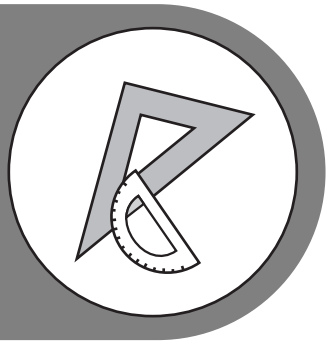
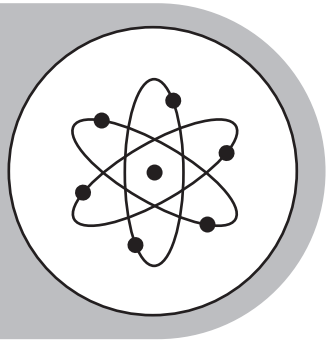
PHYSICAL SCIENCE



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***. This study 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 nine through twelve for the following core high school subjects:

Mathematics

- Algebra I
- Geometry

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 what the ***Physical Science*** **EOCT** specifically 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
- ✓ Highlighter
- ✓ Paper

Resources:
- ✓ Dictionary
- ✓ English textbook
- ✓ 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 each domain and 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 will be given three times a year: once in the spring, once in the summer, and once in the winter.

Administration Time:

Each EOCT is comprised of two sections; each section will take 45 to 60 minutes to complete. You will have 100 to 135 minutes to complete each EOCT. You will be given a 5-minute 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 EOCT contains 40 questions; there are a total of 80 questions on the EOCT.

If you have additional administrative questions regarding the EOCT, please visit the Georgia Department of Education website at 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

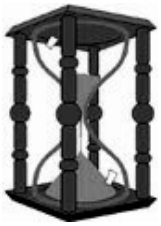
Before you begin preparing for this test, you might want to consider your answers to the following questions. You may write your answers here or on a separate piece of paper.

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. (See Appendices A–D for SAMPLE STUDY PLAN SHEETS that you can use to help you create 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 your 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 do not 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 were you or are you successful?

  Response: _____

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

  Response: _____

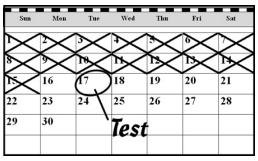
- What changes should you implement to achieve higher scores?

  Response: _____

Before taking the EOCT, work toward removing or minimizing any obstacles that might stand in the way of you performing your best. The test preparation ideas and test-taking strategies in this section are designed to help guide you to 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 standards/skills will be measured on the ***Physical Science*** **EOCT** and then practice understanding and using those standards/ skills. The standards that will be measured in this EOCT are located in the **Georgia Performance Standards** (GPS). The OVERVIEW OF THE EOCT and TEST CONTENT sections of this study guide are 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 the TOP 10 SUGGESTED STRATEGIES TO USE 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 8 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 45 to 60 minutes.

4. **Use positive self-talk.** If you find yourself saying negative things to yourself like, "I can't pass this test," it is important to recognize that you are doing this. Stop and think positive thoughts like, "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 your test score.

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 performance standards. Each performance standard is broken down into more specific standards called elements. 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.

UNDERSTANDING THE STANDARDS

One way to think about **content domains, standards, and elements** 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. The elements would be the types of apples: fuji, gala, red delicious.

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

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 help to direct your study efforts. Your physical science textbook will be your best source of additional information.

Content Domain I: Chemistry—Atomic and Nuclear Theory and the Periodic Table

A LOOK AT CONTENT DOMAIN I

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*★

ENERGY LEVELS

Maximum number of electrons for each energy level:

energy level	# of electrons
1	2
2	8
3	18
4	32

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 only hold 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**. These electrons

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

Which two particles in an atom have opposite charges?

A electron and proton
B neutron and electron
C proton and nucleus
D neutron and proton

The correct answer is **A**. The electron has a single negative charge and the proton has a single positive charge so they have opposite charges. Answer **B** is incorrect. The neutron has a neutral charge while the electron is negatively charged. They do not have opposite charges. Both particles in answer **C** have a net positive charge so this choice is incorrect. The neutron in answer **D** has a neutral charge while the proton is positively charged. Thus, these particles do not have opposite charges.

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 helps to identify the element. For example, an element with an atomic number of 6 (an atom with 6 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. This quantity is calculated very much like your final grade for a course. Let's take an example where three regular tests each count toward 20% of your final grade. The final exam counts as 40%. To find the final grade, you would multiply each of the three test grades by 0.2 and the final exam grade by 0.4. The sum of these products yields your final grade for the course.

