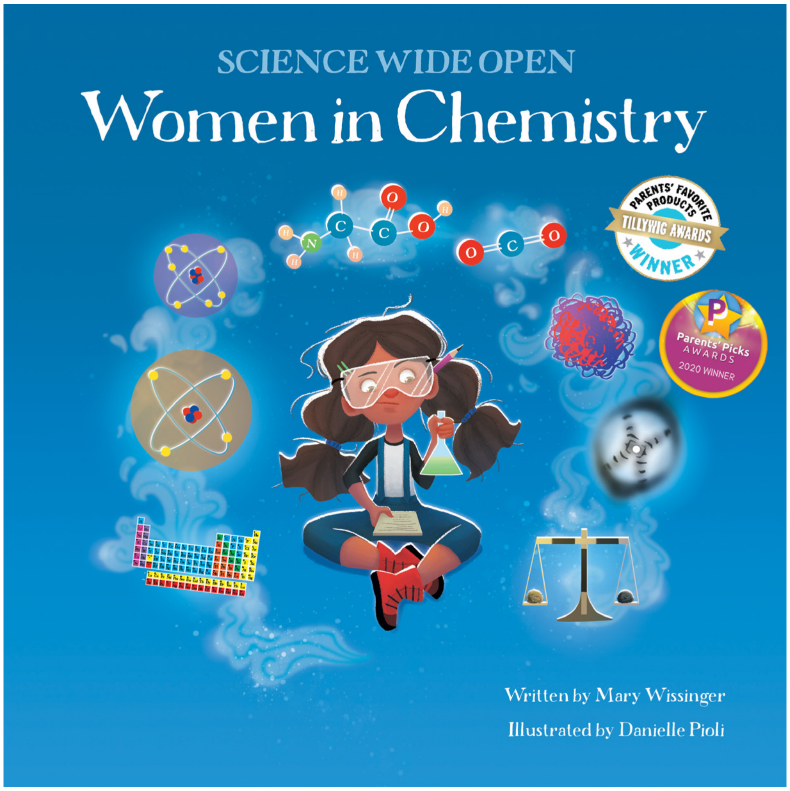
Women in Chemistry Teacher's Guide

Written and designed by Emma Ferdinandi



To be used with *Women in Chemistry* and *Las mujeres en la química*
Written by Mary Wissinger
Illustrated by Danielle Pioli

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Sparking curiosity through reading

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The Science Wide Open Series

Dear Reader,

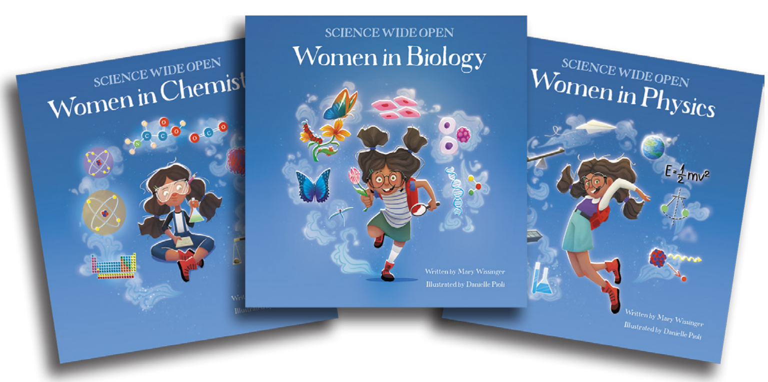
We're excited to introduce you to *Women in Chemistry/Las mujeres en la química*, part of our *Science Wide Open* series. The beautifully illustrated, information-packed titles in this series introduce elementary students to the fascinating world of science through important female figures in history.

Scientific curiosity begins in childhood, with young minds thirstily absorbing information about the world around them. Exposure to chemistry is often at the root of a child's interest in science. Chemistry is a gateway to many important conversations, including health, the human body, climate change, genetics, and matter. As the many activities in this Guide will prove, it also provides the perfect opportunity for education to become hands-on and interactive.

Chemistry might be a complex subject, but introducing children to challenging subjects early in life makes it easier to succeed later on. Young Marie Curie continued to study chemistry at home even though the schools wouldn't teach her. It was this passion that would lead her to research radiation and win two Nobel Prizes. Fredrick Sanger spent much of his school days experimenting in a chemistry lab propelling him to pursue science for the rest of his life. Spark curiosity in a child and watch them develop a lifelong enthusiasm for learning.

More than an educational primer, these stories also illustrate and explore the vital role women have played in history. Showing young girls such role models empowers them to follow their passions and enter a field typically dominated by men. But regardless of gender, *Science Wide Open* books encourage all children to make real-world connections that sharpen their analytical skills and give them a head start in STEM (science, technology, engineering, and math).

