

QUICKSTART GUIDE AND  
EXPERIMENT MANUAL



Happy Atoms

DIGITAL AND PHYSICAL CHEMISTRY SET

THAMES & KOSMOS

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# Welcome to the World of Happy Atoms!



Hello there. I'm Harper. I'll be one of your research colleagues as we explore the world of Happy Atoms together!

**Please start by installing the app.** Follow the instructions on pages 2 and 3 to get started with the Happy Atoms system.

Hi! I'm Andee. I'm your other fellow researcher.

**Take a closer look at the atom models** that came inside your Happy Atoms kit box. What do you notice about them? You can read more about the Happy Atoms system on page 4.



## Unboxing the Atoms



Hydrogen

Here are the 16 elements included in the Happy Atoms system. Note: Depending on which Happy Atoms set you have, you may not have all 16 of these atoms. The quantities of the atoms vary from set to set. Refer to the separate Kit Contents sheet.



Helium



Lithium



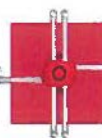
Beryllium



Carbon



Nitrogen



Oxygen



Fluorine



Neon



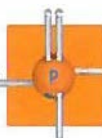
Sodium



Magnesium



Silicon



Phosphorus



Sulfur



Chlorine



Argon

# Getting Started with Happy Atoms

## Installing the App

- 1b Open the App Store or Google Play on your tablet or smartphone. Search for the "Happy Atoms" app.
- 1b Alternatively, you can scan the QR code to the right to open the Happy Atoms product web page. Scroll to the "Download the App" section of the page. There you can find buttons to open the Happy Atoms app store pages.
- 2 When you have found the Happy Atoms app, tap the "Get" or "Install" button to download and install it on your device. The app is free to download and install.
- 3 After the app has finished installing, tap the app icon to open it. Now you are ready to start using the app.



Happy Atoms



## Device Requirements

as of the time of printing of this manual:

- iPad 2 (or later) or iPhone 5 (or later) running iOS 8 (or later); or
- tablet or smartphone running Android 4.4 (or later) with 1GB RAM minimum, dual-core processor, and built-in camera

## Using the App

The Happy Atoms app is designed to guide you through the process of using the Happy Atoms system: Building molecules, scanning molecules to discover them, learning about the molecules you discover, and conducting the guided research tasks. Here are some helpful tips to get you started.

- 3 When you open the app for the first time, you are asked to select which specific Happy Atoms set you have. This customizes the experience to be compatible with your set.
- 2 You are then welcomed aboard The Nucleus, the name of your flying scientific ship, by Harper and Andee, your research colleagues. With this ship and Harper and Andee's guidance, you can navigate the world of Happy Atoms!



- 3 Next, the app takes you through some calibration steps for your device's built-in camera, so that it can function as a molecule scanner.

### Note

In order for the molecule scanner to work properly, you must place your built molecules on a **white surface**. Depending on which Happy Atoms set you have, it may have come with a white storage bag that doubles as a white scanning mat or a white piece of paper. You can place your molecules on the included bag or paper, or on your own white surface, such as a white table or table cloth.

Another important factor in getting your molecules to scan properly is the **light level**. The molecule scanner works best in bright, indoor lighting. It will not work as well in dim lighting or very bright direct sunlight. If you are having trouble getting the app to recognize your molecules, try adjusting the light level and the white background surface.

- 4 Place the Helium, Neon, and Argon atoms on a white surface and click the camera icon on the right side of the screen to take a picture of them.
- 5 Next you will calibrate the camera by making and scanning your first molecule.
- 6 Follow the step-by-step assembly instructions to assemble two Hydrogen atoms and one Oxygen atom into a molecule. Then scan it.
- 7 After successfully scanning, click "Discover" to learn what molecule you made.
- 8 Click "Examine" to learn about the molecule.

Now that you know the basic process for making, scanning, and identifying a molecule, try following the **hints** on other territories to build new molecules. Or click on a territory to open **step-by-step building instructions** for a specific molecule.

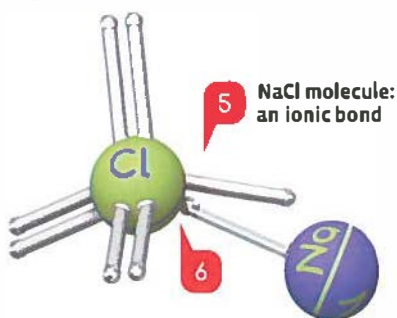
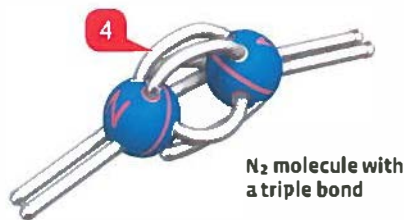
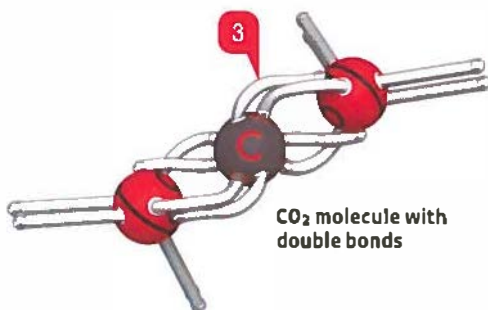
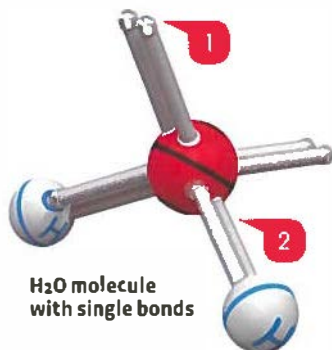
Ultimately, your goal is to build and discover all of the molecules suggested by the app, to complete the **molecule map**. You can also go into Harper and Andee's labs to complete a series of tasks in the **guided lesson plans**.



