :\ddot{\bullet}Cl^+$
- C  $\begin{array}{c} \ddot{\bullet} \\ | \\ \bullet - \end{array} \leftrightarrow \begin{array}{c} \ddot{\bullet} \\ | \\ \cdot \ddot{\bullet} - \end{array} \rightarrow :\ddot{\bullet}F \boxed{\bullet} :\ddot{\bullet}Cl:$
- D  $\begin{array}{c} \ddot{\bullet} \\ | \\ \bullet - \end{array} :\ddot{\bullet}Cl: \rightarrow \text{oval } F \boxed{\bullet} Cl$

- 3** Which type of radiation, from an external source, will penetrate deepest into the human body?

- A alpha
- B gamma
- C ultraviolet
- D x-ray

- 4 Which of the following equations represents a nuclear fission reaction?**



- 5 Gold-191 is a radioactive isotope that has a half-life of 12.4 hours. If a lab starts with a 13.2-milligram sample of gold-191, how much will remain after 37.2 hours?**

A 6.60 mg

B 4.40 mg

C 1.65 mg

D 0.825 mg

- 6 Which of the following is the LEAST likely reason for the popularity of fission as a way of producing electricity?**

A Spent uranium fuel is easier to dispose of than ashes from burned coal.

B Nuclear energy is sometimes less expensive than other energy sources.

C Uranium provides more energy than an equal amount of petroleum.

D Nuclear fission produces less air pollution than burning fossil fuels.

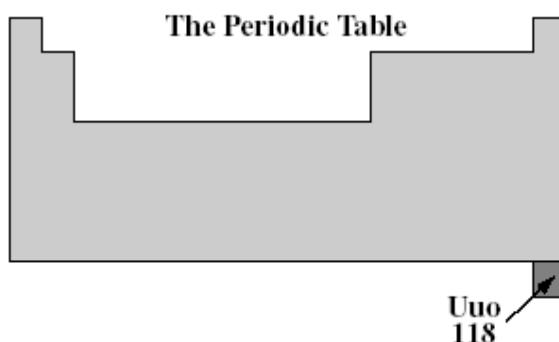
- 7 The valence shell of a neutral atom loses two electrons. Which of the following ions might result?**

A  $O^{2-}$

B  $K^+$

C  $N^{3-}$

D  $Mg^{2+}$



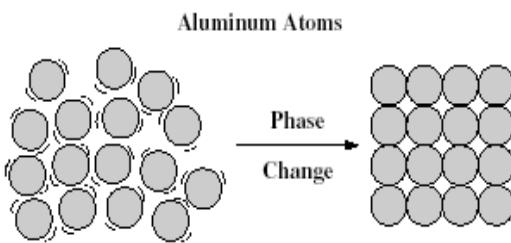
- 8 In the future, nuclear scientists may actually discover a new element named ununoctium (Uuo). Its position is shown in the periodic table above. Which of the following properties might be expected for the element?**

A metalloid solid

B metallic liquid

C nonmetallic gas

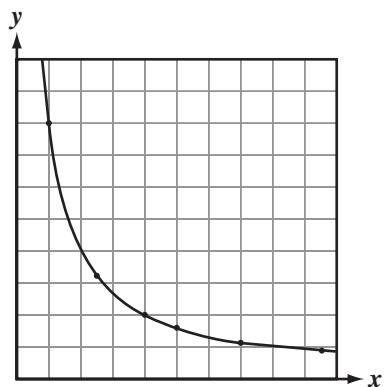
D metallic solid



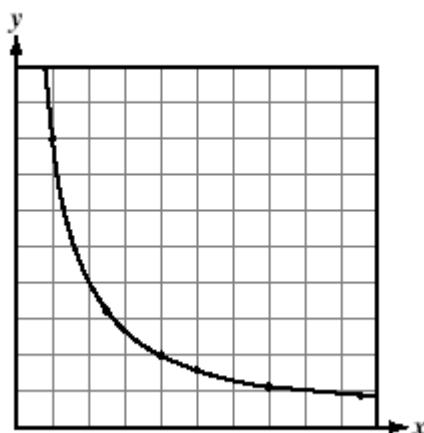
- 9** The above diagram shows the motion of some aluminum atoms before and after a phase change. What phase change has occurred?

- A condensation
- B freezing
- C vaporization
- D melting

#### Results of Gas Experiment



#### Results of Gas Experiment



- 10** A student experiments with nitrogen gas, changing one variable at a time: temperature, pressure, or volume. Unfortunately, the student forgot to label the axes. Which of the following pairs of labels are possible for the graph shown above?

**A**

x-axis	y-axis
Pressure	Volume

**B**

x-axis	y-axis
Temperature	Volume

**C**

x-axis	y-axis
No. of gas molecules	Volume

**D**

x-axis	y-axis
Temperature	Pressure

## Answers to the Content Domain I Sample Questions

**1. Answer: D** **Investigate our current understanding of the atom.** *Examine the structure of the atom in terms of proton, electron, and neutron locations, atomic mass and atomic number, atoms with different numbers of neutrons (isotopes), and atoms with different numbers of protons.*

A proton has a positive charge and is located in the center of the atom, so choice **D** is the correct answer. Choice **A** shows the position of an electron and is incorrect. Choice **B** shows the nucleus of the atom, which contains both protons and neutrons. Choice **C** is incorrect. It shows a neutral particle inside the nucleus.

**2. Answer: C** **Investigate our current understanding of the atom.** *Compare and contrast ionic and covalent bonds in terms of electron position.*

Covalent bonding involves the sharing of electrons back and forth between atoms, so choice **C** is the correct answer. Choices **A** and **B** are incorrect because a complete transfer of electrons has taken place. The result is an ionic bond, not a covalent bond. Choice **D** is incorrect because electrons do not orbit around a molecule of FCl.

**3. Answer: B** **Distinguish the characteristics and components of radioactivity.**

*Differentiate among alpha and beta particles and gamma radiation.*

Gamma radiation is the most energetic radiation; therefore, it penetrates deepest into body tissues. Choice **B** is correct. Choice **A** is incorrect because alpha particles are large and easily stopped. Ultraviolet radiation causes sunburns, but this radiation is stopped at the skin, so choice **C** is incorrect. X-rays, used in medicine to see skeletal features, do not have the penetrating power of gamma rays, so choice **D** is incorrect.

**4. Answer: A** **Distinguish the characteristics and components of radioactivity.**

*Differentiate between fission and fusion.*

The equation in choice **A** shows one large nucleus disintegrating into two smaller atomic nuclei, so choice **A** is correct. Choices **B** and **D** are incorrect because the reactions involve radioactive decay, not fusion. Choice **C** is incorrect because the equation represents a nuclear fusion reaction, not fission. Four smaller nuclei fuse together to produce one larger atomic nucleus.

**5. Answer: C** **Distinguish the characteristics and components of radioactivity.**

*Explain the process half-life as related to radioactive decay.*

The correct answer is choice **C**. The answer is found by creating a chart, such as the one below, where  $t$  is allowed to increase by 12.4-hour increments.

$t$ (hr)	Amount of Gold-191 Remaining (mg)
0	13.2
12.4	6.60
24.8	3.30
37.2	1.65

Choice **A** is incorrect because the original amount of gold-191 was divided by 2 once instead of three times. Choice **B** is incorrect because the half-life is not found by dividing the half-life by the time and multiplying it by the original amount of gold-191. Choice **D** is incorrect because the original amount was divided by 2 four times instead of three.

**6. Answer: A Distinguish the characteristics and components of radioactivity.**

*Describe nuclear energy, its practical application as an alternative energy source, and its potential problems.*

The correct answer is choice **A** because spent nuclear fuel is still radioactive and can be very hazardous to dispose of and store. Choice **B** is incorrect. After a nuclear power plant is built, nuclear energy can be a relatively inexpensive source of electrical energy, a major reason for its use. Choice **C** is incorrect. Uranium fuel (U-238) packs thousands of times more energy than comparable amounts of fossil fuels, another major reason why uranium is used. Choice **D** is incorrect. Nuclear energy is very clean compared to fossil fuels which release tons of pollutants into the atmosphere each year. This makes nuclear energy very attractive in combating greenhouse gases.

**7. Answer: D Investigate the arrangement of the periodic table. Determine the trends of the following: number of valence electrons; types of ions formed by representative elements; location of metals, nonmetals, and metalloids; and phases at room temperature.**

Choice **D** is correct. When a neutral atom such as magnesium (Mg) loses two electrons, it contains two more protons than electrons and takes on a  $+2$  charge. Choice **A** is incorrect because oxygen (O) has gained two electrons; it has not lost two electrons. Choice **B** is incorrect. Though beryllium (Be) lies in group 2, it has lost only one electron to give it a  $+1$  charge. Choice **C** is incorrect because nitrogen (N) has gained three electrons to give it a  $-3$  charge.

**8. Answer: C Investigate the arrangement of the periodic table. Use the periodic table to predict the above properties for representative elements.**

The correct answer is choice **C** because Uuo would lie in group 18, making it a noble gas. Presumably, element 118 would be like radon (Rn), which is a gas. Choice **A** is incorrect. Though Uuo might have some metalloid character, the periodic trend would not lead to the solid phase. Choices **B** and **D** are incorrect because metals lie to the left of the diagonal dividing line.

**9. Answer: B Compare and contrast the phases of matter as they relate to atomic and molecular motion. Compare and contrast the atomic/molecular motion of solids, liquids, gases, and plasmas.**

The correct answer is choice **B**. The diagram is indicative of freezing. Relatively free liquid molecules are cooled so that the molecules slow down and enter into a rigid structure. Choice **A** (condensation, or gas turning into a liquid) is incorrect. A gas would have a much higher degree of motion than shown in the first part of the diagram. In the second part of the diagram, a liquid would not have the rigid structure shown. Choice **C** (vaporization, or liquid turning into a gas) is incorrect. The molecules became less free and more rigid in the diagram. Vaporization involves an increase in freedom and motion.

Finally, choice **D** (melting, or a solid turning into a liquid) is incorrect. Melting is actually the opposite of freezing, so the reverse of the diagram is true.

**10. Answer: A      Compare and contrast the phases of matter as they relate to atomic and molecular motion. Relate temperature, pressure, and volume of gases to the behavior of gases.**

The correct answer is choice **A**. The volume is inversely proportional to pressure; thus, the volume decreases with an increase in pressure. Choice **B** is incorrect. The volume of a gas is directly proportional to the absolute temperature, so the volume should increase, not decrease, as the temperature rises. The volume of a gas increases in direct proportion to the number of gas molecules, so choice **C** is incorrect. The volume should go up, not down, as the number of gas molecules increase. Finally, choice **D** is incorrect because the pressure is directly proportional to the absolute temperature. When the temperature rises, molecules move faster, increasing the pressure.

## Content Domain II: Chemical Reactions and Properties of Matter

### A LOOK AT CONTENT DOMAIN II



Test questions in this content domain will measure your ability to analyze chemical reactions and name different types of matter. You will also investigate and explain the properties of matter and solutions. Your answers to the questions will help show how well you can perform on the following standards:

- Explore the nature of matter, its classifications, and the system for naming types of matter.
- Investigate the properties of solutions.



### Spotlight on the Standards

★Explore the nature of matter, its classifications, and the system for naming types of matter★

**Matter**, the substance that is seen all around us, consists of anything that has mass and volume. The **density**,  $d$ , of a material object is defined as the ratio of the object's **mass**,  $m$ , to its **volume**,  $V$ . The formula used to calculate density is  $d = \frac{m}{V}$ . The density is a unique property of matter.

Gases tend to have very low densities compared to solids and liquids. The large distances between atoms or molecules of gas are responsible for the very low density. Other properties of substances include color, melting point, boiling point, chemical reactivity, and electrical conductivity. A **physical property** is a characteristic of a substance that can be observed or measured without changing the identity of the substance. A **chemical property** characterizes how matter changes into entirely new substances. A set of known physical and chemical properties help to identify a particular chemical substance.

### Some Physical Properties

- Boiling Point
- Color
- Conductivity
- Density
- Malleability
- Mass
- Melting Point
- Odor
- Shape
- State of Matter
- Weight

A question for this standard might look like this:

**A laboratory worker found the following properties for a sample of copper.**

<b>Properties of Copper Sample</b>	
Physical description	<i>Shiny red metal</i>
Melting point (°C)	1084.62
Boiling point (°C)	2562
Mass (g)	50.36
Volume (cm <sup>3</sup> )	5.62

**What is the density of the copper?**

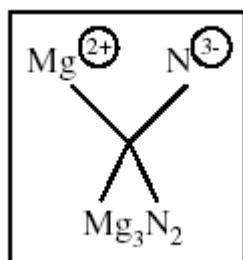
- A** 0.112 g / cm<sup>3</sup>
- B** 8.96 g / cm<sup>3</sup>
- C** 21.6 g / cm<sup>3</sup>
- D** 44.7 g / cm<sup>3</sup>

The correct answer is choice **B**. Dividing 50.36 g by 5.62 cm<sup>3</sup> yields a density of 8.96 g / cm<sup>3</sup>. Choice **A** is incorrect because the volume was divided by the mass. Choice **C** is incorrect. The density is not found by dividing the melting point by the mass. Finally, for choice **D**, the volume was subtracted from the mass instead of the mass being divided by the volume, making choice **D** incorrect. (Note that all the properties given are physical properties.)