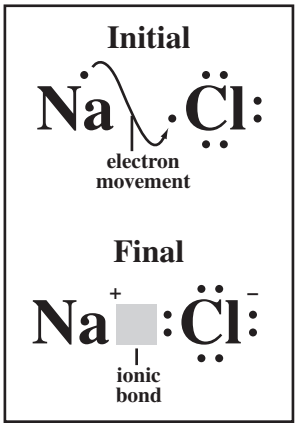
Look it Up!

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

- Element name
- Symbol
- Atomic number
- Atomic mass

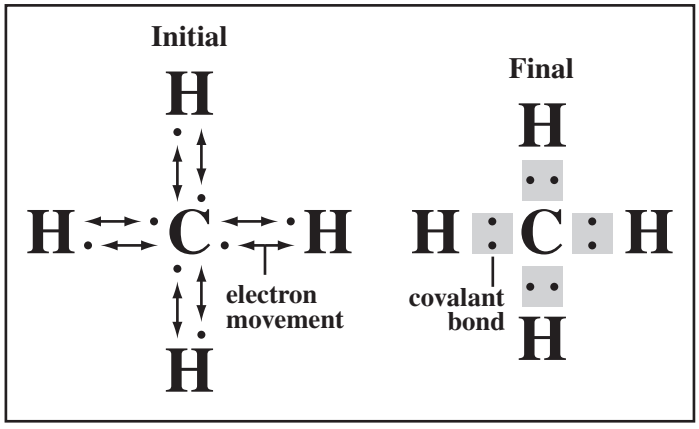
Atoms have the capacity for combining together to form **chemical bonds**. These bonds involve the movement of valence electrons from one atom to another. Some electrons are completely transferred from one atom to another in an **ionic bond**. An ionic bond usually forms between metal and nonmetal atoms. 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 below. Both atoms are most stable when they have 8 electrons in their outermost energy levels. Sodium has one electron in the outermost energy level, while chlorine has 7 electrons. Chlorine accepts one electron from the sodium atom, giving it 8 electrons in the outermost energy level. This leaves sodium with its lower energy level of 8 electrons. This level forms a new, stable valence shell (not shown in the

diagram below). After the electrons have been transferred, the two atoms are now charged, 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) results from the bonding of these two atoms.



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, then the charge is $17 - 18 = {}^{-}1$. The atomic number of sodium is 11. If a sodium atom has only 10 electrons around the nucleus, then 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 8 valence electrons surrounding it. Hydrogen is an exception; it only needs 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 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_4.



STRATEGY BOX–Analyze the Word by Its Parts

When studying physical science, look for familiar prefixes, suffixes, and word roots when faced with an unknown term. 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 retain 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. The protons and neutrons are unable to stick together in the nucleus. Atoms of these elements are radioactive. A radioactive element may give off three types of radiation.

- **Alpha** (α) radiation or particles – These consist of helium (He) nuclei, which are very large. Usually a sheet of paper can stop them.
- **Beta** (β) radiation or particles – These 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** (γ) rays – This radiation is an extremely energetic form of light. It is much more powerful than x-rays. Usually several inches of lead or a few feet of concrete are required to shield people from the damaging effects of this radiation.

Every radioactive element has a distinctive rate of decay. This rate is measured by the **half-life** ($t_{1/2}$). It is the time required for one-half of the atoms to undergo decay to products. 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 **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, **C** is the correct answer. Choices **A**, **B**, and **D** are incorrect.

When some atomic nuclei are bombarded with neutrons, they break into smaller fragments and give off radiation. This process is known as **fission**. Fission provides a significant amount of energy for the United States and other developed nations. On the beneficial side, fuel used for fission provides a huge amount of energy compared to equivalent masses of coal or oil. It also eliminates air pollutants. On the other hand, nuclear waste from fission creates disposal problems. Improper disposal 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, making it an incredibly productive source of energy.