# About the Happy Atoms System

Happy Atoms is a part digital, part physical system for teaching chemistry. The digital component is an educational app. The physical component is a set of atom models representing 16 different elements. The following is an overview of the physical atom models. **If you are already familiar with other molecular modeling systems, it is especially important to understand the unique way atoms and bonds are represented in the Happy Atoms system.**

- 1 The arms represent the **valence electrons** of the atom. (Valence electrons are explained later on in this manual.)
- 3 Unlike a ball-and-stick atomic modeling system, Happy Atoms uses **two arms** to represent a **single bond**. By representing electrons this way, we believe students will better understand that there are two valence electrons involved in a single covalent bond. The ball-and-stick model represents a single covalent bond using just one arm to represent two electrons.
- 3 The flexible arms make it possible to model **double bonds**.
- 3 By using six arms, even **triple bonds** can be modeled.
- 3 Happy Atoms is also able to represent **ionic bonding**. The elements in the first two groups have clear arms and no magnetic bonding sites, to show how they give up, rather than share, electrons.
- 6 The **magnetic connections** offer an embodied, tactile experience of bonding: Energy is released when bonds form, while energy is required to break bonds. Students feel how the magnets and arms easily pull themselves together when forming bonds. They also feel how the magnets and arms resist being pulled apart when bonds break.





# Overview of App Features

Here is an overview of the app features to help you get started.



## 1 Molecular Scanner

Use your tablet or smartphone's camera to scan and identify the molecules you build. After scanning, they are unlocked on the molecule map.



## 2 Molecule Map

This map shows all the molecules you have discovered and gives you hints for building new molecules. As you discover molecules, more hints are revealed.



## 3 Molecular Examination

Tap a molecule's hexagon on the molecule map to learn facts about it, including its composition, systematic name, and how it exists in our world.



## 4 Step-by-Step Assembly

When you need help assembling a specific molecule, assembly instructions can be accessed by tapping an undiscovered molecule on the map.



## 5 Periodic Table

Learn more about the atoms that make up the Happy Atom system in the periodic table view.



## 6 Guided Research

Head into Harper and Andee's labs for guided lessons. Can you complete all the tasks they give you?



## 7 The Nucleus

The bridge of the Nucleus, your research vessel, is your home screen in the app. Tap the discovery map console to see your progress throughout the game.



## Troubleshooting Tips

If you are having trouble using the app or getting the molecule scanner to recognize your molecules, please visit [thamesandkosmos.com](http://thamesandkosmos.com) on the web and click **Support**. There you will find a section of our Knowledge Base dedicated to helping you use Happy Atoms, with up-to-date troubleshooting tips and app information.

# What Is a Happy Atom?

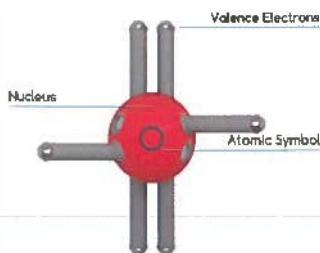
What do you think would happen if you took an object, such as a piece of paper, and split it in half repeatedly? Do you think you could do that forever? Or would you eventually reach a point at which you could no longer split the paper because it would cease to be a piece of paper?

From experiments, scientists have theorized that there is a “smallest particle” that all matter is made up of, which they have called an **atom**. An atom is the smallest particle of a material that still retains the properties of that material. Scientists have also discovered that atoms are made up of three subatomic particles called **protons, neutrons, and electrons**.

The numbers of protons, neutrons, and electrons determine the characteristics of an atom. **Elements** are atoms that all have the same number of protons, and usually the same number of neutrons and electrons. An element can refer to one atom with a specific number of protons, or a group of atoms that all have the same number of protons (also called the **atomic number**).

Protons and neutrons are bound tightly together in the center of an atom, which is called the **nucleus**. Protons are positively charged while neutrons are uncharged or neutral. Electrons are negatively charged and are located outside the nucleus in orbitals. In Happy Atoms, the plastic sphere represents the nucleus, while the arms represent the valence electrons.

**Valence electrons** are the electrons that are involved in chemical bonds between atoms. Atoms bond when they share electrons, or when one atom gives an electron to another atom. When two or more atoms bond, they form **molecules**. You can think of valence electrons as the outermost electrons around an atom.



Since the arms only represent the valence electrons, most elements have a greater total number of electrons than the number of arms on their Happy Atoms model. For example, sulfur actually has 16 electrons. The reason the sulfur Happy Atom only has six valence electron arms is because only the valence electrons are used when atoms bond, so you don't need the other electrons to make molecules with sulfur. Maybe you noticed that sulfur and oxygen have the same number of valence electrons, but that sulfur is a larger atom. This is because it has more total parts; it has a larger nucleus and more electrons orbiting that nucleus. You can explore this more in the experiment on page 8.

The letters on the nucleus represent the **atomic symbols** for the different elements.