Many times, chemical properties describe the reaction of ions with other ions to produce ionic compounds. **Binary ionic compounds** contain only two different elements. Ionic bonds form between metals and nonmetals because of a complete transfer of electrons from the metal to the nonmetal. The resulting oppositely charged ions attract. Sodium chloride, NaCl, is an example of a binary ionic compound. The correct formula for a binary ionic compound can be found by making a cross, as in the example below.

### Some Chemical Properties

- Ability to Burn
- Ability to Corrode
- Ability to Support Burning
- Reactivity with Chemicals
- Reactivity with Light



Notice that the charge on the nitride ion ( $\text{N}^{3-}$ ) becomes the number of magnesium ions in the formula. Likewise, the charge on the magnesium ion ( $\text{Mg}^{2+}$ ) becomes the number of nitride ions in the formula. In this way, the charges are balanced (+6 and -6), making magnesium nitride neutral. This method usually works, except when the charges on the ions are exact opposites. In that case, the ions should be combined in a 1:1 ratio to balance the charges.

Any combination of cations and anions can form a binary ionic compound. To name this type of compound, simply write the name of the element that forms the cation first. Then follow with the name of the anion. The name of the anion will usually contain the first syllable of the element name and end with the suffix *-ide*. For example, the formula unit  $\text{AlCl}_3$  would be named aluminum chloride. Notice that the cation has the element name and that the first syllable of chlorine, *chlor-* has gained the *-ide* ending.

**Covalent bonds** form when atoms share one or more valence electrons. The names of **binary covalent compounds** must include prefixes to show the number of atoms of each element in the compound. The first atom is named after the element it represents. If there are two or more atoms of that element, the prefixes *di-*, *tri-*, *tetra-*, or a higher numeral prefix are used. The prefix *mono-* (one) is never used for the first element. All numerical prefixes, however, are used for the second element. An appropriate prefix indicates the number of the second atom. This prefix is placed before the first syllable of the element name. The suffix *-ide* is then added to the end. For example, the covalent compound  $\text{CO}_2$  is named carbon dioxide. Notice the *di-* prefix for the second element and the lack of a prefix for the first element. Another example is  $\text{P}_2\text{S}_5$ . It is named diphosphorus pentasulfide. Notice that the *di-* prefix is used for the two phosphorus atoms and that the *penta-* prefix is used for the five sulfur atoms in the formula.

### Numerical Prefixes

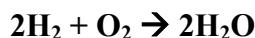
<i>mono-</i>	1
<i>di-</i>	2
<i>tri-</i>	3
<i>tetra-</i>	4
<i>penta-</i>	5
<i>hexa-</i>	6
<i>hepta-</i>	7
<i>octa-</i>	8
<i>nona-</i>	9
<i>deca-</i>	10

## Conservation of Matter in Chemical Reactions

Matter, like energy, is neither created nor destroyed. In a chemical reaction, the same number of atoms occurs in the products as in the original reactants. As a result, the mass of the **products** always equals the mass of the **reactants**. This statement summarizes the **law of conservation of mass**. One example of this law in action involves the burning of firewood. At first glance, it appears that the law of conservation of mass is violated because the mass of the ashes left over is much less than the mass of the original wood. In fact, if one could measure the mass of the smoke, water vapor, and carbon dioxide given off in addition to the ash, the mass would exactly equal that of the unburned firewood.

The law of conservation of matter/mass can be used to balance **chemical equations**, which are used to show what happens in a chemical reaction. In chemical equations, the

coefficients in front of the chemical formulas represent the number of molecules of reactants or products. The combustion reaction of hydrogen and oxygen is shown below.



The chemical equation shows that two molecules of hydrogen plus one molecule of oxygen yields two molecules of water. Notice that the number of hydrogen atoms ( $2 \times 2 = 4$ ) and oxygen atoms ( $1 \times 2 = 2$ ) on the reactant side (left side of the arrow) equals the number of hydrogen and oxygen atoms on the product side (right side of the arrow) of the equation. The equation is balanced because the numbers of atoms of each element (H, O) are same on both sides of the arrow.

The combustion reaction of hydrogen and oxygen is also known as a **synthesis** reaction. In a synthesis reaction two or more simple substances combine to form a complex substance. A synthesis reaction is represented by the general equation  $A + B \rightarrow AB$ . When balancing an equation for a synthesis reaction, the coefficients should be used to make the number of atoms of each element the same on each side of the equation. The following “bookkeeping” method was used to obtain the above balanced equation. The equation was first written without coefficients. Understand that even though no coefficients are written in the original equation, one-coefficients are understood. The following steps are shown below.

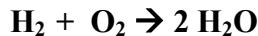
In Step 1, two hydrogen atoms appeared on both sides of the equation. No change was needed.



### **Step 1**

Element	No. of atoms in reactants	No. of atom in product(s)
H	2	2
O	2	1

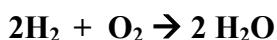
The reactant side contained two oxygen atoms while the product side contained only one oxygen atom. In step 2 the number of water molecules was multiplied by two to balance the oxygen atoms. A two-coefficient was placed before the  $\text{H}_2\text{O}$ .



### **Step 2**

Element	No. of atoms in reactants	No. of atom in product(s)
H	2	4
O	2	1 X2

Finally, in Step 3, the reactant side still contained two hydrogen atoms while the product side contained four hydrogen atoms. The hydrogen molecule ( $H_2$ ) was multiplied by two to balance the hydrogen atoms. The equation is balanced when a two-coefficient is placed before the  $H_2$ .



### Step 3

Element	No. of atoms in reactants	No. of atom in product(s)
H	$2 \times 2$	4
O	2	$1 \times 2$

### STRATEGY BOX REVISITED—Analyze the Word by Its Parts

Remember to look for familiar word parts when faced with an unknown term. Look at the following word parts:

*syn-* means “together with”      *-thesis* means “put (place)”

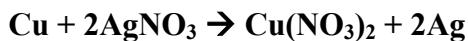
Knowing these meanings will help you determine the meaning of words like *synthesis*.

Similar bookkeeping can be used to balance other types of simple equations. A **decomposition** reaction is the opposite of a synthesis reaction. In a decomposition reaction a complex substance breaks down into simple parts. It is represented by the general equation  $AB \rightarrow A + B$ . An example of this reaction is the decomposition of limestone (calcium carbonate).



Notice that the equation is balanced as written. Count the number of atoms of each element on each side of the equation (right and left of the yield sign  $\rightarrow$ ). On the reactants side of the equation are one atom of calcium, one atom of carbon and three atoms of oxygen. On the product side of the equation are one atom of calcium, one atom of carbon, and three atoms of oxygen. One-coefficients are understood, though not written.

A single replacement reaction involves a single uncombined element replacing another element in a compound forming a different compound. A single-replacement reaction may be represented by the general equation  $A + BC \rightarrow AC + B$ . An example of this reaction is the replacement of a silver ion by copper in a silver nitrate solution.



Notice that the coefficients are placed before the  $AgNO_3$  and  $Ag$  to balance the equation.

In a double replacement reaction two elements in two different compounds replace each other, forming two different compounds. A double-replacement reaction has the general equation  $AB + CD \rightarrow AD + CB$ . The neutralization of hydrochloric acid by sodium hydroxide is a good example of this type of reaction.



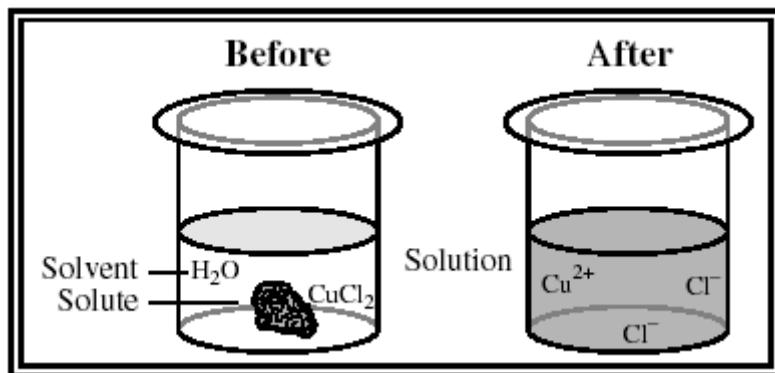
This equation is also balanced as written with no need for coefficients other than the one-coefficients, which are understood. If you count the number of atoms of each element on the reactant side and the number of atoms of the same elements on the products side of the equation you will find that they are equal. There is one sodium (Na) atom on the left side (reactants) and right side (products) of the arrow; one oxygen (O) atom on both sides; one chlorine (Cl) atom on both sides; and two hydrogen (H) atoms on both sides of the arrow. The equation is balanced.



### Spotlight on the Standards

#### ★Investigate the properties of solutions★

Matter is not always pure. It may contain mixtures of elements and compounds. A **solution** is a special type of mixture. It has a uniform composition throughout and is made up of two parts—a solute and a solvent. The **solute** is the substance that is being dissolved or broken down into smaller particles. The **solvent** is the substance doing the dissolving. Usually the solute is the substance that is in smaller quantity. For example, in a copper (II) chloride solution, the CuCl<sub>2</sub> is the solute, while water is the solvent. This example is shown in the box below. The **solubility** is the ability of a substance to dissolve in a solvent, such as water. When the maximum amount of solute that can be dissolved is added to the solvent, the solution becomes **saturated**. Below this maximum amount, the solution is **unsaturated**.



**Conductivity** is the measure of a solution's ability to conduct electricity. The conductivity gives important clues as to the type of solute dissolved. In **aqueous** (water-based) solutions, dissolved ionic compounds yield solutions with high conductivity. Cations and anions readily carry electrical charges through the solution. Strong acids and bases also have a high conductivity for the same reason.

All of these solutions are considered **strong electrolytes**. Weak acids or bases ionize only partially so they form solutions with low conductivity. These compounds are called **weak electrolytes**. Solutions made from covalent compounds have zero conductivity since they dissolve as molecules, not ions. They cannot carry electrical charges. These substances are known as **nonelectrolytes**. Some selected compounds and their electrical conductivity are shown in the box to the right.

Conductivity of Some Aqueous Solutions		
High Conductivity	Low Conductivity	Zero Conductivity
<chem>AlCl3</chem>	<chem>CH3CO2H</chem>	<chem>CH3OH</chem>
<chem>CaCl2</chem>	(acetic acid)	(methanol)
<chem>H2SO4</chem>	<chem>NH3</chem>	<chem>C12H22O11</chem>
<chem>HCl</chem>	(ammonia)	(table sugar)
<chem>KCl</chem>	<chem>HF</chem>	<chem>C6H12O6</chem>
<chem>KOH</chem>	(hydrofluoric acid)	(glucose)
<chem>MgSO4</chem>		
<chem>NaCl</chem>		
<chem>NaOH</chem>		

The **concentration** describes how much solute has been dissolved in solution. Almost all concentration units express some kind of ratio. For example, the mass percent of a solution is equal to the mass of the solute (in grams) divided by the mass of the solution (in grams) times 100%. Solutions with higher concentrations tend to conduct electricity better than dilute solutions. A question for this standard might look like this:

**A light bulb and a solution are made part of an electrical circuit. When the circuit is connected to a battery, which of the following dilute aqueous solutions will carry enough electrical charge to make the light bulb glow brightly?**

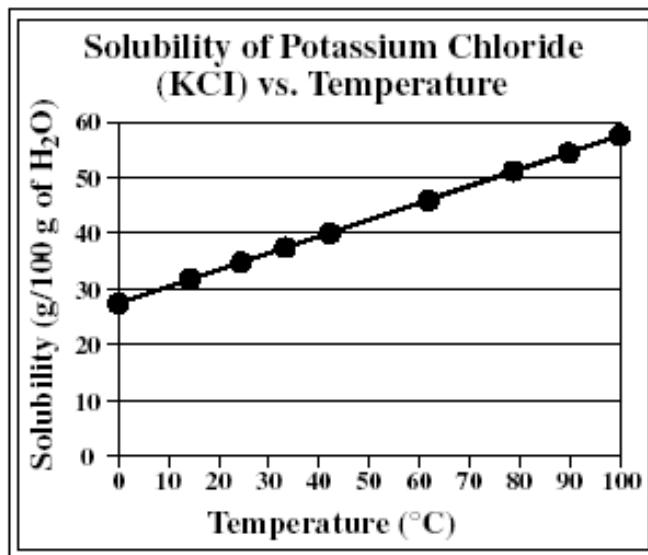
- A** a covalent compound solution
- B** a weak basic solution
- C** a salt solution
- D** a weak acid solution

The correct answer is choice **C**. A salt solution is an ionic compound that dissolves in water, forming many ions. It has a high conductivity even when diluted. The light bulb will glow brightly. Choice **A** is incorrect. A covalent compound does not conduct electricity in solution. It does not ionize. Choice **B** is incorrect because a weak base solution only partially ionizes and thus has a low conductivity. The light bulb would appear dim. Choice **D** is incorrect. A weak acid does not ionize very much, so it is a poor conductor of electricity. The light bulb would appear dim.