An easy choice for the home, library, or classroom, our *Science Wide Open* series has something to spark or sustain budding curiosity in any child.



Enjoy!

Dia

Dia L. Michels
Publisher, Science Naturally

Meet the Women

Women in Chemistry/Las mujeres en la química introduces children to the fascinating world of chemistry through the lens of some of the most important women in scientific history. As readers learn about each woman's accomplishments and her methods of research, they will be able to see the immense impact chemists have had on everyday life. Readers will discover the diverse subjects of chemistry and become confident in starting their own experiments and satisfying their own curiosities.

Women in Chemistry/Las mujeres en la química explores the discoveries of the following women:

Cleopatra the Alchemist
An alchemist whose inventions and writings set the stage for chemistry.

Marie-Anne Paulze Lavoisier
Lavoisier's research signaled the beginning of modern chemistry.

Dawn Shaughnessy
A nuclear chemist who is most known for discovering new elements.

Rosalind Franklin
Franklin's use of X-ray photography led to the discovery of the double helix structure of DNA.

Ada Yonath
Yonath discovered the structure of ribosomes, which has led to countless medical improvements.

About the Author: Mary Wissinger

Mary was born in Wisconsin where she spent most of her childhood singing, reading, and daydreaming. She dove into storytelling through acting, singing, and writing (and writing and writing).

While spending time as a classroom teacher sharing the magic of music, she saw firsthand the incredible life-changing power of stories. The stories children read become the stories they play, and then the stories they tell.

Mary can now be found at her standing desk in St. Louis, MO, writing stories that inspire curiosity about the world and connection with others. (But don't worry, she still sings with the Saint Louis Symphony Chorus.)

Mary is also the author of *Women in Chemistry/Las mujeres en biología* and *Women in Physics/Las mujeres en física. Women in Medicine, Women in Engineering,* and *Women in Botany* will be released in the fall of 2021. She can be reached at Mary.Wissinger@ScienceNaturally.com.

About the Illustrator: Danielle Pioli

As children usually do, Danielle Pioli always loved drawing. The idea of creating a whole universe—from her mind to paper—made her fall in love with art and storytelling. She also always felt like a healer at some level. As a child in Sao Paulo, Brazil, she was so drawn to magic—what she calls Quantum Physics now—that she was certain she could heal and help people. Because of this, she grew up to become an Artist and Hypnotherapist/Energy Healer.

Danielle is also the illustrator of *Women in Chemistry/Las mujeres en química* and *Women in Physics/Las mujeres en física.* She can be reached at Danielle.Pioli@ScienceNaturally.com.

Women in Chemistry:
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Science Naturally would like to thank the following people for their hard work, invaluable insight, and dedicated time in creating *Women in Chemistry* and its accompanying Teacher's Guide:

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Section 1: Book-Based Activities

The activities in this section use only the book and conversation as tools to take advantage of the diversity of subjects in chemistry and to explore key concepts about chemistry and the world at large.

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Pre-Reading: English Book Glossary

Women in Chemistry delves into the many different disciplines in chemistry, introducing children to complex subjects and, consequently, a new set of vocabulary. This list does not need to be mastered before reading—*Women in Chemistry* and the activities in this guide will provide context and information which will clarify these terms—but familiarity with the vocabulary will improve initial reading comprehension.
Note: An expanded glossary with additional words can be found on pages 93 and 94.

The following glossary can be found on pages 38 and 39 of *Women in Chemistry*.

Alchemist: Someone in ancient times who tried to turn ordinary metals into gold or silver or find one cure that would work for all sicknesses.

Atoms: The building blocks that put together our universe. Different kinds of atoms are made by combining different numbers of protons, neutrons, and electrons.

Cells: The basic structural unit for all organisms. Cells hold the biological equipment to keep an organism alive and successful.

Chemical Reaction: A process where the structure of something, like a molecule, is rearranged.

Chemical Structure: The way atoms are arranged in a substance.

Chemistry: The study of matter and the changes that happen to it.

Crystallography: A branch of science that studies the arrangement of atoms in crystals, like salt or diamonds, which are made with strict repeating patterns.

Cyclotron: A circular machine that pushes electrically charged particles, like protons, along a spiral path. They are used to bring about high-speed particle collisions.

DNA (Deoxyribonucleic Acid): The written plan in the cells of living things (like plants, animals, and people) that tells each cell, and by extension, the body, how to grow and function.

Electrons: Very teeny particles with a negative electric charge. Electrons travel around the nucleus of every atom.

Element: A basic substance made of one type of atom that cannot usually be separated into simpler substances.

Experiment: A test to collect information about the world to see if a hypothesis is correct.

Hypothesis: An educated guess that a person makes to explain something they think is true or think will happen.