An **element** is the simplest form of a substance. It cannot be broken down by chemical means. For example, a bar of pure gold contains only gold atoms. There is no way to break the gold atoms down into other substances. What differentiates an atom of one element from an atom of another element are the numbers of protons in their nuclei.

The Russian chemist **Dmitri Mendeleev** found that if you order the elements based on the number of protons in their nucleus, the elements form groups that have similar chemical characteristics. This arrangement is known as the **periodic table**. The number above the atomic symbol for each element is the atomic number and is equal to the number of protons in the nucleus of the element. The rows of the periodic table are called **periods**. The columns are called **groups**.

# The Discovery of the Atom

An atom is a million times smaller than the width of a human hair. Because individual atoms are too small to see with our eyes and too small to manipulate with our hands, many different ways of representing the atom, called **atomic models**, have been developed over time. Happy Atoms is also a model! Models enable us to understand something, even if the model isn't entirely accurate in all ways. Happy Atoms is a model because we're not showing all of the electrons an atom has, only the relevant ones for our model. Here you will learn about some different atomic models.

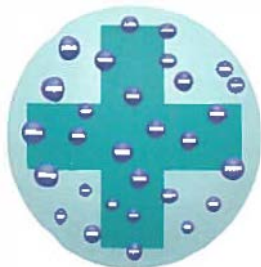
## John Dalton's Billiard Ball Model

In the early 1800s, John Dalton developed an atomic theory to explain scientific findings related to how elements combined together. Dalton visualized atoms as neutrally charged billiard balls.



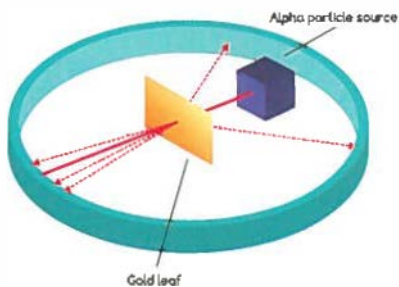
## J. J. Thomson's Plum Pudding Model

In 1897, J. J. Thomson discovered that atoms have small negative particles called electrons using a device called a cathode ray tube. But, since atoms are neutrally charged, Thomson reasoned that atoms must have positive particles inside them too. Thomson proposed that atoms are clouds with positive and negative particles spread evenly throughout, like the plums in a Christmas pudding. This is why Thomson's model is often called the plum pudding model.



## The Gold Foil Experiment

The next great leap in understanding the atom came from the work of Ernest Rutherford, Hans Geiger, and Ernest Marsden in 1909. They sent a beam of alpha particles (a neutron and proton) through a thin layer of gold foil that was only a few atoms thick, and measured how the alpha particles scattered. They observed that most of the particles passed through the gold foil, while a few were deflected backward. As most of the alpha particles passed through the gold foil, this suggested that most of the atom was empty space. However, the few particles that were deflected backward suggested that there was a small concentrated mass of positive charge in the atom.



## The Quantum Atom

From the work of many scientists, such as Schrödinger, Heisenberg, and Bohr, the atom is now known to consist of a nucleus with protons and neutrons, and electrons moving around in orbitals. However, the electrons don't revolve around the nucleus like solid planets. Electrons are more like a cloud around the atom, with areas where the electrons are more likely to be and areas where they are less likely to be. Electrons have characteristics of both waves and particles.





# Hands-On Experiments

## 1. Exploring Atoms and Elements

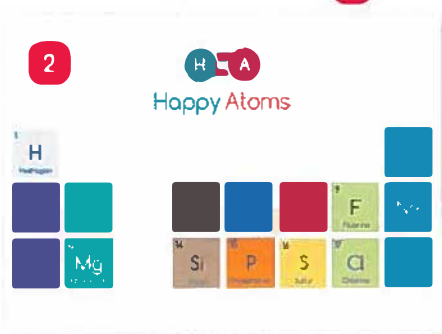
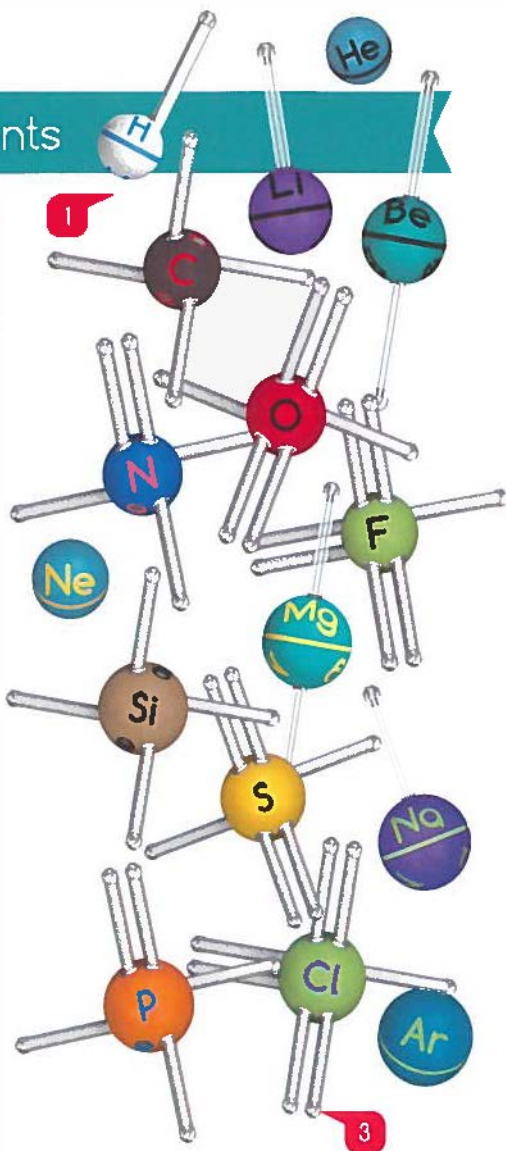
- 1 Arrange the Happy Atoms into groups based on the diameter of the nucleus and the number of valence electrons (arms) each atom has.  
What patterns do you notice about the number of arms each element has?
- 2 Now place your atoms on the periodic table poster.  
What patterns do you notice about the number of arms and the position of the element on the periodic table?
- 3 Examine the metal tips on the arms.  
What do the metal tips on the arms of the different atoms represent?