There are a number of factors that can affect the rate at which a solid solute dissolves in a liquid solvent.

- Stirring increases the amount of fresh solvent that comes in contact with a solute. When there is no stirring, the solvent around the solute becomes nearly saturated. Stirring keeps the solvent near the solute unsaturated, increasing the dissolving rate.
- When a solute is ground into smaller particles, the amount of surface area exposed to the solvent increases. This additional surface area allows the dissolving process to occur faster. The smaller the solute particles, the faster the rate of dissolving.
- Solvent molecules move faster when the temperature increases. These faster solvent molecules come in contact with solute particles more often increasing the dissolving rate. Also, at higher temperatures, the solubility usually increases. Higher temperatures, therefore, favor higher dissolving rates.

A **solubility curve** shows how the amount of dissolved solute changes with temperature. The solubility curve below shows the solubility of potassium chloride (KCl) as a function of temperature. Notice that the dimensions of solubility are grams of solute per 100 grams of solvent (water). The solubility of most salts, such as KCl, increases with higher temperatures, as can be seen in the graph below.



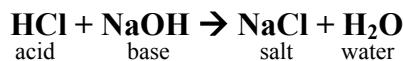
A solubility curve also shows the temperature at which a solute will begin to precipitate from solution. For example, if approximately 54 grams of KCl are dissolved in 100 grams of boiling water, the salt completely dissolves. When the solution cools, though, the KCl begins to precipitate at 90°C because the solution has become saturated. As you can see above, as the solution cools further, more of the KCl will precipitate out until, at 0°C, only 28 grams of the salt remain in solution. Can you determine from the graph how

many grams of KCl will be dissolved in solution at 60°C? If you answered about 43 grams, you are correct.

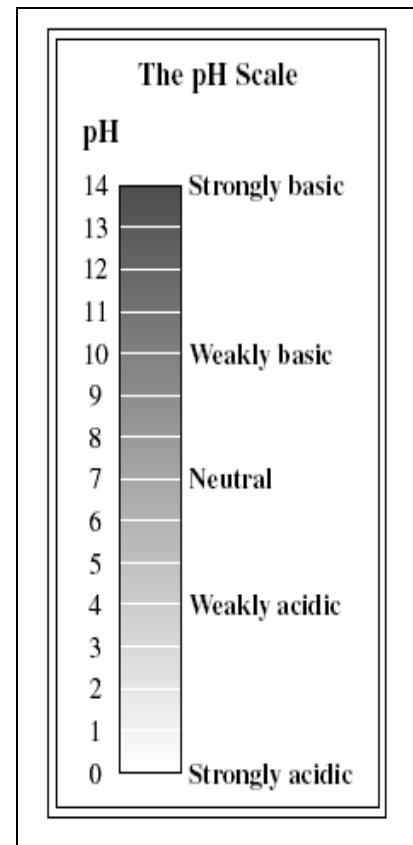
As early as the 1600s, chemists recognized that matter could be classified as either **acid** or **base**. It took many more years to define and describe the behavior of these important compounds. Chemists today know that acids and bases have the properties shown in the following chart:

	<b>Acid</b>	<b>Base</b>
<b>Taste</b>	<ul style="list-style-type: none"> <li>Sour or tart</li> </ul>	<ul style="list-style-type: none"> <li>Bitter</li> </ul>
<b>Touch</b>	<ul style="list-style-type: none"> <li>Feels like water / may sting</li> </ul>	<ul style="list-style-type: none"> <li>Feels smooth and slippery</li> </ul>
<b>Reactions with Metals</b>	<ul style="list-style-type: none"> <li>Vigorously reacts with most metals to produce hydrogen, H<sub>2</sub></li> </ul>	<ul style="list-style-type: none"> <li>Does not react with most metals</li> </ul>
<b>Electrical Conductivity</b>	<ul style="list-style-type: none"> <li>Readily conducts electricity (less so for weak acids)</li> </ul>	<ul style="list-style-type: none"> <li>Readily conducts electricity (less so for weak bases)</li> </ul>
<b>Litmus Paper*</b> Test (*A type of paper containing a dye that changes colors when exposed to acids or bases)	<ul style="list-style-type: none"> <li>Turns blue litmus paper red</li> </ul>	<ul style="list-style-type: none"> <li>Turns red litmus paper blue</li> </ul>

The **pH scale** gives a measure of the acidity or basicity of a solution. The lower the pH of a solution, the more acidic it is. The higher the pH, the more basic it is. Any solution with a pH less than 7 is acidic. A solution with a pH greater than 7 is considered basic. Any solution with a pH of exactly 7 is neutral. See the pH scale on the right. Lemon juice has a pH between 2 and 3. It is acidic. Common household bleach is basic with a pH between 12 and 13. Pure water has a pH of 7 and is neutral. All compounds that give off **hydrogen ions** (H<sup>+</sup>) in solution are acids. Bases are any compounds that accept the hydrogen ions to form a salt. For example, hydrochloric acid and sodium hydroxide react together in a **neutralization reaction**.



The hydroxide ion (OH<sup>-</sup>) from the NaOH accepted the hydrogen ion (H<sup>+</sup>) from the HCl to form water. The salt NaCl was formed from the sodium ion (Na<sup>+</sup>) and the chloride ion (Cl<sup>-</sup>) left over.



A question for this standard might look like this:

**Borax detergent is dissolved in water. The solution turns red litmus paper blue and feels slippery to the touch. Which pH is possible for the solution?**

- A** 1.5
- B** 5.0
- C** 7.0
- D** 9.5

The correct answer is choice **D**. Since the borax detergent tests positive for a base, the pH must be greater than 7. Choices **A** and **B** are incorrect because a pH of 1.5 is strongly acidic and a pH of 5.0 is weakly acidic; thus, choice **C** is incorrect because a solution with a pH of 7.0 is neutral and is not a base.

## Sample Questions for Content Domain II

This section has some sample questions for you to try. After you have answered all the questions, check your answers in the “Answers to the Content Domain II Sample Questions” section that follows. That section will give you the correct answer to each question and will explain why the other answer choices are incorrect.

- 1 The chart shown was taken from a student’s laboratory notebook.**

<b>Density of Copper</b>	
Mass of copper sample (g)	8.539
Volume of water in graduated cylinder before sample added (mL.)	3.74
Volume of water in graduated cylinder after sample added (mL.)	4.69

**What is the density of the copper sample?**

- A  $0.987 \frac{\text{g}}{\text{mL}}$
- B  $1.82 \frac{\text{g}}{\text{mL}}$
- C  $2.28 \frac{\text{g}}{\text{mL}}$
- D  $8.99 \frac{\text{g}}{\text{mL}}$

- 2 What is the formula of the compound containing  $\text{Ca}^{2+}$  and  $\text{F}^-$ ?**

- A  $\text{CaF}$
- B  $\text{Ca}_2\text{F}$
- C  $\text{CaF}_2$
- D  $\text{CaF}_3$

- 3 What is the name of the compound represented by the formula  $\text{NO}_2$ ?**

- A nitrogen dioxide
- B dinitrogen monoxide
- C nitrogen oxide
- D mononitrogen dioxide

- 4 This table above shows the reaction of sodium chloride ( $\text{NaCl}$ ) with silver nitrate ( $\text{AgNO}_3$ ) and the masses of the compounds involved in the reaction.**

Reaction	$\text{NaCl} + \text{AgNO}_3 \rightarrow \text{AgCl} + \text{NaNO}_3$			
Mass before reaction (g)	11.69	33.98	0.00	0.00
Mass after reaction (g)	0.00	0.00	$x$	17.00

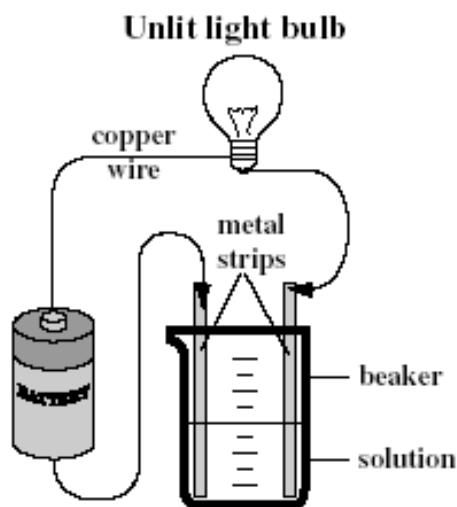
**How many grams of  $\text{AgCl}$ ,  $x$ , are produced by the reaction?**

- A 16.98
- B 28.67
- C 45.67
- D 62.67

**5 Which of the following is a balanced equation for the synthesis of ammonia ( $\text{NH}_3$ )?**

- A  $\text{N}_2 + 3\text{H}_2 \xrightarrow{\text{heat/pressure}} 2\text{NH}_3$
  - B  $\text{N}_2 + \text{H}_2 \xrightarrow{\text{heat/pressure}} \text{NH}_3$
  - C  $\text{N}_2 + \text{H}_2 \xrightarrow{\text{heat/pressure}} 2\text{NH}_3$
  - D  $2\text{N}_2 + 3\text{H}_2 \xrightarrow{\text{heat/pressure}} 2\text{NH}_3$
- 

Solution Number	Name	Formula of Solute	Concentration (%)
1	Ammonia	$\text{NH}_3$	5.0
2	Glucose	$\text{C}_6\text{H}_{12}\text{O}_6$	20.0
3	Calcium chloride	$\text{CaCl}_2$	25.0
4	Hydrochloric acid	$\text{HCl}$	0.25

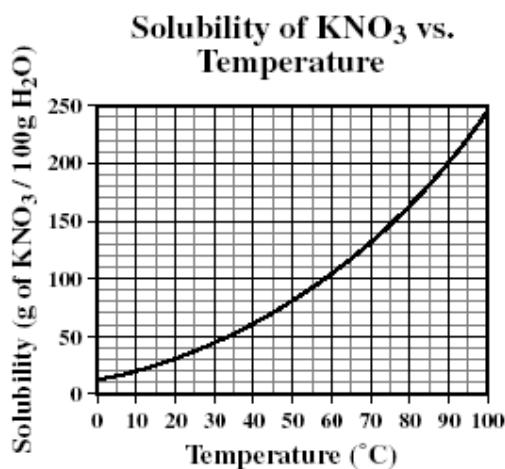


**6 Some students did the experiments above to see what kind of solution conducts electricity and makes the light bulb glow. Which of the four solutions will MOST likely cause the light bulb to remain unlit?**

- A 1
- B 2
- C 3
- D 4

**7** A chemist is trying to dissolve a large crystal of magnesium sulfate ( $\text{MgSO}_4$ ) in water by stirring the solution, but the crystal dissolves very slowly. What can the chemist do to speed up the process?

- A lower the temperature of the water
- B discontinue stirring the solution
- C pour off some of the  $\text{MgSO}_4$  solution
- D break the crystal into smaller pieces

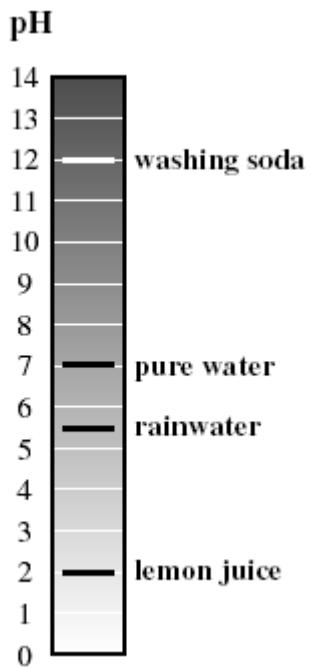


**8** A chemist dissolved 120.00 grams of potassium nitrate ( $\text{KNO}_3$ ) in 200 grams of boiling water. The solution was allowed to cool. According to the above solubility curve, at what temperature should the  $\text{KNO}_3$  begin to precipitate?

- A 18°C
- B 39°C
- C 65°C
- D 88°C

**9** Which of the following substances, when dissolved in water, will turn red litmus paper blue?

- A KOH
- B NaCl
- C  $\text{H}_2\text{O}$
- D  $\text{H}_2\text{SO}_4$



**10** The strip chart above shows the pH of some common substances. Which substance is basic?

- A lemon juice
- B rainwater
- C pure water
- D washing soda

## Answers to the Content Domain II Sample Questions

- 1. Answer: D** **Explore the nature of matter, its classifications, and the system for naming types of matter.** *Calculate density when given a means to determine a substance's mass and volume.*

Choice **D** is correct. The density is found by dividing the mass of the copper sample by its volume. The volume is equivalent to the change in the volume of the water. Choice **A** is incorrect because the density is not found by adding up the volumes of the water and dividing the sum by the mass of the copper. Choice **B** is incorrect because the mass of the copper was divided by the final volume of the water rather than the change in the volume of the water. Choice **C** is incorrect because the mass of the copper sample was divided by the initial volume of the water rather than the change in the volume of the water.