STRATEGY BOX - Fission/Fusion Confusion

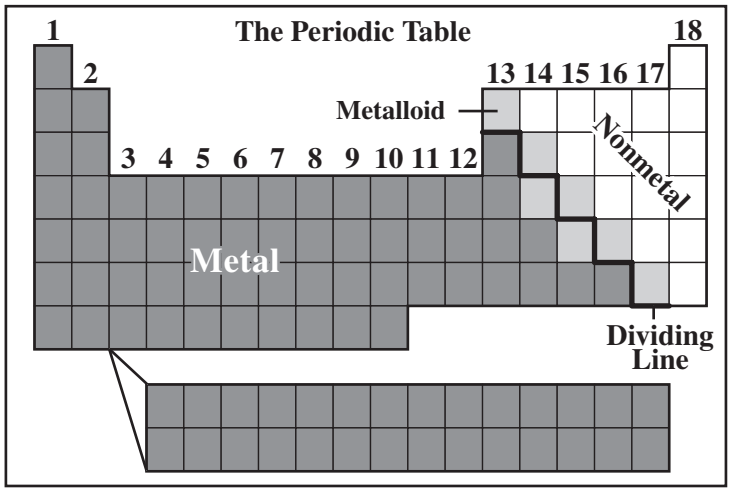
Here is a way to help remember the difference between these two terms. Fission is similar to fissure, the process of splitting. So fission is when the nucleus splits in two. Fusion is like fuse, to unite two things. So fusion is where two nuclei join.

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 in order of increasing atomic number, 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 been discovered yet.

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 electronic semiconductors.

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. They form 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.

STATES OF MATTER

	Shape	Volume
Solids	definite	definite
Liquids	not definite	definite
Gases	not definite	not definite

- In the **solid phase**, atoms or molecules are held in a rigid structure. They are free to vibrate but they cannot move around. As a result, solids have a definite volume and shape.

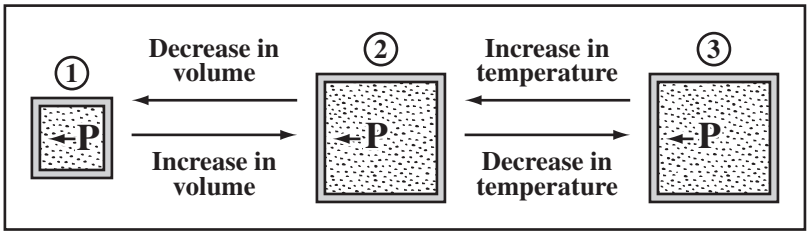
- The **liquid phase** is intermediate between solid and gas. Intermolecular forces hold these atoms or molecules loosely together but do not force them into a rigid structure. Liquid molecules are free to move about to a certain degree so they have a definite volume. However, liquids conform to the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

- 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. The variable, ***n***, describes the number of **moles** of gas. The pressure of a gas is the force exerted on a surface per unit area. To understand how the above variables are related, let us take air in a variable-volume container.



When the temperature of a gas is increased (State 1 to State 2), 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 (State 2 to State 1), the pressure decreases. When a gas is compressed into a smaller volume (State 1 to State 3), the surface area of the walls decreases. This leads to an increase in pressure. When the converse is true (State 3 to State 1), the pressure decreases. Chemists have summarized these relations mathematically with the following laws:

PV = a constant when the temperature is constant
V is directly proportional to **T** when the pressure is constant
V is directly proportional to the number of moles of gas when the temperature and pressure are constant (1 mole of gas = 6.02×10^{23} atoms or molecules)

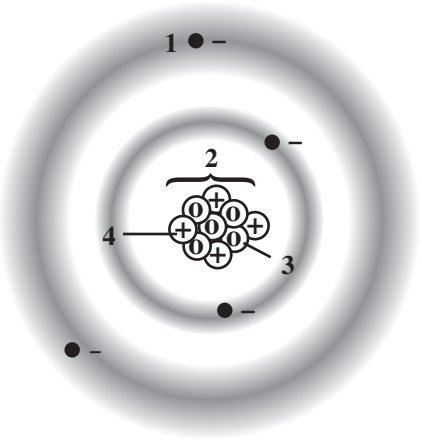
These laws can prove very useful when trying to describe the properties of a gas under changing conditions.

Sample Questions for Content Domain I

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

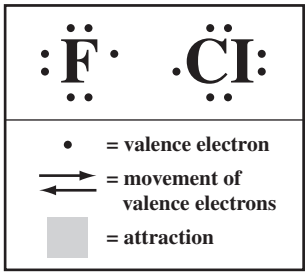
1 **The following diagram shows a model of a beryllium atom.**

Beryllium



Which of the marked particles represents a proton?

A 1
B 2
C 3
D 4

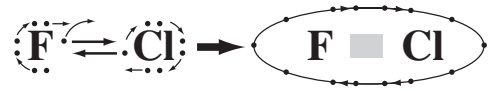


2 **Whenever ionic or covalent bonds form there is a movement of electrons. Using the key given above, which of the following reaction pictures best shows what happens when a covalent bond forms between fluorine and chlorine?**

A 

B 

C 

D 

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?