### Explanation

The number of arms that the elements have increases as you move from left to right on the periodic table, until you reach the column farthest to the right. This pattern reflects the organized way in which atoms hold electrons and the way in which electrons fill up empty spots around atoms' nuclei. You will learn more about this in Experiment 2.

The metal tips on the arms are the **valence electrons**. As you already learned, electrons are small negatively charged particles that are located in shells surrounding the nucleus. The valence electrons are usually the electrons that are in the shells that are farthest from the nucleus.

The valence electrons are involved in the formation of chemical bonds between atoms. When atoms share electrons, it is called **bonding**. In some bonds, the electrons in the bond do not attach to just one nucleus but are rather shared between the nuclei of the two atoms. In other bonds, one atom gives up an electron to another, and the atoms are held together by opposing charges.

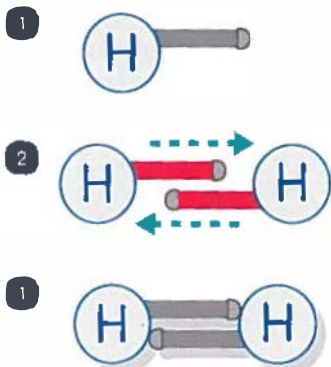


## 2. Covalent Bonds

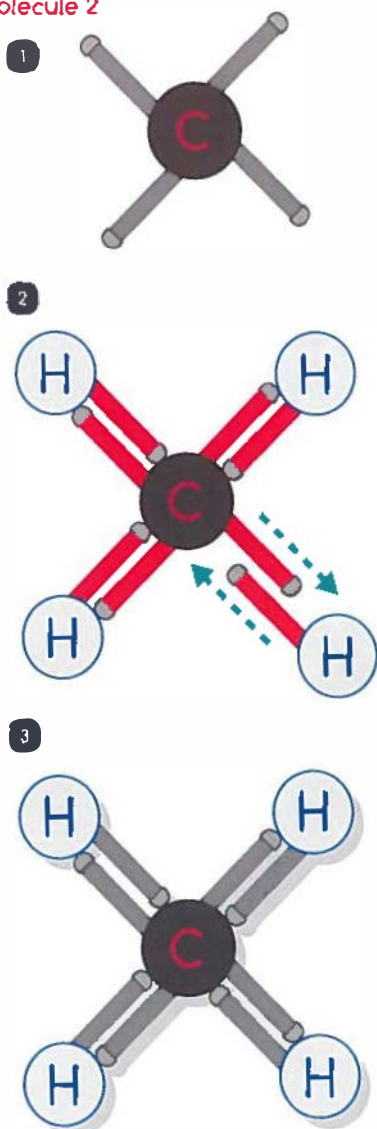
What is a **molecule**? A molecule is simply two or more atoms that are chemically bonded together. Chemists use a special notation to write down the elements that are in a specific molecule. This is called a **chemical formula**. The atomic symbol (such as H, N, F, or Cl) for each element present in the molecule is included in the formula. A subscript number after an element's atomic symbol indicates how many atoms of that element are in the molecule. If there is no subscript number, then it means that there is only one atom of that element in the molecule. For example, water is written as  $H_2O$ , which indicates that there are two hydrogens and one oxygen in that molecule.

- 1 Follow the assembly instructions below and on the next page to build molecules. **What do you notice about how the atoms combine together?**
- 2 Now look at the number of magnets on the sphere of the atoms. **What do you think the magnets on the spheres represent?**
- 3 Count the number of magnets and arms that the carbon, nitrogen, oxygen, and fluorine atoms have. **Do you notice a pattern?**