- 2. Answer: C** **Explore the nature of matter, its classifications, and the system for naming types of matter.** *Predict formulas for stable binary ionic compounds based on balance of charges.*

The correct answer is choice **C**. By crossing the charges, the  $-1$  charge becomes one calcium ion and the  $+2$  charge becomes two fluoride ions. This results in the formula  $\text{CaF}_2$ . Notice that one calcium ion supplies a  $+2$  charge while the two fluoride ions supply a  $-2$  charge, which balance. Choices **A**, **B**, and **D** are incorrect because the positive and negative charges are not balanced.

- 3. Answer: A** **Explore the nature of matter, its classifications, and the system for naming types of matter.** *Use IUPAC nomenclature for transition between chemical names and chemical formulas of binary ionic compounds (containing representative elements) and binary covalent compounds (i.e., carbon dioxide, carbon tetrachloride).*

Choice **A** is correct. There is only one nitrogen atom, but remember the prefix *mono-* is not used for the first element. Because there are two oxygen atoms, the prefix *di-* is used before the *oxide* ending. Choice **B** is incorrect because the prefix *di-* is used before the nitrogen instead of the oxide. The *mono-* prefix is used for oxygen incorrectly. Choice **C** is incorrect because it is named the same way as an ionic compound without the prefixes ( $\text{NO}_2$  is a covalent compound). Finally, choice **D** is wrong because the *mono-* prefix is never used to indicate one atom of the first element.

- 4. Answer: B** **Explore the nature of matter, its classifications, and the system for naming types of matter.** *Demonstrate the law of conservation of matter in a chemical reaction.*

Choice **B** is correct because the mass of  $\text{AgCl}$  is equal to the total mass of the reactants less the mass of the product  $\text{NaNO}_3$ , according to the law of conservation of matter.

Choice **A** is incorrect because the mass of the  $\text{NaNO}_3$  was subtracted from the mass of  $\text{AgNO}_3$  instead of the total mass of the reactants. Choice **C** is not right because the reactant masses were added together to obtain the mass of  $\text{AgCl}$ . Actually, the total reactant mass should equal the total mass of the products  $\text{AgCl}$  and  $\text{NaNO}_3$ . Choice **D** is incorrect because all of the listed masses were added together to give the mass of  $\text{AgCl}$ . This operation disobeys the law of conservation of matter.

**5. Answer: A** *Explore the nature of matter, its classifications, and the system for naming types of matter. Apply the law of conservation of matter by balancing the following types of chemical equations: synthesis, decomposition, single replacement, and double replacement.*

Choice **A** is the correct response. On the reactant side, there are two nitrogen atoms and six hydrogen atoms. The two molecules of  $\text{NH}_3$  on the product side yield the same number of atoms. Choice **B** is incorrect because the equation for the reaction is shown without the coefficients needed to balance it. Choice **C** is wrong because only the nitrogen atoms have been balanced in the equation. Finally, choice **D** is incorrect because the nitrogen atoms have been balanced incorrectly even though the hydrogen atoms have been balanced correctly.

**6. Answer: B** *Investigate the properties of solutions. Describe solutions in terms of solute/solvent, conductivity, and concentration.*

The correct answer is choice **B**. Glucose is a nonelectrolyte, so it will not conduct electricity or allow the light bulb to glow. Choice **A** is an incorrect answer because ammonia,  $\text{NH}_3$ , is a weak electrolyte. It ionizes partially in water and conducts electricity weakly. The light bulb should have a dim glow. Choice **C** is wrong because calcium chloride,  $\text{CaCl}_2$ , is a strong electrolyte and should conduct electricity readily. It would allow the light bulb to shine brightly. Choice **D** is incorrect. Hydrochloric acid is a strong acid and a strong electrolyte. Though the concentration is somewhat low, it should conduct electricity fairly well. The light bulb would shine brightly.

**7. Answer: D** *Investigate the properties of solutions. Observe factors affecting the rate a solute dissolves in a specific solvent.*

Breaking up the crystal into smaller pieces increases the surface area of the solute in contact with the solvent. This change speeds up the dissolving process, so choice **D** is the correct answer. Choice **A** is incorrect because lowering the temperature causes the solvent molecules to move slower and the solubility of the  $\text{MgSO}_4$  to more than likely decrease. Choice **B** is incorrect. If stirring is discontinued, less fresh solvent will come in contact with the crystal. This change will actually slow down the dissolving process. Choice **C** is incorrect because pouring off some of the solution will have little effect on the dissolving rate. In fact, if fresh solvent is poured off, the dissolving rate will decrease.

**8. Answer: B** *Investigate the properties of solutions. Demonstrate that solubility is related to temperature by constructing a solubility curve.*

The amount of  $\text{KNO}_3$  dissolved is 60.00 g / 100 g of  $\text{H}_2\text{O}$ . The solution becomes saturated at 39°C, so choice **B** is correct. Choice **A** is incorrect because the concentration was calculated as 30.00 g / 100 g of  $\text{H}_2\text{O}$  instead of 60.00 g / 100 g of  $\text{H}_2\text{O}$ . Choice **C** is wrong because the concentration was not converted to g / 100 g of  $\text{H}_2\text{O}$ . The temperature was read for twice the correct amount of solute. Choice **D** is incorrect because the solubility was read as 200 g / 100 g of  $\text{H}_2\text{O}$ .

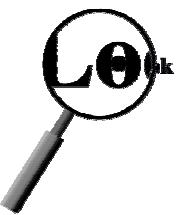
**9. Answer: A      Investigate the properties of solutions.** *Compare and contrast the components and properties of acids and bases.*

Choice **A** is the correct answer. Potassium hydroxide (KOH) contains the hydroxide ion ( $\text{OH}^-$ ). This ion will accept a proton ( $\text{H}^+$ ), so it is basic and will turn red litmus paper blue. Choice **B** is incorrect because NaCl is a neutral salt. Water is neutral as well, so choice **C** is incorrect. Choice **D** is incorrect because  $\text{H}_2\text{SO}_4$  is a strong acid. It will turn blue litmus paper red.

**10. Answer: D      Investigate the properties of solutions.** *Determine whether common household substances are acidic, basic, or neutral.*

Choice **D** is the correct answer because washing soda is the only substance with a pH greater than 7. All substances with a pH greater than 7 are basic. Choices **A** and **B** are incorrect because lemon juice and rainwater have a pH less than 7, making them acidic. Pure water has a pH of 7. It is neutral, so choice **C** is incorrect.

## Content Domain III: Energy, Force, and Motion



### A LOOK AT CONTENT DOMAIN III

Test questions in this content domain will measure your ability to investigate and explain how energy works in the world around us. You will also investigate how forces affect matter. Your answers to the questions will help show how well you can perform on the following standards:

- Relate transformations and flow of energy within a system
- Determine relationships among force, mass, and motion



### Spotlight on the Standards

#### ★*Relate transformations and flow of energy within a system*★

Just as matter is conserved, so is energy. The **law of conservation of energy** states that energy, like matter, cannot be created nor destroyed; it can only be changed from one form of energy to another. Energy takes many forms in the world around us. Each form of energy can be converted to and from other forms of energy. Most people are familiar with sound, light, and electrical energy. **Electrical energy** is used in our homes to produce stereo sound through speakers, light from a fluorescent lamp, and **thermal energy** for cooking and heating. **Thermonuclear energy**, which is stored in the nucleus of atoms, is harnessed to produce electrical energy in modern power plants. **Chemical energy** is stored in the bonds that hold atoms together in molecules. When fuels or foods are broken down, chemical energy is converted to heat energy or to kinetic energy. **Kinetic energy** is the energy contained by moving objects due to their motion. Even objects at rest have energy because of their position.

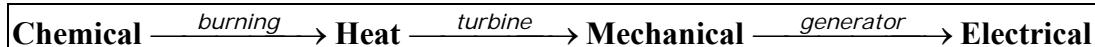
**Potential energy**, also known as stored energy, is the energy of position. When a boulder sits on top of a cliff, it has gravitational potential energy as a result of its height above the ground. When the boulder tumbles off the cliff, its gravitational potential energy is

### Some Types of Energy

- Chemical
- Electrical
- Electromagnetic
- Mechanical
- Nuclear
- Radiant or Light
- Sound
- Thermal

converted to kinetic energy. When a ball is thrown up into the air, the kinetic energy of the ball is converted into gravitational potential energy as the ball approaches its highest point. As the ball falls back to the ground, the potential energy it gained during its upward flight turns back into kinetic energy. Kinetic and potential energy are types of mechanical energy.

We obtain energy from a variety of sources. The most common source of energy used today is coal. The chemical energy contained in coal is converted to electrical energy through the following series of energy transformations.



Petroleum and natural gas represent other fuels, which, along with coal, are known collectively as **fossil fuels**. The box to the right shows some other sources of energy.

The movement of thermal energy from hot to cold materials is called **heat transfer**. There are three basic types of heat transfer: conduction, convection, and radiation.

- **Conduction** is the transfer of heat energy between materials that are in direct contact with each other. Heat transfer by conduction occurs as hot molecules and free electrons become agitated and collide with less energetic neighbors. These neighbors then become agitated and pass along thermal energy in a process similar to a “fire-bucket brigade.” The process of conduction can be felt in the handle of a metal spoon that has been placed in a bowl of hot soup. The hot soup transfers heat to the end of the spoon; the heat is then transferred through the spoon to the handle. The rate of heat transfer depends on the type of material. Good conductors, such as metals, conduct heat rapidly. **Insulators**, such as wood or plastic, conduct heat very slowly.
- **Convection** is the transfer of heat energy by the mass movement of fluids containing heated particles. Fluids are materials that can flow. Liquids and gases are examples of fluids. When particles of a fluid are heated, the particles move farther apart, causing the fluid to expand. This movement of heated particles creates convection currents. Home heating systems force heated air into rooms by way of convection currents. These currents heat the colder air in the room.
- **Radiation** is the transfer of heat energy through electromagnetic waves. These waves originate from accelerated charged particles. Electromagnetic waves travel through matter or through empty space. Heat transfer through empty space is unique to radiation. Both conduction and convection require a medium or matter to transfer heat energy. Since the space between the Sun and Earth is essentially a vacuum, the heat energy from the Sun is transferred to Earth only by radiation.

### Energy Sources

- Fossil Fuels
- Geothermal
- Hydroelectric
- Nuclear
- Solar
- Wind

Different substances have varying capacities for storing energy within their molecules. Heat energy can cause molecules to move about faster, increasing their random kinetic energy. An increase in this energy raises the temperature of the substance. Heat energy can also increase the vibrational or rotational energy of molecules, but this does not result in a temperature increase. Each substance has a unique **specific heat capacity**, meaning different substances have the ability to absorb only a certain amount of heat. Values for some common substances are shown in the table to the right. The specific heat capacity is generally defined as the amount of heat energy required to raise the temperature of 1 kilogram of a substance by 1°C. It is a measure of how much heat energy a particular substance can hold. The units most commonly used are joules per kilogram per degree Celsius. The amount of heat energy that a substance gains or loses,  $Q$ , depends on the mass ( $m$ ), the specific heat, ( $c$ ), and the change in the temperature ( $\Delta T$ ) of the substance. The formula for finding the heat energy is simply the product of the three factors,  $Q = mc\Delta T$ . A question for this standard might look like this:

Substance	Specific Heat, $c$ $\left( \frac{\text{J}}{\text{kg} \cdot ^\circ\text{C}} \right)$
Air (dry)	1010
Aluminum	900
Copper	390
Ethanol	2450
Glass	840
Ice (at $-15^\circ\text{C}$ )	2000
Mercury	140
Steel	450
Water (at $15^\circ\text{C}$ )	4190

**A copper ornament has a mass of 0.0693 kg and changes from a temperature of  $20.0^\circ\text{C}$  to  $27.4^\circ\text{C}$ . How much heat energy did it gain?**

- A** 200 J
- B** 460 J
- C** 540 J
- D** 740 J

The correct answer is choice **A**. Using the value for the specific heat capacity of copper above,

$$Q = (0.0693 \text{ kg}) \left( 390 \frac{\text{J}}{\text{kg} \cdot ^\circ\text{C}} \right) (27.4 - 20.0)^\circ\text{C} = 200 \text{ J.}$$

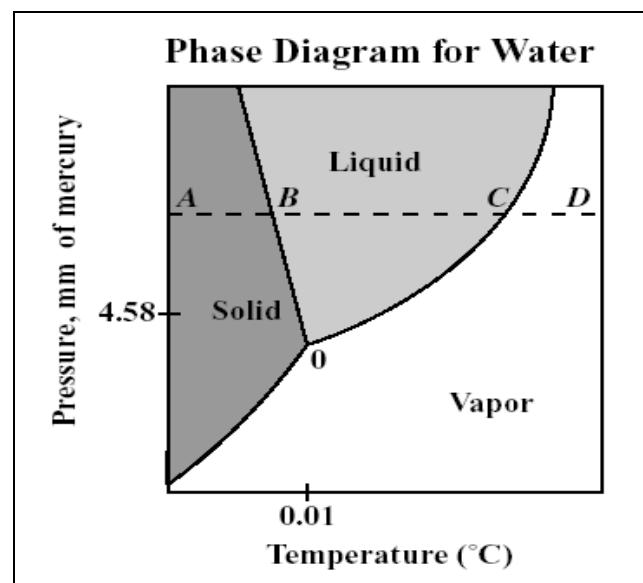
Choice **B** is incorrect because the specific heat capacity of aluminum was used instead of the specific heat capacity of copper. Choice **C** is incorrect. The initial temperature of  $20.0^\circ\text{C}$  was used instead of the  $7.4^\circ\text{C}$  change in temperature. Finally, choice **D** is incorrect because the final temperature of  $27.4^\circ\text{C}$  was used instead of the  $7.4^\circ\text{C}$  change in temperature.