A $^{1}_{0}n + {}^{235}_{92}U \longrightarrow {}^{132}_{50}Sn + {}^{101}_{42}Mo + 3\,{}^{1}_{0}n$

B $^{238}_{92}U \longrightarrow {}^{4}_{2}He + {}^{234}_{90}Th$

C $4\,{}^{1}_{1}H + 2\,{}^{0}_{-1}e \longrightarrow {}^{4}_{2}He$

D $^{32}_{15}P \longrightarrow {}^{32}_{16}S + {}^{0}_{-1}e$

5 Gold-191 is a radioactive isotope which 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?

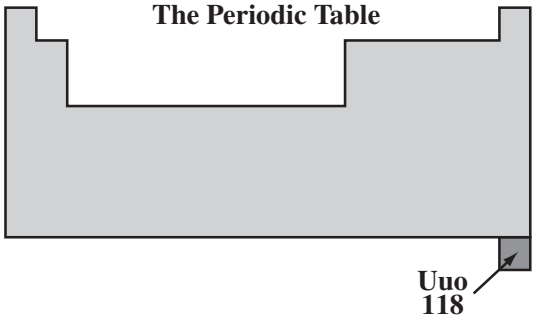
A 6.60 mg
B 4.40 mg
C 1.65 mg
D 0.825 mg

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.

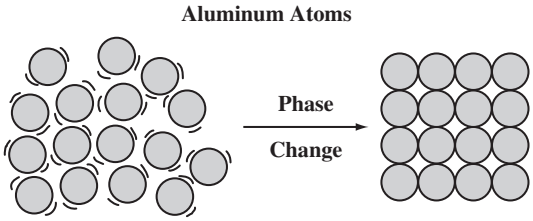
7 The valence shell of a neutral atom loses two electrons. Which of the following ions might result?

A O^{2-}
B Be^{+}
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?

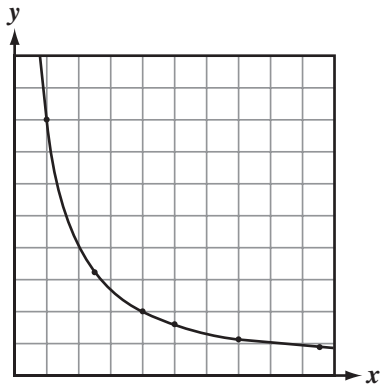
A metalloid solid
B metallic liquid
C nonmetallic gas
D metallic solid



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



10 A student worked on an experiment where nitrogen gas was allowed to change. 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
moles of gas	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 **D** is the correct answer. Answer **A** shows the position of an electron and is incorrect. Answer **B** shows the nucleus of the atom which contains both protons and neutrons. Answer **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 **C** is the correct answer. Answers **A** and **B** are incorrect because a complete transfer of electrons has taken place. The result is an ionic bond, not a covalent bond. Answer **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. Answer **B** is correct. Answer **A** is incorrect because alpha particles are large and easily stopped. Ultraviolet radiation causes sunburns, but this radiation is stopped at the skin, so **C** is incorrect. X-rays, used in medicine to see skeletal features, do not have the penetrating power of gamma rays so **D** is incorrect.

4. Answer: **A** **Distinguish the characteristics and components of radioactivity.** *Differentiate between fission and fusion.*
The equation in **A** shows one large nucleus disintegrating into two smaller atomic nuclei so **A** is correct. Answers **B** and **D** are incorrect since the reactions involve radioactive decay not fusion. Answer **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 **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**

Answer **A** is incorrect because the original amount of gold-191 was divided by 2 once instead of three times. **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. Answer **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 **A** because spent nuclear fuel is still radioactive and can be very hazardous to dispose of and store. Answer **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. **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. Answer **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.*
Answer **D** is correct. When a neutral atom like magnesium (Mg) loses two electrons, it contains two more protons than electrons and takes on a $^{+}2$ charge. Answer **A** is incorrect because oxygen (O) has gained two electrons; it has not lost two electrons. **B** is incorrect. Though beryllium (Be) lies in group 2, it has lost only one electron to give it a $^{+}1$ charge. **C** is incorrect because nitrogen (N) has gained 3 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 **C** because Uuo would lie in group 18, making it a noble gas. Presumably element 118 would be like radon (Rn) which is a nonmetallic gas. Answer **A** is incorrect. Though Uuo might have some metalloid character, the periodic trend would not lead to the solid phase. Answers **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 **B**. The diagram is indicative of melting. Relatively free liquid molecules are cooled so that the molecules slow down and enter into a rigid structure. Answer **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. Answer **C** (vaporization or liquid turning into a gas) is incorrect. The molecules became less free and rigid in the diagram. Vaporization involves an increase in freedom and motion. Finally, **D** (melting or solid turning into 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 **A**. The volume is inversely proportional to pressure, thus the volume decreases with an increase in pressure. Answer **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 moles of gas so Answer **C** is incorrect. The volume should go up, not down, as the moles of gas increase. Finally, Answer **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: Chemistry—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

Some Physical Properties

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

properties help to identify a particular chemical substance. A question for this standard might look like this:

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

Properties of Copper Sample	
Physical description:	*Shiny red metal*
Melting Point (ºC):	*1084.62*
Boiling Point (ºC):	*2562*
Mass (g) :	*50.36*
Volume (cm^3):	*5.62*

What is the density of the copper?