Mass: A measure of how much matter is in an object. Mass is usually measured in kilograms (1 kg = a little over 2 pounds). Mass is different from weight because the mass of an object never changes, but its weight will change based on its location in the universe.

Matter: Anything that takes up space and has mass.

Molecule: A group of atoms that are bonded together.

Neutrons: Very teeny particles with no electric charge, found in the nucleus of most atoms.

Nobel Prize: A set of very prestigious annual international awards recognizing academic, cultural, and scientific advances. The awards are named for Swedish scientist Alfred Nobel, and were first awarded in 1895.

Periodic Table: A chart that arranges chemical elements. It is organized by the element's atomic number. The atomic number comes from how many protons the element contains.

Proteins: Chain-like molecules that are made up of small substances called amino acids. Muscles, organs, and the immune system are mostly made of proteins.

Protons: Very teeny particles with a positive electric charge. Protons are in the nucleus of every atom.

Ribosomes: Sphere-shaped structures inside a cell that read the cell's mRNA (messenger Ribonucleic Acid) and make proteins.

X-Ray: Invisible waves of energy that can pass through solid objects. X-ray images can show the inside of an object, such as a suitcase or a person's body.

Pre-Reading: Spanish Book Glossary

Las mujeres en la química delves into the many different disciplines in chemistry, introducing children to complex subjects and, consequently, a new set of vocabulary. This list does not need to be mastered before reading—the book and the activities in this guide will provide context and information which will clarify these terms—but familiarity with the vocabulary will improve initial reading comprehension.

The following glossary can be found on pages 38 and 39 of *Las mujeres en la química.*

ADN (ácido desoxirribonucleico): El plan genético de todas las células que tienen todos los seres vivos tales como (las plantas, animales y los humanos). En consecuencia, el ADN es la proteína que compone el cuerpo y dirige su funcionamiento.

Alquimista: Es una persona de tiempos antiguos que intentaba transformar metales ordinarios en oro o plata. El alquimista también intentaba buscar la cura para todo tipo de enfermedades.

Átomos: Los bloques fundamentales que forman nuestro universo. Las distintas combinaciones de protones, neutrones y electrones forman diferentes tipos de átomos.

Células: Son las unidades estructurales básicas de todos los organismos. Las células sostienen el equipo biológico que mantiene un organismo vivo y exitoso.

Ciclotrón: Es una máquina circular que acelara partículas cargadas eléctricamente, como los protones, a lo largo de un camino espiral. el circlotrón es usado para colisionar particulas de alta velocidad.

Cristalografía: Es una rama de la ciencia que estudia la disposición de los átomos en cristales, como sal o diamantes, que están hechos de patrones restringidos.

Electrones: Son partículas muy pequeñas que tienen una carga negativa de electricidad. Los electrones se mueven al rededor del núcleo de cada átomo.

Elemento: Un elemento es una sustancia compuesta de un tipo de átomo que usualmente no puede ser separado en otras substancias más simples.

Estructura Química: Es la manera que en la que los átomos se organizan dentro de una substancia.

Experimento: Es un estudio para recolectar información acerca del mundo para ver si una hipótesis es correcta.

Helix: Es un espiral largo, como un sacacorchos o una furtiva.

Hipótesis: Es una suposición hecha por una persona para explicar algo que se piensa cómo verdadero o posible.

Masa: La masa es una medida de cuánta materia existe en un objeto. La masa es usualmente medida en kilogramos (1 kg = un poco más de 2 libras).

Materia: Todo lo que tiene masa y ocupa espacio.

Molécula: Un grupo de átomos que se enlazan juntos.

Neutrones: Son partículas muy pequeñas con ninguna carga de electricidad. Los neutrones se encuentran en la mayoría de los átomos.

Premio Nobel: Es un conjunto de prestigiosos premios internacionales que ocurren anualmente y son reconocidos por la academia, cultura y los avances científicos. Los premios son nombrados por el científico Suizo Alfred Nobel y fueron otorgados por primera vez en 1895.

Proteínas: Moléculas parecidas a cadenas que están compuestas de partes pequeñas llamados aminoácidos.

Protones: Son partículas muy pequeñas que tienen una carga positiva de electricidad. Los protones se encuentran en el núcleo de cada átomo.

Química: El estudio de la materia y los cambios que la misma.

Rayos X: Son un tipo de radiación invisible de alta energía y de onda corta que pueden traspasar cualquier cosa haciendo que sea posible observar el interior de una cosa o un cuerpo sin la necesidad de abrirlo.

Reacción Química: Es el proceso donde la estructura de algo, tal como una molécula puede ser reorganizada.