### Molecule 1



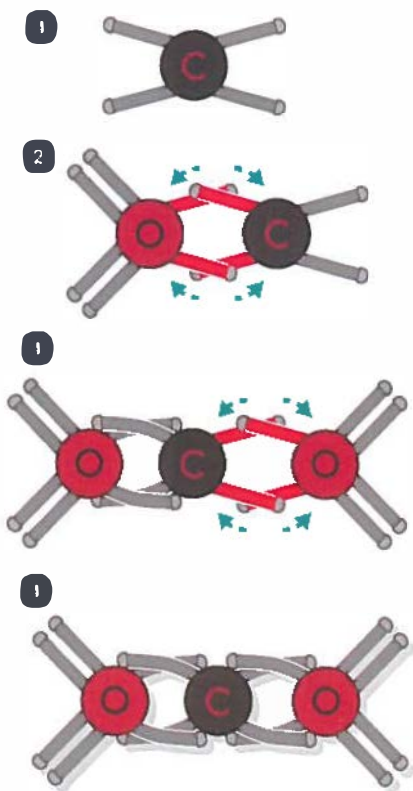
### Molecule 2



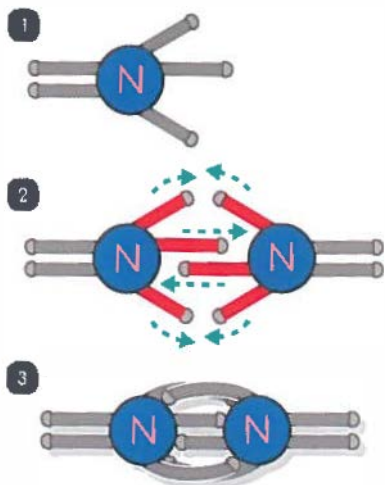
### Note

It is best to disassemble the molecule when you are done using it. We do not recommend leaving the molecules in double bonds or triple bonds for a long time, as the stress on the arms may permanently deform them.

### Molecule 3



### Molecule 4



### Now Scan Your Molecules!



After you have assembled your molecules, open the Happy Atoms app and scan them with the molecule scanner. Once the app identifies a molecule and you discover what it is, the molecule gets placed on the molecule map. From the molecule map, you can tap to examine the molecule to learn all about it.

### Explanation

The **magnets** represent the number of electrons that an element needs to fill its outer valence shell. The metal tips on the arms that represent the valence electrons of one atom magnetically attach to these bonding sites on other atoms. You also saw that the **number of arms** and the **number of magnets** for the elements carbon, nitrogen, oxygen, and fluorine add up to eight. Why eight?

From the previous experiment, you noticed that the elements in the column farthest to the right on the periodic table (Helium, Neon, and Argon) do not have arms or magnets. This means that these atoms are not able to bond with other elements to form molecules. This group of elements is called the **noble gases**. The noble gases rarely bond with other elements because they each already have a full outer shell of valence electrons. Chemistry teachers often say that atoms are “happiest” when they have a full valence shell. This is why we named this system Happy Atoms!

Because the elements in the other groups of the periodic table do not have filled valence shells they want to complete their valence shells by gaining or losing electrons.

This explains the bonding behavior of the different elements. For example, it is easier for a sodium atom to lose one electron, having the same number of electrons as neon, instead of gaining seven electrons. It is easier for oxygen to gain two electrons than it is to lose six electrons. This behavior is summarized in the chemistry rule of thumb called the **octet rule**.

## 3. States of Matter

There are three common **states of matter**: solids, liquids, and gases. You are probably familiar with the three states of water: ice, liquid water, and water vapor.

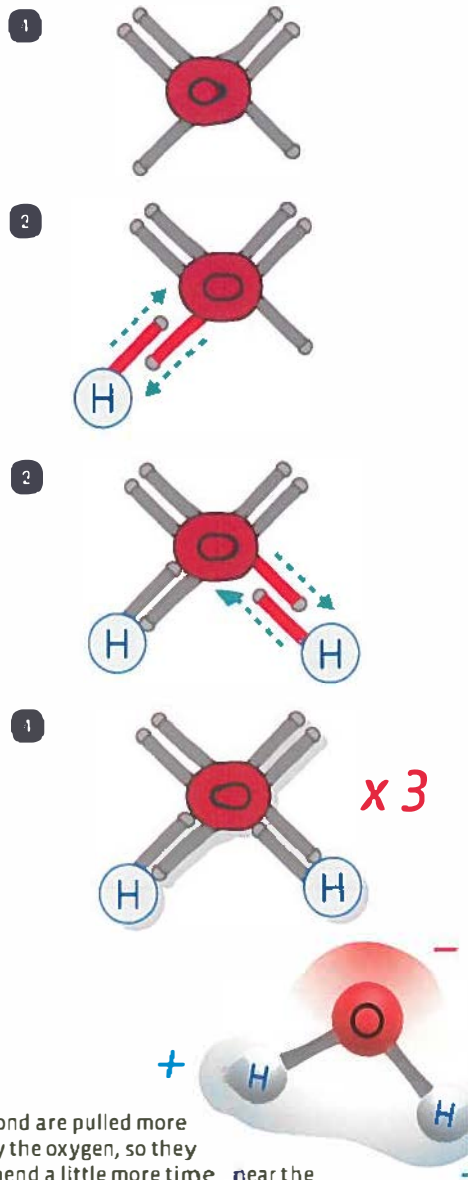
How do you get ice to change into liquid water and then into water vapor? By adding heat! In this experiment you will learn how adding heat changes how the molecules in water behave.

- 1 Follow the assembly instructions to the right to build three water molecules.
- 2 Squish the water molecules into a tight pile. This is how the molecules in solid ice behave. They are tightly packed together and are not able to move around much.
- 3 Lay the water out on a flat surface, such as desk, and slide the atoms around. This represents how the water molecules move in liquid water. The molecules are able to move past each other, but are still constrained to the container that they are in.
- 4 Now hold a water molecule in each hand. Move them around rapidly in the air. This represents how water molecules behave when they are in the gas phase. The molecules are able to move freely in all directions.

### Water as a Polar Molecule

An important property of water is that it is a polar molecule. This means that one side of the molecule has a slight positive charge while the other has a slight negative charge.

Water is **polar** because the oxygen atom is a much larger atom than the two hydrogens. The oxygen atom has eight protons and eight neutrons while each hydrogen only has one of each. The electrons that are shared in the covalent



bond are pulled more by the oxygen, so they spend a little more time near the oxygen atom than near the hydrogens. This makes the oxygen side slightly more negative (because electrons are negative), while the end with the hydrogen atoms becomes slightly more positive.