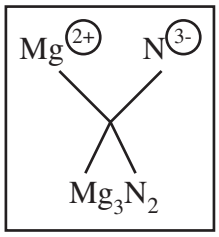
A 0.112 g / cm^3
B 8.96 g / cm^3
C 21.6 g / cm^3
D 44.7 g / cm^3

The correct answer is **B**. The density d = 50.36 g / 5.62 cm^3 = 8.96 g / cm^3. Answer **A** is incorrect because the volume was divided by the mass. Answer **C** is incorrect. The density is not found by dividing the melting point by the mass. Finally, for answer **D,** the volume was subtracted from the mass instead of the mass being divided by the volume making **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. 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 the charge on the nitride ion (N^{3-}) becomes the number of magnesium ions in the formula. Likewise, the charge on the magnesium ion (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 $AlCl_3$ would be named aluminum chloride. Notice the cation has the element name and the first syllable of chlorine, "chlor-" has gained the "-ide" ending.

Binary covalent compounds are named in a similar manner. There are just a few differences. The names of 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 prefix di-, tri-, tetra- or a higher numeral prefix is 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, 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 P_2S_5. It is named

Numerical Prefixes	
mono-	1
di-	2
tri-	3
tetra-	4
penta-	5
hexa-	6
hepta-	7
octa-	8
nona-	9
deca-	10

diphosphorus pentasulfide. Notice the "di-" prefix is used for the two phosphorus atoms and the "penta-" prefix is used for the five sulfur atoms in the formula.

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 mass can be used to balance **chemical equations** which are used to show what happens in a chemical reaction. Earlier it was mentioned that 1 mole of gas was equivalent to 6.02×10^{23} atoms or molecules. The mole is also equal to that amount of substance having a mass (in grams) that is equal to the formula mass. The **formula mass** is simply the sum of the atomic masses of all the atoms represented in the chemical formula. This quantity is expressed in **atomic mass units** (AMU). Water has the chemical formula H_2O. Using the atomic masses in the periodic table, the formula mass would equal $2 \times 1.008 + 16.00 = 18.02$ AMU. One mole of water, therefore, would have a mass of 18.02 grams. In chemical equations, the coefficients in front of the chemical formulas represent the number of moles of reactants or products. The combustion reaction of hydrogen and oxygen is shown below.

$$2H_2 + O_2 \rightarrow 2H_2O$$

The chemical equation shows that 2 moles of hydrogen plus 1 mole of oxygen yields 2 moles of water. Notice that the moles of hydrogen atoms ($2 \times 2 = 4$) and oxygen atoms ($1 \times 2 = 2$) on the reactant side equal the number of hydrogen and oxygen atoms on the product side.

The combustion reaction of hydrogen and oxygen is also known as a **synthesis** reaction. A synthesis reaction is represented by the general equation: $\mathbf{A + B \rightarrow AB}$. 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 (shown on the next page), one-coefficients are understood even though they are not explicitly shown. The following steps are shown on the next page.

$$H_2 + O_2 \rightarrow H_2O \text{ (Initial)}$$

Step	Atom	No. of atoms	No. of atoms
1	H	2	2
2	O	2	1 × 2

$$H_2 + O_2 \rightarrow 2H_2O$$

Step	Atom	No. of atoms	No. of atoms
3	H	2 × 2	4

$$2H_2 + O_2 \rightarrow 2H_2O \text{ (Balanced)}$$

In Step 1, two hydrogen atoms appeared on both sides of the equation. No change was needed. In Step 2, the reactant side contained two oxygen atoms while the product side contained only one oxygen atom. The number of water molecules was multiplied by two to balance the oxygen atoms. A two-coefficient was placed before the H_2O. Finally, in Step 3, the hydrogen atoms were balanced all over again. 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.

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-* = together with** ***-thesis* = 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. It is represented by the general equation: $\boldsymbol{AB \rightarrow A + B}$. An example of this reaction is the decomposition of limestone (calcium carbonate).

$$CaCO_3 \rightarrow CaO + CO_2$$

Notice the equation is balanced as written. One-coefficients are understood, though not written.