Ribosomas: Son estructuras con forma de esfera que se encuentran dentro de la célula la cual lee el mRNA de la célula (mensajero ácido ribonucleico) y crea proteínas.

Tabla Periódica: Es un diagrama que organiza los elementos químicos. Estos son organizados de acuerdo a su número atómico. El número atómico proviene de la cantidad de protones que posee cada elemento.

Pre-Reading: Book Walk

Grades: K–5
Subject: Reading, language arts
Skills: Active listening, critical thinking, making predictions
Common Core English Language Arts: CCSS.ELA-LITERACY.CCRA.R: Key Ideas and Details

A book walk is a pre-reading activity that aids in reading comprehension and builds curiosity and enthusiasm about reading this book. It prepares students to think about the important questions they should be asking as they read. For younger students, this book walk (or picture walk) also helps develop their reading skills. They learn to use the visual text of the pictures to understand what the story means and make educated guesses about unfamiliar words.

Get set up for reading time. Have students sit in a circle so they can all see you and can talk with one another.

Tell your students that you will be reading a book called *Women in Chemistry/Las mujeres en la química*. Discuss and ask them: What do you think this book will be about?

If you have gone over the terms first, this is a perfect time to review. Ask your students questions. What is chemistry? What words do you know that are related to chemistry?

Then, show them the book's cover and ask them new questions. Now what do you think it will be about? Can they be more specific than before? Can you name the objects on the cover? What is the girl holding? What do these items have to do with chemistry?

Slowly flip through the book, page by page (or looking at a few pages you selected in advance), without reading any of the words. Ask your students questions about the pictures they see. What is going on here? What are the women doing on the page? What animals and plants do you see? What objects do you recognize? What relationship do all of these things have with science? What don't you recognize?

Give vague responses that don't give away the story. Say things like, "Are you sure about that?" or "That's possible!" or "What makes you think that?" This will plant the seed for an enthusiastic discussion while you read the book or when the reading is done.

Flip the book over and read the back cover, then start your usual read-aloud session.

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Pre-Reading: Exploring Chemistry

Grades: 2–5

Subject: Chemistry, science

Skills: Identifying, sorting, observation, active reading

Materials: *Women in Chemistry/Las mujeres en la química*

Next Generation Science Standards
ETS1.B: Developing Possible Solutions

Common Core English Language Arts
CCSS.ELA-LITERACY.CCRA.R: Key Ideas and Details

Background

Chemistry is a complex area of science. Because of this, many chemists specialize in one area of chemistry. Specialization, the process of becoming an expert on one subject, allows a scientist to study a specific subject in depth. Some subdisciplines within chemistry include the following!

Analytical Chemistry: The science of separating, identifying, and measuring matter.

Biochemistry: The study of chemical reactions and properties within living organisms and systems.

Environmental Chemistry: The study of matter and the environment.

Inorganic Chemistry: The study of chemistry in things that are not living, such as metals and minerals.

Organic Chemistry: The study of chemical reactions in compounds and materials that contain the element carbon.

Physical Chemistry: The study of the effect of chemical structure on physical things and substances.

Theoretical Chemistry: The branch of chemistry that makes predictions about chemical reactions using physics and math.

Activity

1. Go over the background information with your students. If needed, write the definitions of the subdisciplines within chemistry on a whiteboard visible to all students.

2. Flip through the pages of *Women in Chemistry/Las mujeres en la química* without reading the words. Point to specific items on the page and ask what type of chemist would study that item. With some objects there may be overlap.

3. This activity will aid in reading comprehension and build enthusiasm for the book. Once students have finished guessing, return to the beginning of the book and read *Women in Chemistry/Las mujeres en la química* aloud.

Women in Chemistry

Physical Chemistry- atoms, energy, reactions - Marie Curie
Biochemistry- cells, lipids, systems - Mildred Cohn
Organic Chemistry - carbon, living thing - Ada Yonath
Analytical Chemistry - matter, measure, identify - Nancy Allbritton
Inorganic Chemistry - metal, matter, reactions - Edith Humphry
Theoretical Chemistry - reactions, predictions, math - Odile Eisenstien

Discussion

Talk to your students about the ease or difficulty of the activity. The distinction between the different branches of chemistry is not always clear, and some can be very similar to each other. Is this overlap good?