This has an important influence on the way that water interacts with other ions, as you will learn in the next experiment.

## 4. Ionic Bonds

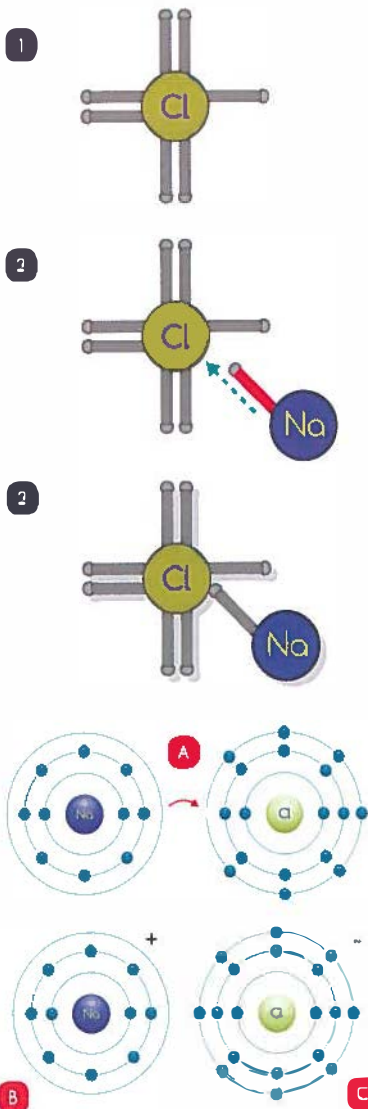
You will need: a *drinking glass*, *water*, *table salt*, and a *spoon*

- 1 Mix the table salt and water in the drinking glass with the spoon.  
**What do you observe happening?**
- 2 Follow the assembly instructions to the right to build a sodium chloride molecule ( $\text{NaCl}$ ). Build a water molecule ( $\text{H}_2\text{O}$ ) as you did in Experiment 3.  
**What do you notice about the bond between the sodium and chlorine atoms? How does this bond compare to the bond between the hydrogens to the oxygen in the water molecule?**

### Explanation

The bond between the sodium and chlorine atoms is not a **covalent bond** like you built in Experiment 2. It is an **ionic bond**. In a covalent bond, both nuclei share two valence electrons. In an ionic bond, one atom gives an electron to another atom (A). The atom that has lost an electron (in this case, the sodium atom) now has a positive charge because the atom has one more proton than it has electrons (B). The atom that receives the electron (in this case, the chlorine atom) now has a negative charge, because the atom has one more electron than it has protons (C). The two charged atoms, called **ions**, then come together because **opposite charges attract**.

What does ionic bonding have to do with the salt dissolving in water? Because water is a polar molecule, the slightly more positive hydrogens of the water molecules are attracted to the negatively charged chloride ions. While the partial negatively charged oxygen is attracted to the positively charged sodium ion. Thus, when the table salt is added to the water, the water molecules are able to surround and pull apart the sodium and chloride ions, dissolving the salt!



### Did you know?

“Sodium chloride” is what is known as a **systematic name** for  $\text{NaCl}$ . There is also another name for this molecule that you are probably more familiar with: table salt. “Table salt” is the **common name**. The systematic name, just as the name implies, comes from a system of rules used to name molecules.



## 5. Acids and Bases

### A. Making Red Cabbage Indicator

You will need: a *small red cabbage*, *knife*, *cooking pot*, *stove*, *spoon*, *water*, *strainer*, *glass jar*, *label*, *pen*

- 1 Chop up the leaves of a small red cabbage.
- 2 Place the chopped cabbage in a cooking pot and add enough water to completely submerge the cabbage.
- 3 Place the pot on the stove. Set the stove burner to high and bring the contents of the pot to a boil. Let it boil for about 15 minutes. Then, remove it from the heat and let it cool.
- 4 After the pot has cooled, use the strainer to separate the cabbage from the liquid, keeping the liquid.
- 5 Store the liquid in a small clean glass jar. Attach a label to the jar.

### Explanation

Red cabbage contains substances called **anthocyanins**, which are pigmented (colored) molecules. By cutting up the cabbage and boiling it, you broke down the cabbage tissue that contained the anthocyanins, turning the water purple. In the solution, the anthocyanins can easily move around and react to chemicals added to the solution.

### B. Identifying Bases

You will need: a *teaspoon of baking soda*, a *quarter cup of water*, *red cabbage indicator*

- 1 Mix the teaspoon of baking soda into the quarter cup of water.
- 2 Add red cabbage indicator to the mixture of baking soda and water. Record your observations.