A single replacement reaction may be represented by the general equation: $\boldsymbol{A + BC \rightarrow AC + B}$. An example of this reaction is the replacement of a silver ion by copper in a silver nitrate solution.

$$Cu + 2AgNO_3 \rightarrow Cu(NO_3)_2 + 2Ag$$

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

A double replacement reaction has the general equation: $\boldsymbol{AB + CD \rightarrow AD + CB}$. The neutralization of hydrochloric acid by sodium hydroxide gives a good example of this type of reaction.

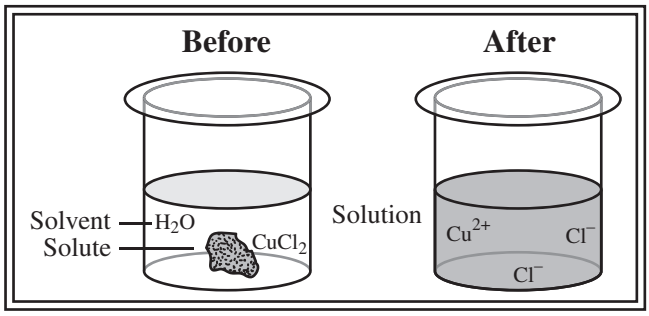
$$NaOH + HCl \rightarrow NaCl + HOH$$

This equation is also balanced as written with no need for the placement of coefficients.

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 $CuCl_2$ is the solute while water is the solvent. This example is shown in the box above. 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
$AlCl_3$	CH_3CO_2H	CH_3OH
$CaCl_2$	(acetic acid)	(methanol)
H_2SO_4	NH_3	$C_{12}H_{22}O_{11}$
HCl	(ammonia)	(table sugar)
KCl	HF	$C_6H_{12}O_6$
Kl		(glucose)
KOH		
$MgSO_4$		
NaCl		
NaOH		

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) / mass of solution (in grams) × 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 make the light bulb glow brightly?

A ammonia (NH_3)
B hydrofluoric acid (HF)
C potassium chloride (KCl)
D methanol (CH_3OH)

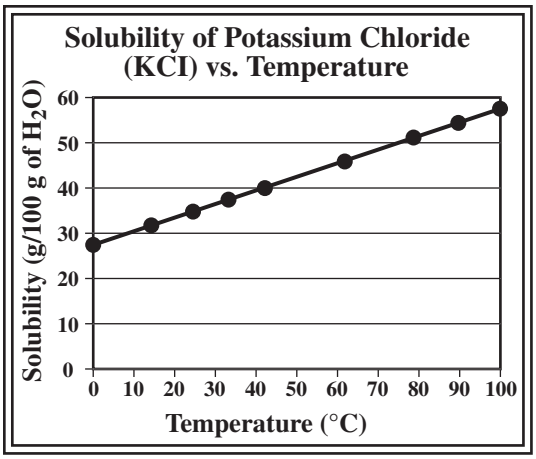
The correct answer is **C**. Potassium chloride is an ionic compound that dissolves in water forming many ions. It has a high conductivity even when diluted. The light bulb will glow brightly. Answer **A** is incorrect. An ammonia solution is a weak base. It does not ionize very much so it is a poor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

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-sized 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. Faster 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.

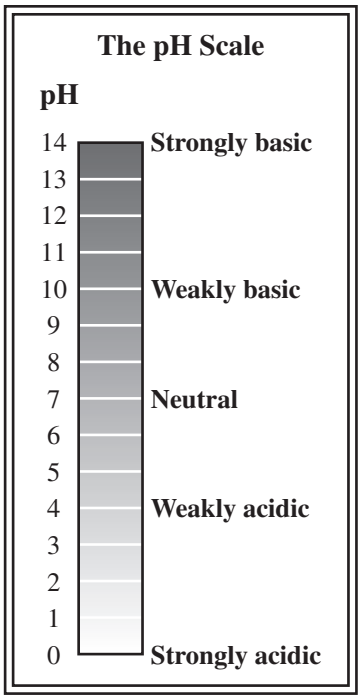


A **solubility curve** shows how the amount of dissolved solute changes with temperature. The solubility curve on the right shows the solubility of potassium chloride (KCl) as a function of temperature. Notice the dimensions of solubility are grams of solute per 100 grams of solvent (water). The solubility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

A solubility curve also shows the temperature at which a solute will begin to precipitate from solution. For example, if 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 the solution cools further, more of the KCl will precipitate out until at 0°C, only 28 grams of the salt remain in solution.