Activity: Careers in Chemistry

Grades: 2-5

Subject: Chemistry, research, compare and contrast

Skills: Researching and Organizing

Materials: *Women in Chemistry/Las mujueres en la química*, worksheet

Next Generation Science Standards: ETS1:B Developing Possible Solutions

Background

All of the women featured in *Women in Chemistry/Las mujeres en química* are chemists. They all study how molecules interact with each other and chemical reactions. This is because there are several branches of chemistry, like physical and organic chemistry, which means there are a variety of career paths for chemists. Below are just some career paths/jobs for chemists:

Toxicologists
Chemical Engineer
Forensic Scientist
Chemistry Teacher
Bioengineer
Chemical Technician
Water Chemist
Analytical Chemist
Synthetic Chemist
Hazardous Waste Chemist
Pharmacologist
Agricultural Chemist
Epidemiologist
Environmental Consultant

Activity

1. Read *Women in Chemistry/Las mujeres en la química* to your students, as well as the background information above.

2. Have students choose and research two careers from the list above. Ask them to take notes on how those careers are similar and how they are different. Some categories to pay attention to are educational requirements, skills needed, and branch of chemistry.

3. Ask the students to fill out the template found on the next page, to compare and contrast the two careers.

Discussion

Ask your students why they chose the two particular careers. What was similar about them and what was different? What did they like and dislike about them? Do they think that either of them is the career that they would like to pursue when they grow up?

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Name____________________ Date:_______

Compare and Contrast: Careers in chemistry!

____ and

________________________________ are similar because...

____

____

____

____ and

________________________________ are different because...

____

____

____

Activity: Branches of Chemistry

Grades: 2-5

Subject: Chemistry, research, sorting

Skills: Researching and Organizing

Materials: *Women in Chemistry/Las mujueres en la química*

Next Generation Science Standards:
ETS1:B Developing Possible Solutions

Background

Chemistry is the scientific study of elements and compounds made of atoms, molecules, and ions, as well as the changes that compounds go through during reactions. Rarely is there a chemist who studies just one branch of chemistry, just like the women in *Women in Chemistry/Las mujeres en la química*. There are different disciplines of chemistry that scientists can specialize or work in. Take a look at the list below:

Agrochemistry: the study and application of chemistry and biochemistry for agricultural needs.
Astrochemistry: the study of the abundance and reaction of chemical elements and molecules in the universe and their reaction with radiation.
Chemical Engineering: a branch of engineering that applies physical or life sciences in chemistry to convert chemicals to more valuable forms.
Chemistry Teacher: someone who educates people on several topics of chemistry, such as chemical reactions, the periodic table, and subatomic particles.
Electrochemistry: the study of chemistry that focuses on the reaction between a conductor of electricity and an electrolyte.
Environmental Chemistry: the study of chemical effects in the different aspects of the environment such as the air, water, and soil.
Geochemistry: the chemical study of the major systems of geology.
Medicinal Chemistry: a discipline that applies chemistry for medicinal purposes.
Neurochemistry: the study of neurochemicals and the role they play in formatting, maintaining, and modifying the nervous system.
Nuclear Chemistry: the study of how subatomic particles come together to form nuclei.
Photochemistry: the study of chemical reactions that proceed with the absorption of light by atoms and molecules.
Radiochemistry: the study of the chemistry of radioactive materials.
Sonochemistry: the study of the effect of sonic waves and wave properties of chemical systems.
Synthetic Chemistry: the study of chemicals produced artificially.
Thermochemistry: the study of the relationship between chemical action and the amount of heat absorbed or generated.

Activity

1. Read *Women in Chemistry/Las mujeres en la química* to your students, as well as the background information above.
2. Ask students to get into pairs or groups to discuss the different branches of chemistry. Specifically, ask them to come up with careers in each branch. Once they have had time to come up with specific careers, ask them to come up with information about one career for one branch. Ask them to present their findings to the class.

Discussion

Ask your students why they chose that particular career. What did they like or dislike about their chosen career, and what did they like or dislike about the other chosen careers? What did they find similar or different about their careers and others?

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Activity: Tools of the Trade

Grades: 2-5

Subject: Problem solving, scientific tools, variety of organisms, chemistry

Skills: Identifying, sorting, observation, active reading

Materials: *Women in Chemistry/Las mujeres en la química*

Next Generation Science Standards
LS4.D: Biodiversity and Humans
ETS1.A: Defining and Delimiting an Engineering Problem

Common Core English Language Arts
CCSS.ELA-Literacy.CCRA.R: Key Ideas and Details

Background

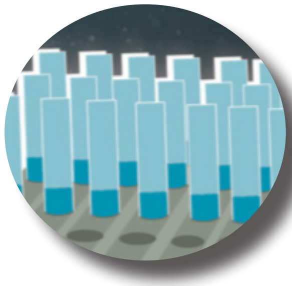
All science is about solving problems. Part of the process is deciding on which tools will help scientists find the solution. Tools help us study chemicals and their reactions safely. A tool is an object used to extend the ability of an individual to modify features of their environment. There are many types of equipment to help scientists observe, measure, gather, and collect data. Once all the data has been gathered, there are different tools that are used to make sure that the data is logical, clear, and concise, so it can be shared with the world.