A **phase diagram** shows how a pure substance changes from one phase to another based on the temperature,  $T$ , and the pressure,  $P$ . The phase ( $P$ - $T$ ) diagram for water, on the next page, shows how water changes phases. At point  $O$  on the diagram,  $T = 0.01^\circ\text{C}$  and  $P = 4.58 \text{ mm of mercury}$  which is 0.6% of one atmosphere of pressure. One atmosphere of pressure is equal to 760 mm of mercury. This amount of pressure on Earth is found at

sea level at a temperature of 0°C. At this point, all three phases of water exist in equilibrium. Above point *O*, pathway *AD* has been marked on the diagram. Let's see what happens to water as we trace along that pathway. At point *A*, water exists as a solid. As the temperature increases at constant pressure, we reach point *B* on the diagram. At that point, solid ice melts and the temperature remains constant until all ice has melted.

From point *B* to point *C*, water exists as a liquid and the temperature increases. At point *C*, water boils turning into a vapor (or gas). The

temperature remains constant again during this phase change. After vaporization is complete, the temperature of the resulting vapor increases until we reach point *D*. There are no other phase changes after this point. Notice if another pathway is marked out at a constant pressure less than 4.58 mm of mercury (below point *O*), water will experience only one phase change, solid to vapor.



### Spotlight on the Standards

#### ★Determine relationships among force, mass, and motion★

Simply stated, a **force** is an action that can change the motion of an object. A push or pull is an example of a force. The unit for force is the newton (N). All the forces acting on an object can be combined to determine the net force acting on the object. If all the forces acting on the object are balanced, the net force is zero and the motion of the object does not change. If an object is already at rest, it will remain at rest. If an object is moving, it will keep on moving. **Balanced forces** do not change the motion of an object, but if the combination of forces acting on an object are not balanced, then the net force is greater than zero and the motion of the object changes. **Unbalanced forces** change the motion of an object.

The distance an object moves per unit of time is known as the **speed**. The **velocity** is the speed of the object plus its direction. The average speed can be found by dividing the change in the displacement of an object by the change in time.

$$v_{\text{ave}} = \frac{d_{\text{final}} - d_{\text{initial}}}{t_{\text{final}} - t_{\text{initial}}}$$

**Acceleration**, like velocity, has magnitude and direction. The average acceleration of an object is found by dividing the change in the velocity of the object by the change in time.

$$a_{\text{ave}} = \frac{v_{\text{final}} - v_{\text{initial}}}{t_{\text{final}} - t_{\text{initial}}}$$

Sir Isaac Newton was the first scientist to describe the relationships among force, mass, and motion clearly. The three laws of motion are named after him.

- **Newton's first law** of motion states that an object *at rest* will stay at rest unless it is acted upon by an unbalanced force. An object *in motion* will continue to move in the same direction and with the same speed unless acted upon by an unbalanced force. An object's tendency to resist a change in motion is called **inertia**. Inertia is directly related to an object's mass. An object with a large mass has a large amount of inertia, while an object with a small mass has a small amount of inertia. Large forces are required to change the motion of objects with large masses, while small forces can change the motion of objects with low masses.
- **Newton's second law** of motion states that the acceleration,  $a$ , of an object is directly related to the net force,  $F$ , applied to the object and inversely related to the mass,  $m$ , of the object. The following equation represents Newton's second law of motion.

$$a = \frac{F}{m} \text{ or } F = ma$$

According to the equation, the greater the net force acting on an object, the greater the acceleration of the object. Also, the greater the mass of the object, the lower the acceleration of the object. For example, a large truck has a much lower acceleration than a compact car given the same applied force by each engine. The larger mass (or inertia) of the truck resists acceleration.

- **Newton's third law** of motion states that forces occur as equal and opposite pairs. For every action force there is an equal and opposite reaction force. For example, when a book is sitting on a table, the weight of the book produces a downward action force on the table. The tabletop in turn pushes on the book with an upward reaction force. These forces are equal in magnitude but opposite in direction.

**Gravitational force** is a force between any two objects. The strength of the force is related to the mass of the objects and the distance between them. The more mass an object has, the greater the gravitational force it exerts. The Moon has less mass than Earth. The resulting lower gravitational force made the astronauts appear nearly “weightless” as they moved across the lunar surface. One should note that mass and **weight** are not the same quantity. An

### Types of Forces

- Gravitational
- Electromagnetic
- Nuclear (Atomic)
- Frictional

object has mass regardless of whether gravity or any other force is acting upon it. Weight, on the other hand, changes depending on the influence of gravity. The relationship between weight,  $W$ , and mass,  $m$ , can be written as the following equation:

$$W = mg$$

In this equation,  $g$  represents the acceleration due to gravity. At the surface of Earth, the acceleration of gravity is  $9.80 \text{ m / s}^2$ . The value of  $g$  decreases the farther away from the center of Earth an object gets. This means the weight of an object would decrease if it was placed on top of a mountain or put into space. Numerically, as the distance between two objects increases, the force of gravity decreases by a factor equal to the square of the distance. For example, if the distance between two objects is doubled, the force of gravity will decrease by a factor of four.

Other forces include **electromagnetic forces**. These forces include both electric forces and magnetic forces. The forces exerted within the nucleus of an atom are called **nuclear forces**. These forces hold the protons and neutrons together. **Frictional forces** tend to stop the motion of an object by dispersing its energy as heat. There are three types of frictional forces: sliding friction, rolling friction, and static friction. **Sliding friction** occurs when one solid surface slides over another solid surface. **Rolling friction** occurs when an object rolls across a solid surface. **Static friction** occurs between the surfaces of two objects that touch but do not move against each other. Static friction must be overcome for one of the objects to move. A question for this standard might look like this:

A block is placed on a horizontal table. The block is then pulled to the right with a string. The block remains at rest. A spring scale, attached to the string, reads 7.5 N. Which force acting on the block is equal to 7.5 N?

- A gravitational force exerted on block
- B force to the left exerted by air
- C upward force exerted by table
- D force exerted by static friction

The correct answer is choice **D**. Static friction occurs between the surfaces of two objects that are in contact but not moving. Since the block is at rest, static friction is equal to 7.5 N, and choice **D** is the correct answer. The forces in choices **A** and **C** do not resist a force to the right so these answers are incorrect. Choice **B** is incorrect because the object is not moving. No drag or force is exerted by the air.

**STRATEGY BOX—Picture Perfect**

Remember to look carefully at diagrams, illustrations, and other graphics. Information might be provided to help you answer questions on the EOCT.

If a visual aid is not provided, you might want to make a diagram to summarize important information that might help you answer a question.

The idea of work is familiar to most people. For example, it takes more work to move heavier objects like a car at rest than a much lighter bicycle. **Work** is the transfer of energy when an applied force moves an object over a distance. For work to be done the force applied must be in the same direction as the movement of the object and the object must move a certain distance. A person may push on a wall and get tired muscles as a result, but unless the wall moves, the person has done zero work. Work can be summarized using the following equation:

$$W = Fd$$

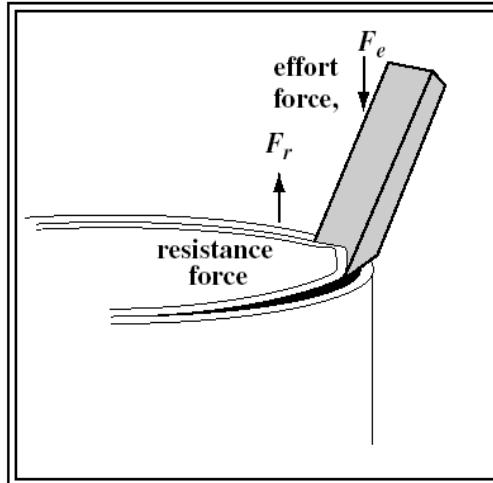
In the equation,  $W$  is equal to work,  $F$  is equal to the force applied, and  $d$  is equal to the distance that an object has moved. Remember, force is measured in newtons (N) and distance is measured in meters (m). A unit of work is the newton-meter (N·m), or the joule (J).

Work can be made easier or done faster by using machines. Machines that work with one movement are called **simple machines**. There are six types of simple machines. These are listed in the box to the right.

**Simple Machines**

- Inclined Plane
- Lever
- Pulley
- Screw
- Wedge
- Wheel and Axle

Simple machines cannot increase the amount of work done, but they can change the size and direction of the force applied. The force applied to a simple machine is called the **effort force**,  $F_e$ . For a machine to do work, an effort force must be applied over a distance. The force exerted by the machine is called the **resistance force**,  $F_r$ . For example, consider how a painter uses a screwdriver as a lever to pry open the lid on a can of paint. An illustration showing the bottom end of the screwdriver and the top of a paint can is shown on the right. When the painter pushes down on the screwdriver, an effort force is applied over a distance, known as the **effort distance**,  $d_e$ . As a result, the tip of the



screwdriver exerts a resistance force against the lid of the paint can. This force moves the lid of the can over the **resistance distance**,  $d_r$ .

The number of times a machine multiplies the effort force is called the **mechanical advantage**. The mechanical advantage is determined using the following equations:

$$MA = \frac{F_r}{F_e} \text{ or } MA = \frac{d_e}{d_r}$$

For example, if 15 N of force is applied to the handle of the screwdriver to lift a resistance of 150 N, the mechanical advantage of the screwdriver is 10. The tip of the screwdriver has multiplied the effort force 10 times. Refer to your textbook to see how the mechanical advantage of other simple machines can be calculated.

## Sample Questions for Content Domain III

This section has some sample questions for you to try. After you have answered all of the questions, check your answers in the “Answers to the Content Domain III Sample Questions” section that follows. That section will give you the correct answer to each question and will explain why the other answer choices are incorrect.

- 1 Which energy transformation takes place when a match is struck against the side of a matchbox and bursts into flames?**

- A electrical energy → light energy
- B heat energy → kinetic energy
- C chemical energy → heat energy
- D potential energy → electrical energy

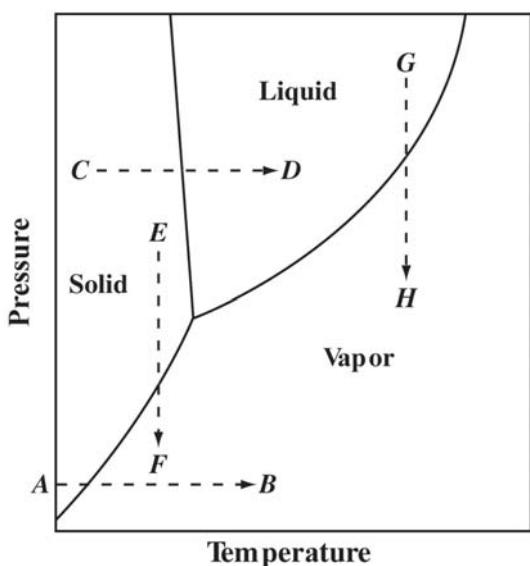
- 2 Conduction can BEST be described as the transfer of heat energy by**

- A waves traveling through empty space
- B fluids traveling through other fluids
- C gases expanding within a fluid medium
- D atoms colliding with their neighbors

- 3 A 0.0150 kg cylinder of zinc cooled from 100.0°C to 20.0°C. The metal lost 466 J of heat energy. What is the specific heat capacity of the zinc?**

- A  $311 \frac{\text{J}}{\text{kg} \cdot ^\circ\text{C}}$
- B  $388 \frac{\text{J}}{\text{kg} \cdot ^\circ\text{C}}$
- C  $559 \frac{\text{J}}{\text{kg} \cdot ^\circ\text{C}}$
- D  $1550 \frac{\text{J}}{\text{kg} \cdot ^\circ\text{C}}$

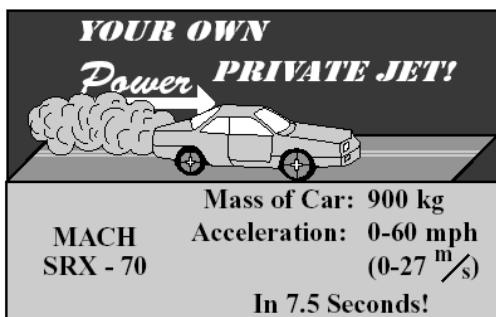
- 4** Use the following phase diagram for water to answer the question.



Some ice crystals are released from the space shuttle into the near vacuum of space. Solar radiation causes a phase change. Which path indicated in the diagram BEST illustrates what happens to the ice crystals?