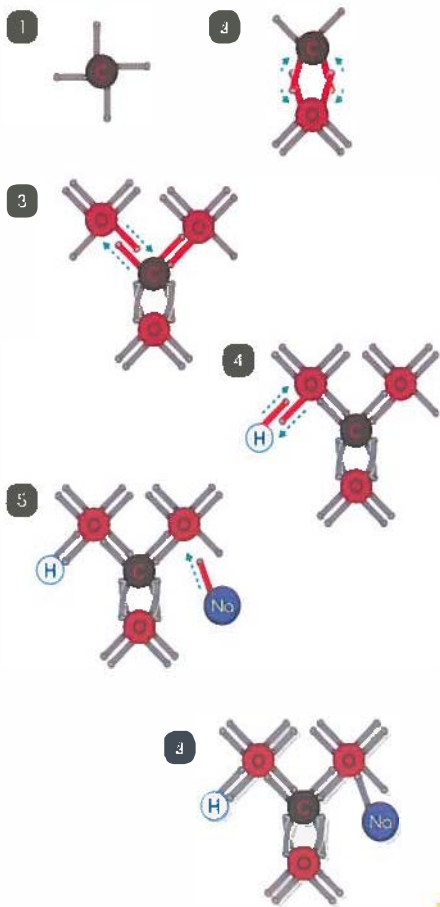
### Explanation

The systematic name for baking soda is sodium bicarbonate. You observed that when you added the red cabbage indicator to the mixture of baking soda and water, the red cabbage indicator changed to a green color. As with the table salt, this is due to the way that sodium bicarbonate interacts with water.

### C. Modeling It with Happy Atoms

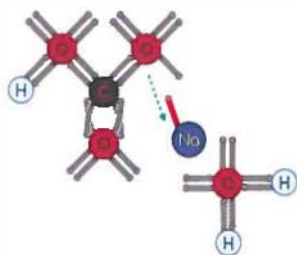
- 1 Follow the assembly instructions to build one sodium bicarbonate ( $\text{NaHCO}_3$ ) molecule. Build one water molecule ( $\text{H}_2\text{O}$ ) as you did in Experiment 3.

What do you notice about the bond between the sodium atom (Na) and the oxygen (O)?



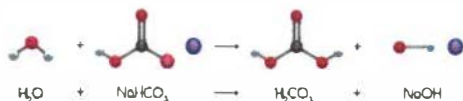
## Explanation

The bond between the sodium and oxygen in the sodium bicarbonate molecule is an ionic bond. As you learned in the previous experiment, water is a polar molecule. This means that when sodium bicarbonate is added to water, the oxygen of the water molecule is attracted to the sodium ion while the hydrogens are attracted to the oxygen ion of the sodium bicarbonate molecule. Thus, the water molecules are able to pull the sodium ion off of the oxygen. This only occurs in a small number of sodium bicarbonate molecules as the bond between the sodium and oxygen is actually quite strong.



The valence electron of the sodium ion stays with the oxygen when this happens so the sodium ion has a positive charge while the oxygen has a negative charge.

The sodium bicarbonate then pulls a hydrogen ion from a water molecule to replace the sodium ion. This forms a new molecule called carbonic acid along with a hydroxide ion ( $\text{OH}^-$ ), and a sodium ion ( $\text{Na}^+$ ). This can be written as a chemical equation like this:



Water + Sodium bicarbonate  $\rightarrow$  Carbonic acid + Hydroxide Ion + Sodium Ion

A molecule that releases a hydroxide ion ( $\text{OH}^-$ ) is called a **base**. When a base is added to red cabbage indicator, the hydroxide ions cause the anthocyanins to change color to a blue or greenish color.

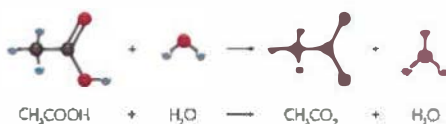
## D. Identifying Acids

You will need: a *teaspoon of vinegar, red cabbage indicator*

- 1 Add red cabbage indicator to the teaspoon of vinegar. Record your observations.

### Explanation

Vinegar contains between 5–20% acetic acid. When acetic acid is added to water a small number of acetic acid molecules give up a hydrogen ion ( $\text{H}^+$ ) forming a new molecule called acetate and a hydronium ion ( $\text{H}_3\text{O}^+$ ). This can be represented by this chemical equation:



Acetic acid + Water  $\rightarrow$  Acetate + Hydronium Ion

## E. Modeling It with Happy Atoms

- 1 Assemble an acetic acid molecule and a water molecule. This time, use the assembly instructions in the app if you need help building the acetic acid. Use the molecules you assembled to go through the steps in the reaction above.

### Explanation

A substance that releases a hydrogen ion ( $\text{H}^+$ ) is called an **acid**. The hydrogen ions cause the anthocyanin molecules in the red cabbage indicator to turn a reddish color.

There are many different molecules that are acids and bases, which have very important uses. For example, the acid in your stomach is used to digest food!

### Did you know?

The substances on the left side of the chemical equation are called the **reactants**, and the substances on the right are called the **products**.

## 6. Combustion Reactions

2 Build one methane molecule ( $\text{CH}_4$ ) as you did in Experiment 2. Build two oxygen molecules ( $\text{O}_2$ ) by attaching two oxygen atoms to each other with a double bond.



+



→



+



Methane

+

2 Oxygen

→

Carbon dioxide

+

2 Water

### Explanation

As you learned in Experiment 2, the subscript after an element's atomic symbol tells you how many of that specific type of atom there are in a molecule. For example, the four in  $\text{CH}_4$  tells you that there are four hydrogen atoms in a methane molecule.

In a chemical equation, when a number is in front of a molecule it represents the number of molecules involved in the **chemical reaction**. The 2 in front of the  $\text{O}_2$  indicates that two oxygen molecules react with one methane molecule ( $\text{CH}_4$ ). These numbers are necessary since atoms are not created or destroyed. You have to have the same number and types of atoms on one side of the chemical equation as on the other.