Scale, Thermometer, and Graduated Cylinder
These tools are used for measuring the mass of the elements chemists are studying.

Safety Glasses
These help protect the eyes when chemists are working with chemicals during an experiment.

Pipet, Scoopula, Funnels
Chemists use these to transport liquids to make sure the samples aren't contaminated.

Charts, Diagrams, Drawings, Journals
Chemists use these to record, organize, and present their research.



Test Tubes
These are used in the mixing, measuring, and heating of liquids during the work of a chemist.

Microscope and Slides
Microscopes help scientists look closely at an organism by magnifying it, even something as small as a cell.

Activity

1. Go over the background information and types of tools with your students.

2. Read *Women in Chemistry/Las mujeres en la química*, pay specific attention to the kinds of tools the scientists are using. Ask your students the following questions: What tool is this? How and why is it being used? Do we have these tools in our school? Could a different tool be used here? How does this tool help you?

Expanding the Activity

To cement your students' knowledge, name chemicals or objects not in the book and ask what tool could be used to study them. Try to get them to think outside of the box and use tools that weren't in the book either. For example, pick an object that is high up in the room and out of reach. Can your students recognize the need for a ladder?

More Tools

Bunsen burner, stricker, gloves, labcoat, stirring rod, balance, evaporating dish, mortar and pestle, calculator, periodic table, first aid kit, crucible, flask, notes, charts, ring clamp, wash bottle, watch glass

Discussion

Do the students recognize the different uses of these tools? Do your students know any other branches of science that uses these tools?

Section 2: In the Lab with the Women

The women in this book have been carefully chosen to illustrate the importance of women's contributions in the field of chemistry and in the world. Their discoveries play an essential role in the way we go about our daily lives, impacting our understanding of everything from medicine to genetics.

The activities in this section allow students to further delve into these women's discoveries and conduct experiments of their own.

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Cleopatra the Alchemist

Third or Fourth Century

Egypt

Alchemy

Most known for her work with measurements and inventing a way to distill, or purify, liquids.

Who Is Cleopatra the Alchemist?
Not much is known about Cleopatra the Alchemist outside of her contributions to chemistry. Historians do know that she lived in Alexandria, Egypt during a period of time when many women were allowed and even encouraged to practice science—which was not common in other parts of the world. Cleopatra the Alchemist was a Greek alchemist, author, and philosopher who lived in the 3rd or 4th century. She is not the same Cleopatra who ruled Egypt in mid-1st century BCE. She is credited with inventing the alembic, which was used to distill, or purify, liquids. Only three of Cleopatra's works remain: *A Dialogue of Cleopatra and the Philosophers*, *On Weights and Measures*, and *Chrysopoeia (changing matter into gold) of Cleopatra*.

An Alchemist's Goals
Alchemy is the science that preceded and led to chemistry. The main goals of alchemy were to create or find a) a liquid that could bring wealth, health, and immortality; b) a substance called the "Philosopher's Stone" that could turn metal into gold; c) to understand the relationships between humans and the universe. In addition to these large goals, alchemists also used physics, medicine, astrology, philosophy, and more to investigate the world.

From Alchemy to Chemistry
Alchemy was primarily concerned with states of matter and interactions in the world. This knowledge could not be gained without an understanding of chemical reactions and processes. Though the greater quests of alchemy were abandoned in the Enlightenment, a period of time in the 17th and 18th centuries that placed an emphasis on reason and logic, the study of chemical reactions and processes was continued and encouraged. Modern chemistry would certainly not be where it is today without alchemy.

Information adapted from the American Chemical Society.

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Activity: Measure It!

Grades: K–3

Subject: Measurements, accuracy, precision

Skills: Measuring, observation, critical thinking

Materials: Paper, items to measure, and Legos, blocks, or bricks

Next Generation Science Standards
ETS1.A: Defining and Delimiting Engineering Problems

Background

Accurate and precise measurement is a necessity in chemistry. ***Accuracy*** refers to how close a measurement comes to a perfect measurement, and ***precision*** refers to how consistent a series of measurements is. Chemists often work with unstable and complex materials, so they would never grab a handful of chemicals without knowing how much they were taking. Scientists realized they needed to standardize measurements so they made common and consistent systems for measuring. This allows scientists from different parts of the country to easily interpret and repeat each other's experiments.

Activity

1. Go over the background information with your students and read Cleopatra's section in *Women in Chemistry/Las mujeres en la química*.

2. Before the activity begins, come up with a list of items or bring in items for students to measure. There should be as many of each item as there will be groups of students.

3. Divide students into groups and seat them at different stations through which the items will be rotated. Give each group a pile of Legos, blocks or bricks. They will need to have enough to measure the tallest item you have selected. Students will stack the bricks and count how many bricks tall an item is.