- A AB
- B CD
- C EF
- D GH

- 5** The following advertisement shows some data about a new car.



What is the magnitude of the average acceleration of the car?

- A  $1.2 \text{ m/s}^2$
- B  $2.0 \text{ m/s}^2$
- C  $3.6 \text{ m/s}^2$
- D  $8.0 \text{ m/s}^2$

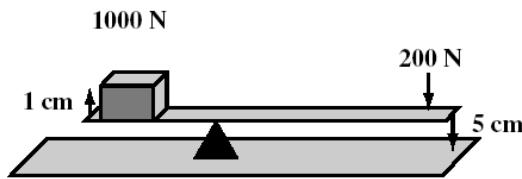
- 6** On the Moon, gravity causes a rock hammer to fall more slowly to the ground than on Earth. Which lunar factor causes the slower rate of fall?

- A smaller radius
- B slower rotation
- C lower density
- D lesser mass

**7 A stone is carried up Mount Everest, elevation 8850 meters. The weight of the stone decreases while the mass of the stone remains constant. The BEST explanation for this difference is that the mass is unaffected by outside forces, while the weight is influenced by the**

- A weaker gravitational force
- B lower density of air
- C weaker magnetic field
- D lower air temperature

**8 A lever is used to lift a box, as shown in the diagram below.**



**What is the mechanical advantage of the lever?**

- A 4
- B 5
- C 10
- D 25

## Answers to the Content Domain III Sample Questions

**1. Answer: C Relate transformations and flow of energy within a system.** *Identify energy transformations within a system.*

When the match is struck, the chemical energy of the phosphorus in the match head and the oxygen in the atmosphere is converted to heat energy, so choice **C** is correct. Choice **A** is incorrect because the match did not have electrical energy. Choice **B** is incorrect because the match did not initially have heat energy. It had to be struck against the side of the box. Choice **D** is incorrect. Though the match may be said to have had potential (chemical) energy, it was not converted to electrical energy. Heat energy is not electrical energy.

**2. Answer: D Relate transformations and flow of energy within a system.**

*Investigate molecular motion as it relates to thermal energy changes in terms of conduction, convection, and radiation.*

Conduction is the transfer of energy by more energetic atoms colliding with not-so-energetic neighboring atoms, so choice **D** is the correct answer. Radiation is the transfer of energy by waves traveling through space, while convection is the transfer of energy by the movement of large masses of liquids and gases (fluids). That makes choices **A** and **B** incorrect. Conduction is not the transfer of energy by the expansion of gases, so choice **C** is incorrect.

**3. Answer: B Relate transformations and flow of energy within a system.**

*Determine the heat capacity of a substance using mass, specific heat, and temperature.*

The specific heat capacity is found using the formula  $c_p = \frac{Q}{m\Delta T}$ . Using specific values in the formula results in the solution  $c_p = \frac{466 \text{ J}}{(0.0150 \text{ kg})(100.0 - 20.0)^\circ\text{C}} = 388 \frac{\text{J}}{\text{kg} \cdot {}^\circ\text{C}}$ .

Thus, choice **B** is the correct answer. Choice **A** is incorrect because the final temperature of  $100.0^\circ\text{C}$  was used instead of  $\Delta T = 80.0^\circ\text{C}$ . Choice **C** is wrong because the incorrect formula,  $c_p = Qm\Delta T$ , was used. Choice **D** is incorrect because the initial temperature of  $20.0^\circ\text{C}$  was used instead of  $\Delta T = 80.0^\circ\text{C}$ .

**4. Answer: A Relate transformations and flow of energy within a system.** *Explain the flow of energy in phase changes through the use of a phase diagram.*

In space, the pressure is essentially zero and constant. The path in the phase diagram must be at such a low pressure that an increase in temperature from incoming solar radiation will cause a phase change from solid to vapor. This means choice **A** is correct. Choice **B** is incorrect because the pressure is too high. This path would occur at normal atmospheric pressure. Choices **C** and **D** are incorrect. The temperature does not remain constant while the pressure changes in the near vacuum of space.

**5. Answer: C** Determine relationships among force, mass, and motion. Calculate velocity and acceleration.

The average acceleration is the change in the velocity (or speed) divided by the change in time:  $\frac{V_f - V_i}{t_f - t_i} = \frac{27 \text{ m/s} - 0 \text{ m/s}}{7.5 \text{ s} - 0.0 \text{ s}} = \frac{27 \text{ m/s}}{7.5 \text{ s}} = 3.6 \text{ m/s}^2$ . Thus, choice **C** is correct.

Choices **A**, **B**, and **D** are incorrect because the wrong numbers were plugged into the formula or the formula itself was incorrect.

**6. Answer: D** Determine relationships among force, mass, and motion. Relate falling objects to gravitational force.

The mass of the Moon is much less than that of Earth. Since the mass of the attracting object (the Moon) is less, the gravitational attraction on the rock hammer is less. This means the rock hammer will fall at a slower rate, so choice **D** is correct. Gravitational attraction is not dependent on an object's relative size or density, but total mass, so choices **A** and **C** are incorrect. Though the rate of rotation can reduce the downward force on an object, the Moon's rate of rotation is less than that of Earth, so any resistance to downward gravitational force would be less, not more. Thus, choice **B** is incorrect as well.

**7. Answer: A** Determine relationships among force, mass, and motion. Explain the difference in mass and weight.

Mass is a fundamental property of matter. It is a measure of the quantity of matter contained with an object. Weight is the gravitational force exerted on an object, so choice **A** is correct. The lower density of air would actually provide less buoyancy for the stone, so the weight would actually appear to increase; thus, choice **B** is incorrect. Weaker magnetic fields and lower air temperatures would have no effect on the weight of the stone, so choices **C** and **D** are incorrect.

**8. Answer: B** Students will determine relationships among force, mass, and motion. Calculate amounts of work and mechanical advantage using simple machines.

The mechanical advantage of a lever can be determined by using the following equation:

$$MA = \frac{F_r}{F_e} \text{ or } MA = \frac{d_e}{d_r}$$

From the diagram, we know that the effort distance is 5 cm and the resistance distance is 1 cm; the effort force is 200 N and the resistance force is 1000 N. Substituting the known values into either equation, given above, the answer would be determined as

$MA = \frac{1000 \text{ N}}{200 \text{ N}}$  or  $MA = \frac{5 \text{ cm}}{1 \text{ cm}}$ . The mechanical advantage,  $MA$ , is 5. So choice **B** is the correct answer, and choices **A**, **C**, and **D** are incorrect.

## Content Domain IV: Waves, Electricity, and Magnetism

### A LOOK AT CONTENT DOMAIN IV



Test questions in this content domain will measure your ability to investigate the energy, characteristics, and phenomena of waves. You will also investigate static electricity, alternating and direct current electricity, and applications of electromagnetism. Your answers to the questions will help reveal how well you can perform on the following standards:

- Investigate the properties of waves
- Investigate the properties of electricity and magnetism



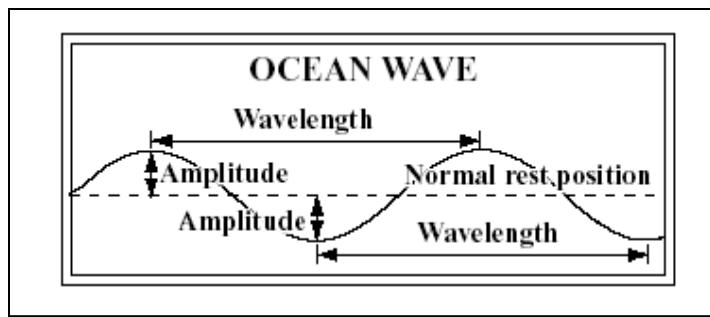
### Spotlight on the Standards

#### ★*Investigate the properties of waves*★

**Waves** are phenomena that occur, seen and unseen, all around us. Suppose that a student drops a stone in a pond. The surface of the water becomes disturbed. Some of the kinetic energy of the stone, as it falls in the water, is transferred to surrounding water molecules. This causes the surface of the water to be disturbed as water molecules move up and down while transferring energy through the water. This energy transfer can be seen moving in all directions through waves moving outward in concentric circles. Particles of matter do not move along with the waves. Only the energy that creates the waves moves with them. Waves by definition are disturbances that repeat the same cycle of motion and transfer energy through matter or empty space.

**Mechanical waves** (such as the water waves) and **electromagnetic waves** (such as light and radio waves) share some basic properties.

- **Amplitude** is the distance from the equilibrium point, or normal rest position, to a crest or trough.
- The **wavelength** is the distance between two consecutive crests or troughs of a wave. The symbol lambda ( $\lambda$ ) is used to represent wavelength. The diagram above shows these properties.
- **Frequency** is the number of complete waves, or cycles of oscillation, in a given period of time. The symbol  $f$  is used to represent frequency. The unit for frequency is hertz (Hz), which is equal to one wave, or cycle, per second. The time it takes to complete one full cycle is called the **period**, which is measured in seconds.
- **Speed** measures how fast a wave is moving. The speed of a mechanical wave depends on the type of medium (substance in which the wave moves), but the speed is constant for any given medium. In electromagnetic waves, the speed is directly proportional to the frequency and wavelength of the wave according to the relationship  $v = f \lambda$ .
- The **energy** transmitted by a mechanical wave is directly proportional to the square of the amplitude of the wave. For electromagnetic waves, the energy is carried by photons (tiny packets of energy). These photons also act like waves. The energy of photons is directly proportional to the frequency of the wave or is inversely proportional to the wavelength of the wave emitted. In other words, if the frequency of a wave is doubled (or the wavelength decreased by one-half), the energy of the wave is doubled, resulting in a different electromagnetic wave.



Mechanical waves (such as sound waves) are similar to electromagnetic waves (such as light waves) in that both types of waves transmit energy over a distance. However, there are some major differences.

- Sound waves require a medium for propagation. Light waves may travel either through a transparent medium or through empty space.
- Sound travels through all substances, but light is absorbed by opaque materials.
- A sound wave travels slowly through air at a speed of about 340 meters per second at 15°C. Electromagnetic waves, on the other hand, travel through air or the vacuum of space at extremely high speeds of about 300,000 kilometers per second.

Sound waves travel by vibrating from particle to particle. Because of this, the nature of a medium has a significant effect on the speed of sound. Sound travels faster through solids and liquids than it does through gases because particles are closer together in solids or liquids than in gases. Sound also travels fastest through elastic materials. For example, sound travels at about 1500 meters per second in water, but in aluminum, which is more elastic, the speed of sound is at about 5000 meters per second. In materials of the same

phase, or state of matter, the speed of sound tends to decrease as the density increases. The molecules of a denser substance have greater inertia and do not move as quickly as molecules of a less dense substance. The table on the right shows the speed of sound in various substances.

Because waves involve the transfer of energy, the properties of a wave will change when a wave encounters another wave or an object. Waves undergo four basic interactions. **Reflection** occurs when a wave hits an object that it cannot pass through or when it reaches the boundary of the medium of transmission. Both situations involve the return of the wave as it bounces off the object or medium boundary. **Refraction** takes place when a wave passes from one medium into another at an angle and bends (changes direction) due to a change in speed. **Diffraction** results when a wave passes through a hole or moves past a barrier and spreads out in the region beyond the hole or barrier. Finally, **interference** occurs when two or more waves arrive at the same point at the same time. As a result, they combine to produce a single wave. This new wave will have different properties from the two waves that composed it.

On the test, you may be asked to identify and explain wave properties and interactions. A question might look like this:

Speed of Sound (at 25°C)		
Substance	State	Speed (m/s)
Air	Gas	346
Helium	Gas	965
Ethanol	Liquid	1497
Water	Liquid	1162
Steel	Solid	5960
Lead	Solid	1960

**Plastic lenses bend light waves making it possible for a near-sighted person to focus light onto the retina. The interaction of the light waves with the plastic lenses is known as**

- A diffraction
- B interference
- C reflection
- D refraction

Refraction is the bending of light waves when waves pass from one medium to another, so choice **D** is the correct answer. Diffraction, interference, and reflection do not involve bending light at a medium boundary, so choices **A**, **B**, and **C** are incorrect.

When a sound source moves toward a listener, the pitch, or apparent frequency, of the sound increases. This is because the sound waves are compressed closer together and reach the listener with a higher pitch. As the sound source passes by the listener and moves away from the listener, the same sound waves are stretched farther apart. This results in a decrease in the pitch, or apparent frequency. This phenomenon is known as the **Doppler Effect**. It can be heard at a train crossing every time a train approaches, passes, and leaves a crossing while blowing its whistle.



## Spotlight on the Standards

### ★Investigate the properties of electricity and magnetism★

The word **electricity** sounds very much like *electron*. The similarity between the words is no accident. Recall that electrons are negatively charged particles, while protons are positively charged particles. When like charges come near each other, the charges repel each other. When opposite charges come near each other, the charges attract each other. **Static electricity** results from the buildup of electric charges on an object. The buildup of charges can be caused by friction, conduction, or induction.