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 chart below.

	Acid	Base
Taste:	• Sour or tart	• Bitter
Touch:	• Feels like water / may sting	• Feels smooth and slippery
Reactions with metals:	• Vigorously reacts with most metals to produce hydrogen, H_2	• Does not react with most metals
Electrical Conductivity:	• Readily conducts electricity (less so for weak acids)	• Readily conducts electricity (less so for weak bases)
Litmus paper test:	• Turns blue litmus paper red	• Turns red litmus paper blue



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^+) 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**.

$$\underset{\text{acid}}{HCl} + \underset{\text{base}}{NaOH} \rightarrow \underset{\text{salt}}{NaCl} + \underset{\text{water}}{H_2O}$$

The hydroxide ion (OH^-) from the NaOH accepted the hydrogen ion from the HCl to form water. The salt NaCl was formed from the sodium ion (Na^+) and the chloride ion (Cl^-) 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 **D**. Since the borax detergent tests positive for a base, the pH must be greater than 7. Answers **A** and **B** are incorrect since a pH of 1.5 is strongly acidic and a pH of 5.0 is weakly acidic, thus, answer **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 additional questions that you can try. After you have answered all of the questions, check your answers in the "Answers to the Content Domain II Sample Questions" section that follows. This section will give you the correct answer to each question, and will explain why the other answer choices are incorrect.

Density of Copper	
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

1 The chart, shown above, was taken from a student's laboratory notebook. What is the density of the copper sample?

A $0.987 \frac{g}{mL}$

B $1.82 \frac{g}{mL}$

C $2.28 \frac{g}{mL}$

D $8.99 \frac{g}{mL}$

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

A CaF
B Ca_2F
C CaF_2
D CaF_3

3 What is the name of the compound represented by the formula NO_2?

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

Reaction:	**$NaCl + AgNO_3 \rightarrow AgCl + NaNO_3$**			
Mass before reaction (g):	11.69	33.98	0.00	0.00
Mass after reaction (g):	0.00	0.00	x	17.00

4 The table above shows the reaction of sodium chloride (NaCl) with silver nitrate ($AgNO_3$) and the masses of the compounds involved in the reaction. How many grams of 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 (NH_3)?

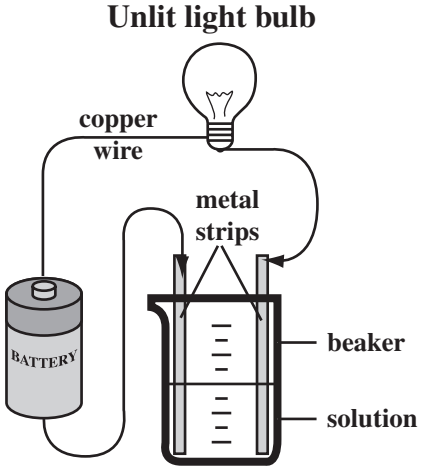
A $N_2(gas) + 3H_2(gas) \xrightarrow{heat/pressure} 2NH_3(gas)$

B $N_2(gas) + H_2(gas) \xrightarrow{heat/pressure} NH_3(gas)$

C $N_2(gas) + H_2(gas) \xrightarrow{heat/pressure} 2NH_3(gas)$

D $2N_2(gas) + 3H_2(gas) \xrightarrow{heat/pressure} 2NH_3(gas)$

Solution number	Name	Formula of solute	Concentration (%)
1	Ammonia	NH_3	5.0
2	Glucose	$C_6H_{12}O_6$	20.0
3	Calcium Chloride	$CaCl_2$	25.0
4	Hydrochloric Acid	HCI	0.25

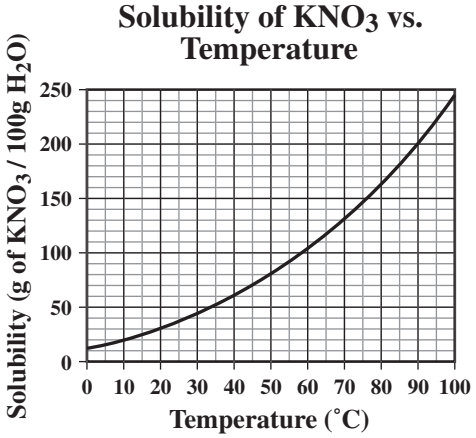


6 Some students did the experiments above to see what kind of solution conducts electricity and makes the light bulb glow. Which of the four solutions will most likely cause the light bulb to remain unlit?