4. Have students divide a piece of paper lengthwise. On one side they will write the name of the object they are measuring; on the other side they will write how many bricks tall an item is.

Discussion

After every group has measured each item, write the item names on a whiteboard. Beneath each item, write the measurement that each group came up with. Then, ask the students if the class results were precise. If all answers are similar, the results are precise.

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Activity: Making Dough

Grades: 3–5

Subject: Measurements, accuracy, precision

Skills: Measuring, observation, critical thinking

Materials: Flour, salt, cream of tartar, hot water, cooking oil, food coloring, measuring cups, bowls

Next Generation Science Standards
ETS1.C: Optimizing the Design Solution
PS1.B: Chemical Reactions

Background

Chemistry might seem like something that is beyond the grasp of everyday people, but the truth is that chemistry happens in people's kitchens quite often. It is a misconception that all chemicals are toxic and should be avoided. Table salt and even water are chemicals! Heating, freezing, cutting, mixing and blending are all processes that can be found in a laboratory and a kitchen.

Activity

1. Go over the background information with your students. Tell them that they will be using chemistry to make their own play-dough.

2. Depending on the age group of students, have them measure the ingredients themselves or provide help.

3. Combine the dry ingredients first, then add the wet. Mix with hands until the desired consistency.

2 cups flour	1 cup of hot water
1/2 cup salt	2 tbsp cooking oil
2 tbsp cream of tartar	Food coloring

4. After students have mixed their ingredients, ask them to see if their play-dough is too dry or too wet. If it is too dry, ask them what ingredient they think they should add (water). If it is too wet ask what would make it dry (flour). Add these extra ingredients in small amounts until the desired consistency is reached.

Additional Information

Molecular gastronomy is a field which combines food with science to an even higher degree. Chefs who specialize in this area investigate the chemical and physical processes of cooking. To become a molecular gastronomist, a chef must study principles of chemistry—such as states of matter, the behavior of heat and energy, solubility problems—in addition to their culinary education. Some results of molecular gastronomy include creating new food textures, such as gels and foams, and making dishes that are frozen on the outside but hot and liquid in the center.

Information about molecular gastronomy was adapted from the article "Molecular Gastronomy – The Food Science."

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Activity: Imitating Alchemy

Grades: K–5

Subject: Chemical reactions, alchemy

Skills: Measuring, following instructions, active listening

Materials: Dull pennies, paper cups, vinegar, liquid soap, paper towels

Next Generation Science Standards
PS1.B: Chemical Reactions

Common Core English Language Arts: CCSS.ELA-LITERACY.CCRA.R: Key Ideas and Details

Background

One of the main goals of alchemy, the precursor to chemistry, was to create the "philosopher's stone." Alchemists believed that this stone would be able to turn any solids into gold. Scientists no longer believe this to be a worthy pursuit, but chemists are able to create many kinds of change with different chemical reactions. A ***chemical reaction*** is the change that occurs when different chemical substances interact with each other.

Activity

1. Go over the background information with your students and read Cleopatra the Alchemist's biography on page 27 of this guide.

2. This activity can be done as a demonstration or in groups. Have students guess whether soap or vinegar will clean a penny the best.

3. Place a penny in two cups. Pour soap in one cup and vinegar in the other, making sure both coins are completely covered. Wait at least 10 minutes, then remove the pennies, rinse them in water, and rub them with a paper towel.

4. Compare the pennies and determine if the students guessed correctly at the beginning of the activity.

How It Works

Pennies are mainly made of copper, which grows dull over time from the oxygen in the air. When oxygen and copper mix, they form the dark substance on pennies, which is called copper oxide. Vinegar is an acid, which eats away at copper oxide and leaves the copper surface looking shiny. Soap, unlike acidic liquids, can't dissolve copper oxides.

Expand the Activity

Bring different acidic liquids, such as lemon juice, pickle water, and cola, to test which acid cleans pennies the best. Have students guess which will be the most effective before testing the different juices to find the results. After the pennies have been cleaned, ask students if they think the liquid that worked the best is the most or the least acidic. Another variable to introduce is time. What happens when you leave a penny in the acidic solution for 30 seconds compared to one minute? One hour compared to one day?

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Marie-Anne Paulze Lavoisier

1758–1836

France

Chemistry

Most known for her scientific drawings and translations.

Information adapted from the webpage History of Scientific Women.

Power Couple

Marie-Anne Paulze was born in Loire, France in 1758. Her mother died when she was 3 and she was placed in a convent where she received her formal education. She was married to 28-year-old nobleman and scientist, Antoine Lavoisier, when she was only 13. As a teenager, she studied chemistry, managed and worked in her husband's laboratory, and created scientific drawings. She assisted him by translating documents about chemistry from English into French, which he would then study and analyze. Together, the Lavoisiers changed chemistry from a science that still relied heavily on principles of alchemy into the beginnings of what it is today.