- Rubbing two objects together can cause the electric charges on the objects to separate. The charging that results is due to **friction**. In this process, only electrons can be transferred from one object to another object. One object will become negatively charged as it gains electrons, while the other object will become positively charged as it loses electrons.
- In **conduction**, electrons flow through one object into another by direct contact. Silver, copper, aluminum, and magnesium are examples of good conductors. These materials allow electrons to flow freely.
- **Induction** involves electrons being rearranged. No contact need occur between two objects for induction to take place. A neutral object only needs to approach a charged object. For example, a negatively charged rubber rod picks up tiny slips of paper by induction. The electrons on the parts of the paper nearest the rod are pushed away, leaving positive charges. Because the positive charges are closer to the negatively charged rod, the slips of paper are attracted to the rod.

Electric charges leave a charged object during an **electric discharge**. Lightning is probably the most dramatic example of an electric discharge. The repulsion and attraction of particles can be described in terms of **electric fields**, the area in which the electric force is noticeable. The strength of the electric field depends on the distance from the charged particle.

A question on the test may ask you to distinguish electric charges and forces in static electricity situations. It might look something like this:

**What particle do objects MOST likely lose or gain to become electrically charged?**

- A atoms
- B electrons
- C neutrons
- D protons

When an object becomes electrically charged, only electrons are transferred, so choice **B** is the correct answer.

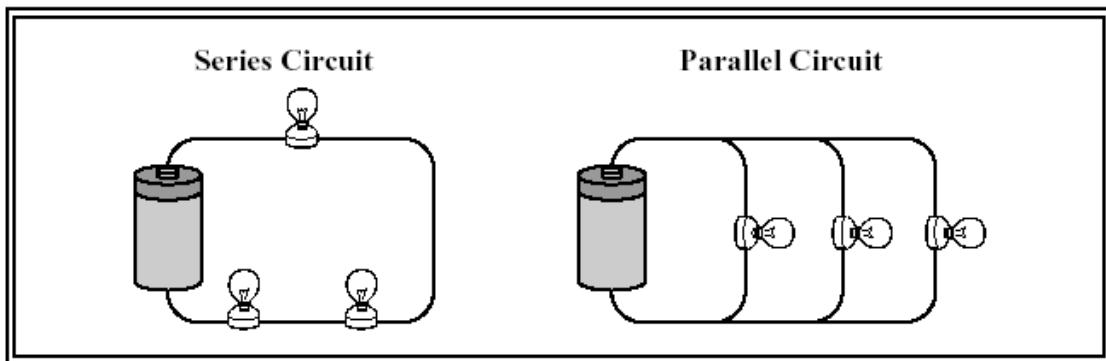
**Electric current** results from the movement of electric charges. A **circuit** is a complete, closed path for electron flow. A simple circuit consists of a source of electrons, such as a battery, a resistance or load, conducting wires, and a switch. In a battery, electrical energy is produced by a chemical reaction. When charged particles flow through the wire in a circuit, an **electric current** ( $I$ ) results. The current is measured in amperes ( $A$ ). The electron is the charged particle that most likely moves through the circuit. To get electrons flowing through a circuit, a voltage ( $V$ ) is applied. **Voltage**, which is measured in volts ( $V$ ), is the potential difference in electrical potential energy between two places in a circuit. In other words, voltage is the energy per unit of charge that causes charges to move. The opposition to current is called **resistance** ( $R$ ), which is measured in ohms ( $\Omega$ ). Light bulbs and resistors are examples of objects with a resistance. Materials, like copper, that are good conductors of electricity, have low resistance. The resistance of wires that are good conductors depends on the wire's thickness, length, and temperature. Insulators keep electrons from flowing easily. Although electrons move one way through a wire, the current, by convention, is the relative movement of a positive charge. Electrons flow opposite the direction of the current.

Charges can move through a circuit continuously in the same direction, producing a **direct current** or **DC**. Electrons can also change direction moving back and forth in cycles. This kind of current is known as **alternating current** or **AC**. Batteries, such as those found in cars, produce DC, while a gasoline-driven generator usually produces AC.

**Ohm's law** relates electric current, voltage, and resistance and can be summarized in the following equation:

$$V = IR$$

When the electric charges in a circuit have only one path in which to flow, the circuit is called a **series circuit**. If the circuit has different branches in which the electric charges can flow, the circuit is called a **parallel circuit**. Parallel circuits are used in houses. The following box shows examples of these circuits. Refer to your textbook to determine how to apply Ohm's law to different circuits.



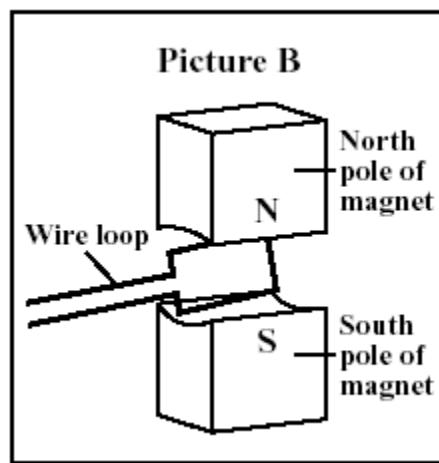
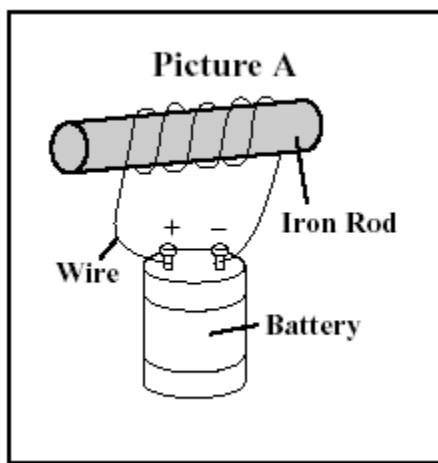
An electric current will also produce a magnetic field. A **magnetic field** is a region around a magnet or current-carrying wire where magnetic forces can be measured. **Magnetism** is the force of attraction or repulsion that is produced by an arrangement of electrons. Magnets have two poles: a north pole and a south pole. *Unlike* magnetic poles attract each other, while *like* magnetic poles repel each other. Groups of atoms with magnetic poles aligned are called **magnetic domains**. Materials with most of these domains lined up are considered magnetized. When a metal bar or other object is composed of stable, magnetic domains, a **permanent magnet** results.

When an electric current is used to produce a magnetic field in a coil of wire, the coil becomes an electromagnet. A rotating electromagnet is used in **electric motors** to convert electrical energy to mechanical energy.

When a magnet is moved near a wire, an electric current is generated. This process, called **electromagnetic induction**, is used to operate a **generator**. A generator is a device that converts mechanical energy to electrical energy. In a commercial generator, an electric current is produced when a large coil of wire is rotated in a strong magnetic field.

For this standard on the test, you may be asked to compare methods of generating an electric current or to identify examples of electric and magnetic interactions. A question might look something like this.

Use the diagram to answer the question.



Which of the following statements correctly identifies both devices illustrated in the pictures?

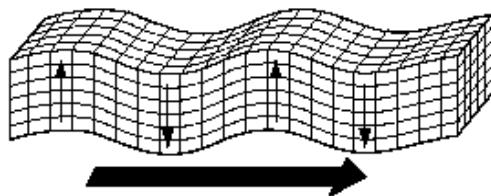
- A Picture A shows an electric generator, while Picture B shows an electromagnet.
- B Picture A shows an electromagnet, while Picture B shows an electric motor.
- C Picture A shows an electric motor, while Picture B shows an electromagnet.
- D Picture A shows an electric generator, while Picture B shows an electric motor.

Picture A shows an iron rod surrounded by a coil of wire through which an electric current is passed. An electromagnet has been constructed. Picture B could show an electric generator if mechanical energy rotated the coil or an electric motor if a current was forced through the coil of wire. Choice **B** is the only answer that could be correct, and choices **A**, **C**, and **D** are incorrect answers. An electric generator uses electromagnetic induction to change mechanical energy to electrical energy (electricity), while an electric motor uses electromagnetism to change electrical energy to mechanical energy to do work.

## Sample Questions for Content Domain IV

This section has some sample questions for you to try. After you have answered all the questions, check your answers in the “Answers to the Content Domain IV Sample Questions” section that follows. That section will give you the correct answer to each question and will explain why the other answer choices are incorrect.

- 1** The following diagram shows a type of earthquake wave called an s-wave.



Besides the wave, what else is moving to the right?

- A rocks in the wave
- B the wavelength
- C energy of the wave
- D electromagnetic waves

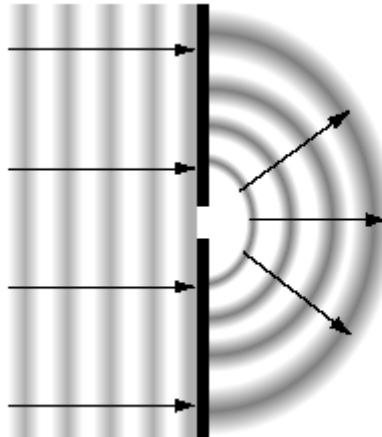
- 2** A system of filters gradually turns a beam of orange light ( $f = 5.0 \times 10^{14}$  Hz) into green light ( $f = 6.0 \times 10^{14}$  Hz). Which of the following experiences an increase during the color change?

- A wavelength of the wave
- B speed of the wave
- C average number of photons
- D average energy of the photons

- 3** Sound waves and ultraviolet light waves both share the property of being able to

- A move through space
- B travel at  $300,000 \frac{\text{m}}{\text{s}}$
- C carry energy
- D propagate through rock

- 4** The following diagram shows what happens to some water waves.



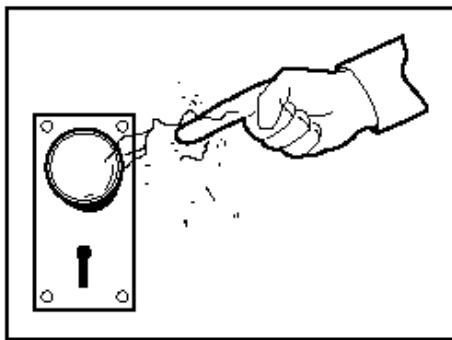
What process are the waves undergoing?

- A refraction
- B diffraction
- C reflection
- D interference

- 5 A truck is blowing its horn as it approaches a bystander at an intersection. According to the Doppler Effect, the bystander will notice that the sound**

- A decreases in frequency
- B increases in wavelength
- C increases in pitch
- D decreases in speed

- 6 Use the diagram to answer the question.**



**A person received an electrical shock when reaching for the metal doorknob. The shock was caused by the**

- A high number of electrons on the doorknob
- B discharge of an imbalance of electrons
- C highly conductive surface of the doorknob
- D low resistance of the person's skin

- 7 What is the resistance of an electrical device that allows a current of 10 amperes with 120 volts?**

- A  $12\Omega$
- B  $110\Omega$
- C  $130\Omega$
- D  $1200\Omega$

- 8 When a loop of wire is turned at a right angle to Earth's magnetic field, the wire and magnetic field will create a weak**

- A electric transformer
- B electromagnet
- C electric motor
- D electric generator

## Answers to the Content Domain IV Sample Questions

- 1. Answer: C** **Investigate the properties of waves.** *Recognize that all waves transfer energy.*

An earthquake is an example of a mechanical wave. All waves carry energy in the same direction as the wave disturbance, so choice **C** is correct. Choice **A** is incorrect because the rocks (or particles of the medium) do not move in the direction of the wave. They just cycle up and down. Choice **B** is incorrect because the wavelength of a wave is the distance between two crests of a wave. It does not change or move. Mechanical waves do not produce electromagnetic waves, so choice **D** is incorrect.

- 2. Answer: D** **Investigate the properties of waves.** *Relate frequency and wavelength to the energy of different types of electromagnetic waves and mechanical waves.*

When the frequency of an electromagnetic wave increases, so does the energy. The energy of the photons is directly proportional to the frequency of the wave. Therefore, choice **D** is the correct response. Choice **A** is incorrect because the wavelength of a wave is inversely proportional to the frequency. Choice **B** is incorrect because the speed of light waves is constant. The frequency of a wave is not related to the number of photons, so choice **C** is also incorrect.

- 3. Answer: C** **Investigate the properties of waves.** *Compare and contrast the characteristics of electromagnetic and mechanical (sound) waves.*

All waves have the ability to carry energy along with them, so choice **C** is correct. Choice **A** is incorrect because only electromagnetic waves can travel through the vacuum of space. Sound waves do not travel at such high speeds as 300,000 km/s. That is the speed of light, so choice **B** is incorrect. Ultraviolet light does not propagate through rock, while sound waves do, making choice **D** incorrect.

- 4. Answer: B** **Investigate the properties of waves.** *Investigate the phenomena of reflection, refraction, interference, and diffraction.*

Diffraction results when a wave passes through a hole and spreads out in the region beyond the hole, so choice **B** is correct. Refraction involves bending of light waves, so choice **A** is incorrect. The waves do not undergo reflection as they do not bounce off a surface, so choice **C** is incorrect. Finally, choice **D** is wrong because the waves are not being superimposed.