A 1
B 2
C 3
D 4

7 A chemist is trying to dissolve a large crystal of magnesium sulfate ($MgSO_4$) 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 $MgSO_4$ solution.
D Break the crystal into smaller pieces.

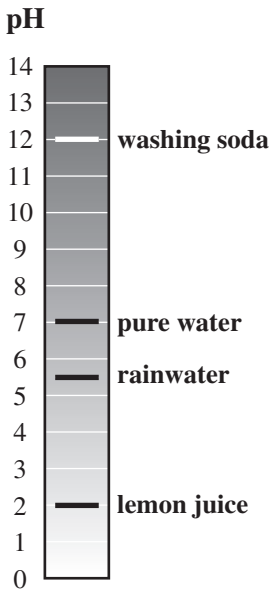


8 A chemist dissolved 120.00 grams of potassium nitrate (KNO_3) in 200 grams of boiling water. The solution was allowed to cool. According to the above solubility curve, at what temperature should the KNO_3 begin to precipitate?

A 18ºC
B 39°C
C 65ºC
D 88ºC

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

A KOH
B NaCl
C H_2O
D H_2SO_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.*

Answer **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. Answer **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. Answer **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. Answer **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 **C**. By crossing the charges, the −1 charge becomes 1 calcium ion and the +2 charge becomes 2 fluoride ions. This gives the formula CaF_2. Notice 1 calcium ion supplies a +2 charge while the 2 fluoride ions supply a −2 charge which balance. Answers **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*).

Answer **A** is correct. There is only one nitrogen atom, but remember the prefix "mono-" is not used. Because there are two oxygen atoms, the prefix "di-" is used before the "oxide" ending. Answer **B** is incorrect because the prefix "di-" is used before the nitrogen instead of the oxide. The "mono-" prefix is used for oxygen incorrectly. Answer **C** is incorrect because it is named the same way as an ionic compound without the prefixes (NO_2 is a covalent compound). Finally, answer **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.*

Answer **B** is correct because the mass of AgCl is equal to the total mass of the reactants less the mass of the product $NaNO_3$ according to the law of conservation of matter. Answer **A** is incorrect because the mass of the $NaNO_3$ was subtracted from the mass of $AgNO_3$ instead of the total mass of the reactants. Answer **C** is not right because the

reactant masses were added together to obtain the mass of AgCl. Actually, the total reactant mass should equal the total mass of the products AgCl and $NaNO_3$. Answer **D** is incorrect because all of the listed masses were added together to give the mass of 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.*

Answer **A** is the correct response. On the reactant side, there are 2 nitrogen atoms and 6 hydrogen atoms. The two molecules of NH_3 on the product side yield the same number of atoms. Answer **B** is incorrect because the equation for the reaction is shown without the coefficients needed to balance it. Answer **C** is wrong because only the nitrogen atoms have been balanced in the equation. Finally, answer **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 **B**. Glucose is a nonelectrolyte so it will not conduct electricity or allow the light bulb to glow. **A** is an incorrect answer because ammonia, NH_3, is a weak electrolyte. It ionizes partially in water and conducts electricity weakly. The light bulb should have a dim glow. Answer **C** is wrong because calcium chloride, $CaCl_2$ is a strong electrolyte and should conduct electricity readily. It would allow the light bulb to shine brightly. **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 **D** is the correct answer. Answer **A** is incorrect because lowering the temperature causes the solvent molecules to move slower and the solubility of the $MgSO_4$ to more than likely decrease. Answer **B** is incorrect. If stirring is discontinued, then less fresh solvent will come in contact with the crystal. This change will actually slow down the dissolving process. Answer **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 KNO_3 dissolved is 60.00 g / 100 g of H_2O. The solution becomes saturated at 39ºC so answer **B** is correct. Answer **A** is incorrect because the concentration was calculated as 30.00 g / 100 g of H_2O instead of 60.00 g / 100 g of H_2O. Answer **C** is wrong because the concentration was not converted to g / 100 g of H_2O. The temperature was read for twice the correct amount of solute. Answer **D** is incorrect because the solubility was read as 200 g / 100 g of H_2O.

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

A is the correct answer. Potassium hydroxide (KOH) contains the hydroxide ion (OH^-). This ion will accept a proton (H^+) so it is basic and will turn red litmus paper blue. Answer **B** is incorrect because NaCl is a neutral salt. Water is neutral as well, so answer **C** is incorrect. Answer **D** is incorrect because H_2SO_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.*

Answer **D** is the correct answer because washing soda is the only substance with a pH greater than 7. All substances with a pH > 7 are basic. Answers **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 answer **C** is incorrect.