Describe what is happening with the atoms and electrons in this reaction. Was it easier to pull a hydrogen off of the methane molecule or to add the hydrogens to the oxygen atoms?

A chemical reaction transforms one set of molecules into another as bonds between atoms are formed and broken. You felt that it was easier to connect the atoms together than to pull this apart. This

2 Rearrange the atoms in the molecules to form one carbon dioxide molecule and two water molecules using the following chemical equation:

is because when bonds are formed, energy is released. Conversely, energy is required to break bonds. So, a chemical reaction will always be accompanied with an overall energy change — energy will either be released or energy will be absorbed.

A reaction that releases energy is called an **exothermic reaction**, while a reaction that absorbs energy is called an **endothermic reaction**.

You might be familiar with the more common form of methane: natural gas. Natural gas is used to heat homes and cook food on gas stoves. The reason that methane is useful for this purpose is because when natural gas is burned in air it releases a lot of energy. Now you know that this energy comes from the rearrangement of bonds in the methane molecule, and you have held a model of it in your own hands!

# Guidance for Teachers

## Using Happy Atoms in the Chemistry Classroom

Teachers: After going through this manual, we hope you have some ideas about how to use Happy Atoms in your classroom. Here is how Happy Atoms satisfies the performance expectations for the Next Generation Science Standards (NGSS). This text is adapted from the public domain document titled *A Framework for K-12 Science Education*.

### Elementary School

Starting in 5th grade, students are able to describe that matter is made of particles too small to be seen through the development of a model.

### Middle School

The performance expectations in PS1: Matter and its Interactions help students to formulate an answer to the question, "How do atomic and molecular interactions explain the properties of matter that we see and feel?" by building an understanding of what occurs at the atomic and molecular scale.

In middle school, the PS1 Disciplinary Core Idea from the NRC Framework is broken down into two sub-ideas: the structure and properties of matter, and chemical reactions. By the end of middle school, students will be able to apply understanding that pure substances have characteristic physical and chemical properties and are made from a single type of atom or molecule. They will be able to provide molecular level accounts to explain states of matters and changes between states, that chemical reactions involve regrouping of atoms to form new substances, and that atoms rearrange during chemical reactions. In the PS1 performance expectations, students are expected to demonstrate proficiency in developing and using models.

### High School

The performance expectations in PS1: Matter and its interactions help students formulate an answer to the question, "How can one explain the structure, properties, and interactions of matter?"

The PS1 Disciplinary Core Idea from the NRC Framework is broken down into three sub-ideas: the structure and properties of matter, chemical reactions, and nuclear processes. Students are expected to develop understanding of the substructure of atoms and to provide more mechanistic explanations of the properties of substances. Chemical reactions, including rates of reactions and energy changes, can be understood by students at this level in terms of the collisions of molecules and the rearrangements of atoms. Students are able to use the periodic table as a tool to explain and predict the properties of elements. Using this expanded knowledge of chemical reactions, students are able to explain important biological and geophysical phenomena. Phenomena involving nuclei are also important to understand, as they explain the formation and abundance of the elements, radioactivity, the release of energy from the sun and other stars, and the generation of nuclear power. Students are also able to apply an understanding of the process of optimization in engineering design to chemical reaction systems. The crosscutting concepts of patterns, energy and matter, and stability and change are called out as organizing concepts for these disciplinary core ideas. In the PS1 performance expectations, students are expected to demonstrate proficiency in developing and using models, planning and conducting investigations, using mathematical thinking, and constructing explanations and designing solutions; and to use these practices to demonstrate understanding of the core ideas.

# Glossary

**Atom:** the smallest unit of matter; the smallest unit of an element that still exhibits the same properties as that element

**Atomic model:** a way of representing the atom and molecules based on their behaviors and properties that enable people to better understand them

**Atomic orbital:** a mathematical function that describes how likely an electron is to be in a specific region of space around the nucleus of an atom

**Atomic symbol:** a one- to three-letter code for each element

**Chemical formula:** a special notation for writing down the elements that are in a specific molecule

**Chemical reaction:** a process that transforms one set of molecules into another by breaking and reforming chemical bonds

**Chemistry:** the scientific study of the composition, structure, properties, and changes of matter

**Combustion reaction:** exothermic reaction between a fuel and an oxidant, usually atmospheric oxygen

**Covalent bond:** a chemical bond in which both nuclei share two valence electrons

**Electron:** subatomic particle with a negative charge

**Element:** the simplest form of a substance that cannot be broken down by chemical means

**Endothermic reaction:** a reaction that absorbs energy from its surroundings

**Exothermic reaction:** a reaction that releases energy

**Group:** one column in the periodic table

**Indicator:** a chemical compound that changes color to indicate pH

**Ion:** an atom or molecule in which the total number of electrons does not equal the total number of protons

**Ionic bond:** a chemical bond in which one atom gives up an electron to another atom, resulting in one atom having a positive charge and the other atom having a negative charge. The opposite charges then cause the atoms to attract each other

**Molecule:** two or more atoms held together by chemical bonds

**Neutron:** a subatomic particle with no net electric charge

**Period:** one row in the periodic table

**Periodic table of elements:** an orderly arrangement of the elements organized by their properties

**pH:** a numeric scale used to measure the acidity or basicity of a substance

**Proton:** a subatomic particle with a positive electric charge

**State of matter:** a distinct form of matter

**Valence electron:** the electrons involved in bonding; usually the outermost electrons around the nucleus