- 5. Answer: C** **Investigate the properties of waves.** *Explain the Doppler Effect in terms of everyday interactions.*

As the sound source approaches the bystander, the sound waves bunch up, increasing the pitch, or perceived frequency, of the sound, so choice **C** is correct. Choices **A** and **B** are incorrect because the actual frequency, or wavelength, of the sound waves does not change. The speed of sound in air is constant and does not change, so choice **D** is incorrect as well.

**6. Answer: B** **Investigate the properties of electricity and magnetism.** *Investigate static electricity in terms of friction, induction, and conduction.*

The person received a shock when reaching for the doorknob because electrons moved between the person's hand and the doorknob. This resulted in a static discharge and a loss of static electricity. Static electricity is a buildup of electric charge in one place, creating an imbalance of electrons. Choice **B** is the correct answer. There is not an extra high number of electrons on the doorknob, the conducting surface of the doorknob does not create the shock, and the person's skin having a low resistance does not cause an electrical discharge, so choices **A**, **C**, and **D** are incorrect.

**7. Answer: A** **Investigate the properties of electricity and magnetism.** *Explain the flow of electrons in terms of alternating and direct current, the relationship among voltage, resistance, and current, and simple series and parallel circuits.*

To determine the resistance of the device, the equation  $V = IR$  is used. The equation must be solved for resistance, resulting in the equation  $R = \frac{V}{I}$ . Substituting the values

given in the question results in the solution  $R = \frac{120\text{ V}}{10\text{ A}} = 12\Omega$ . The correct answer is

choice **A**. Choices **B**, **C**, and **D** are incorrect as a result of the equation being used incorrectly.

**8. Answer: D** **Investigate the properties of electricity and magnetism.** *Investigate applications of magnetism and/or its relationship to the movement of electrical charge as it relates to electromagnets, simple motors, and permanent magnets.*

When a loop of wire is turned in a magnetic field, electrical charges move through the wire, creating an electrical current. This is the basis for an electric generator, so choice **D** is correct. An electric transformer does not produce electricity; it increases or decreases the voltage or current, so choice **A** is incorrect. Choice **B** is incorrect because an electromagnet consists of loops of wire, surrounding an iron core, which carry a current from an electrical source. This creates a magnetic field. Finally, choice **C** is incorrect because an electric motor converts electrical energy to mechanical energy through rotation of loops of wire.

## Co-requisite Domain: Characteristics (and Nature) of Science



### A LOOK AT THE CO-REQUISITE DOMAIN

Test questions in this content domain will be integrated within the four physical science domains. These questions will measure content as well as your ability to use scientific processes and solve problems. Along with your knowledge of the four domains of physical science your answers to these questions will help show how well you:

- Identify tools, terms, and processes used in scientific inquiry, including laboratory safety and scientific research.
- Comprehend how scientific knowledge is developed.
- Recognize how scientific information is properly verified and communicated.

This part of the domain will test how well you understand the importance of ethics in science. Scientists should be curious, honest, open, and skeptical in the pursuit of knowledge. You should develop these traits during your own activities in the lab and classroom. In the lab, you might have noticed that different explanations can often be given for the same evidence. The four qualities just mentioned should lead you and others to find the most accurate explanation for the evidence. This requires further understanding of the scientific problem. It will require you to design and perform new experiments. These experiments will either support or weaken the opposing explanations.

Before starting the experiments, you and your classmates should use standard safety practices. These should be carefully followed in the classroom, in the laboratory, and in the field. These practices include the following:

- Always use correct procedures when working with scientific apparatus.
- Always use proper techniques in the laboratory.
- Immediately identify and report safety problems and violations.

### Laboratory Safety

- Conduct and Preparation in the Laboratory
- Eye Safety
- Safety Equipment
- Dress Code and Neatness
- Working with Sharp Instruments
- Working with Chemicals
- Working with Glassware
- First Aid and Handling Emergencies
- Waste Disposal and Cleanup

After you have addressed all safety issues, you are ready to identify and investigate a scientific problem. First, reasonable hypotheses should be suggested for an identified problem. Then procedures should be developed to solve the problem. These procedures, when carried out, will require you and your lab group to gather, organize, and record data. At the end of the experiment, the data points should be graphed so you can compare and analyze your results. Statistics should be summarized as well. Based on this work, you should develop reasonable conclusions based on the data. You will evaluate whether your conclusions are reasonable by reviewing the process and checking your data against all other available information.

You will find that good data collection and organization are vital for success. As a result, you should learn to use tools and instruments for observing and measuring data. As part of this process, you should do the following:

- Develop and use orderly procedures for recording and organizing information.
- Use technology to produce tables and graphs.
- Use technology to develop, test, and revise your experimental or mathematical models.

#### **STRATEGY BOX—Graphs**

When working with graphs, carefully read the title and the label on each axis. Check for any other information that might be included on the graph. When you think you have the answer, double-check the information given in the graph.

On the test, you will need computation and estimation skills to analyze data and create scientific explanations. Sometimes you will notice large differences between your estimates and your calculated answers. Measurement errors may have a noticeable effect on calculations. Good computation and estimation skills are needed to produce reliable results. You should know that accuracy indicates how close your measurements approach the accepted value. Precision is the agreement between two or more measurements. You should be able to express the correct number of significant figures in your calculations. Scientific notation should be used to report very large or very small values. Finally, you should be able to solve problems by substituting values into simple algebraic formulas. You might also use dimensional analysis. An example of a question about proper use of significant digits is shown on the next page.

A lab student used the following mathematical setup to calculate the density of a solid sphere of ice.

$$d = \frac{121 \text{ kg}}{\frac{4}{3}(3.1416)(0.3158 \text{ m})^3}$$

What is the density of the ice, using the proper number of significant figures?

- A 900 kg / m<sup>3</sup>
- B 917 kg / m<sup>3</sup>
- C 917.19 kg / m<sup>3</sup>
- D 917.2 kg / m<sup>3</sup>

The correct number of significant figures is three in accordance with the rules for computing values and measurements. The value with the fewest significant digits (121 kg) dictates how many digits can be used in the answer after the multiplication and division is completed. Choice **B** is the correct answer. The fraction 4 / 3 is an exact number, not a measurement, so the answer should not contain one significant figure, as appears in the fraction; thus, choice **A** is incorrect. The answer should not contain the same number of significant figures as the number with the most digits, as with  $\pi$ , so choice **C** is incorrect. Choice **D** is incorrect because 0.3158 m (with four significant figures) is not the measurement with the least number of significant figures.

One of the goals of scientists is to communicate scientific investigations and information clearly. With this in mind, you should be able to write clear, logical laboratory reports. You should also be able to write clear, understandable critiques of current scientific issues, including possible alternative interpretations of scientific data. When presenting data, you should use it to support scientific arguments and claims during a group discussion.

### Investigating Like a Scientist

- State the Problem: Ask a question.
- Do Background Research: Gather information.
- Form a hypothesis: Suggest an answer.
- Design an Investigation: Perform an experiment to test the answer.
- Collect Data: Record the Results of the experiment; make a data table if necessary.
- Analyze Data: Interpret the results of the experiment.
- Draw Conclusions: Explain your results.
- Ask questions: Identify new questions raised by the Conclusions for further investigation.
- Communicate Results: Share your results.

To understand how science leads to new discoveries, you should be able to analyze how scientific knowledge is developed. In order for science to grow and develop, certain assumptions are required. First, scientists assume that the universe is a vast single system in which basic principles are the same everywhere.

These universal principles are discovered through observation and experimental confirmation. Science is not exact or perfect. From time to time, scientific explanations may change as new data result in changes in the scientific view of how the world works. Most of the time, small changes to previous models lead to shifts in scientific knowledge. Major changes in scientific views typically occur when a new phenomenon is observed. These changes also occur when an individual or research group gives an insightful interpretation of existing data. Hypotheses often cause scientists to develop new experiments. These experiments produce additional data. The results of these experiments are tested and revised. New and old theories may occasionally be rejected. The process of testing and fine-tuning theories never ends as scientists try to gain new insights into old problems.

Finally, you should understand the important characteristics of the process of scientific inquiry. These characteristics include the following:

- The conditions of the experiment should be controlled to obtain valuable data.
- The quality of data, including possible sources of bias in hypotheses, observations, data analyses, and interpretations, should be critically examined and tested.
- Peer review and publication should be employed to increase the reliability of scientific activity and reporting.
- It should be remembered that the merit of a new theory is judged by how well scientific data are explained by the new theory.
- The ultimate goal of science should be to develop an understanding of the natural universe that is free of human bias.
- It should be remembered that scientific disciplines and traditions differ from one another. These differences include what is being studied, the techniques used, and the outcomes being sought.

If you develop a good understanding of all the concepts presented here, you will be successful answering the questions in this co-requisite domain.

## **Appendix A**

### **EOCT Sample Overall Study Plan Sheet**

Here is a sample of what an OVERALL study plan might look like. You can use the Blank Overall Study Plan Sheet in Appendix B or create your own.

**Materials/Resources I May Need When I Study:**  
(You can look back at page 2 for ideas.)

1. *This study guide*
2. *Pens*
3. *Highlighter*
4. *Notebook*
5. *Dictionary*

**Possible Study Locations:**

- First Choice: *The library*
- Second Choice: *My room*
- Third Choice: *My mom's office*

**Overall Study Goals:**

1. *Read and work through the entire study guide*
2. *Answer the sample questions and study the answers*
3. *Practice reading and answering the general questions*

**Number of Weeks I Will Study:** *6 weeks*

**Number of Days a Week I Will Study:** *5 days a week*

**Best Study Times for Me:**

- Weekdays: *7:00 p.m. – 9:00 p.m.*
- Saturday: *9:00 a.m. – 11:00 a.m.*
- Sunday: *2:00 p.m. – 4:00 p.m.*

## **Appendix B**

### **Blank Overall Study Plan Sheet**

**Materials/Resources I May Need When I Study:**  
(You can look back at page 2 for ideas.)

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_
6. \_\_\_\_\_
7. \_\_\_\_\_

**Possible Study Locations:**

- First Choice: \_\_\_\_\_
- Second Choice: \_\_\_\_\_
- Third Choice: \_\_\_\_\_

**Overall Study Goals:**

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_

**Number of Weeks I Will Study:** \_\_\_\_\_

**Number of Days a Week I Will Study:** \_\_\_\_\_

**Best Study Times for Me:**

- Weekdays: \_\_\_\_\_
- Saturday: \_\_\_\_\_
- Sunday: \_\_\_\_\_

## **Appendix C**

### **EOCT Sample Daily Study Plan Sheet**

Here is a sample of what a DAILY study plan might look like. You can use the Blank Daily Study Plan Sheet in Appendix D or create your own.

**Materials I May Need Today:**

1. *Study Guide*
2. *Pen*
3. *Notebook*

**Today's Study Location:** *the desk in my room*

**Study Time Today:** *From 7:00 p.m. to 8:00 p.m. with a short break at 7:30 p.m.*

(Be sure to consider how long you can actively study in one sitting. Can you sit for 20 minutes? 30 minutes? An hour? If you say you will study for three hours, but get restless after 40 minutes, anything beyond 40 minutes may not be productive—you will most likely fidget and daydream your time away. “Doing time” at your desk doesn’t count for real studying.)

**If I Start to Get Tired or Lose Focus Today, I will:** *do some sit-ups*

**Today's Study Goals and Accomplishments:** (Be specific. Include things like number of pages, sections, or standards. The more specific you are, the better able you will be to tell if you reached your goals. Keep it REALISTIC. You will retain more if you study small “chunks” or blocks of material at a time.)

<i>Study Task</i>	<i>Completed</i>	<i>Needs more work</i>	<i>Needs more information</i>
1. <i>Review what I learned last time</i>	X		
2. <i>Study the first standard in Content Domain I</i>	X		
3. <i>Study the second standard in Content Domain I</i>		X	

**What I Learned Today:**

1. *How to balance a synthesis reaction*
2. *What the questions about covalent bonds might look like*
3. *How to tell the difference between nuclear fission and nuclear fusion*

**Today's Reward for Meeting My Study Goals:** *eating some popcorn*

## **Appendix D**

### **Blank Daily Study Plan Sheet**

**Materials I May Need Today:**

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_

**Today's Study Location:** \_\_\_\_\_**Study Time Today:** \_\_\_\_\_

(Be sure to consider how long you can actively study in one sitting. Can you sit for 20 minutes? 30 minutes? An hour? If you say you will study for three hours but get restless after 40 minutes, anything beyond 40 minutes may not be productive—you will most likely fidget and daydream your time away. “Doing time” at your desk doesn’t count for real studying.)

**If I Start to Get Tired or Lose Focus Today, I will:** \_\_\_\_\_

**Today's Study Goals and Accomplishments:** (Be specific. Include things like number of pages, sections, or standards. The more specific you are, the better able you will be to tell if you reached your goals. Keep it REALISTIC. You will retain more if you study small “chunks” or blocks of material at a time.)

<i>Study Task</i>	<i>Completed</i>	<i>Needs More Work</i>	<i>Needs More Information</i>
1.			
2.			
3.			
4.			
5.			

**What I Learned Today:**

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_

**Today's Reward for Meeting My Study Goals:** \_\_\_\_\_