More Than a Translator

Paulze had mastery over the French, Latin, and English languages, which allowed her to translate many different scientific texts. As she translated different works, she added notes and critiques along the way. Her husband relied on these notes and translations for the work he did in the laboratory.

Chemistry as We Know It

In 1789 Lavoisier published the *Elementary Treatise on Chemistry* with the help of Pauleze. The treatise was the first work to present a unified view of chemistry and is considered the first modern chemistry textbook. Paulze contributed thirteen drawings of laboratory equipment and instruments they used in their research and experiments. Her notes and tidy records of laboratory procedures also gave credibility to the work.

A Turn for the Worse

During the Reign of Terror, a particularly violent period during the French Revolution, Paulze's husband was accused of being a traitor. She worked hard to prove his innocence, pointing out that his contributions to science were worth keeping him alive, but he, along with her father, were guillotined on May 8, 1794. Even after his death, Paulze worked to gather Lavoisier's research and defend his name.

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Activity: Poundcakium

Grades: K–5

Subject: Elements, atoms

Skills: Critical thinking, active listening, inference

Materials: Pound cake, knife, gloves, copper wire

Next Generation Science Standards
PS1.A: Structure and Properties of Matter

Background

Chemistry is the study of matter, and matter is made up of atoms. An ***atom*** is the smallest particle of an ***element***, which is a material consisting of the same types of atoms. A ***compound*** is a material consisting of two or more elements that are chemically bound together.

Activity

1. Go over the background information with your students.

2. Present the pound cake to the students and tell them to imagine that it is a new element "poundcakium." Ask students to describe it's characteristics, and lead them to realize that it is all one flavor, texture, and color (at least on the inside).

3. Cut the cake in half. Ask students if the cake is still poundcakium. The answer is yes, but it has been cut into two pieces.

4. Cut it in half again. Ask what it is now. It is still poundcakium. Continue this process until it is clear your students have grasped this concept. Show them a single crumb and ask if any poundcakium has been destroyed or created. The answer is no: cutting poundcakium does not make it into something else.

5. If desired, serve students the pound cake. After, ask students what they think pound cake is made of. Then, read the recognizable ingredients on the pound cake label.

6. Tell students that flour, sugar, milk and eggs etc. are made up of elements. Hold up the copper wire and explain that elements are made up of a single kind of atom. The copper wire has only copper atoms. If the copper is cut, it is still copper, just like the poundcakium.

Discussion

Ask your students if poundcakium is an element. They should answer that they were pretending it was an element for the activity. Then ask if pound cake is an element. The answer is no, it is a compound made of different ingredients.

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Activity: Element Bottles

Grades: K–5

Subject: Elements, atoms

Skills: Critical thinking, active listening, inference

Materials: Beads of different colors (see page 40), measuring spoons and cups, clear cups, bottles, or containers, Element Composition Key (page 41)

Next Generation Science Standards
PS1.A: Structure and Properties of Matter
ETS1.B: Developing Possible Solutions

Background

Most elements can be found anywhere on Earth, but they came from different places. Many elements were created in the Big Bang, the rapid expansion of matter that marked the beginning of our universe. ***Oxygen***, which humans need to breathe, and ***Carbon***, which is present in all organic material and is one of the most common elements in the world, was made by nuclear fusion in the interior of stars. Scientists are still researching and observing this topic because they are not certain where all the elements, such as copper, originated.

Activity

1. Go over the background information with your students and read *Women in Chemistry/ Las mujeres en la química* with them. This activity can be done as a demonstration for younger students.

2. Break students into groups. Pass out the Element Composition Key (page 41 of this guide), a set of beads, measuring cups and spoons, and three cups to each group.

3. Tell students they will be creating a model of the elemental composition of three different objects: the sun, the human body, and Earth's atmosphere.

4. Then, instruct students to pour beads into the cups according to the measurements on the Element Composition Key.

5. When the models have been completed, have students discuss the similarities and differences in elemental composition among the three objects.

Discussion

Ask your students why they think it is important to create ***models*** in science. What does the term 'model' mean to them? Lead them to realize that not everything in science can be seen because it is too small or is a reaction that happens too quickly for the human eye to see. Models help scientists visualize and study different concepts in science. Ask your students what they think makes a good model. The most useful models explain, predict, and accurately represent an object or process.

Activity continues on the following page.

Expand the Activity

For this demonstration, each element will again be represented by a different color of bead. You will need seven different colors of beads and a small scoop. Start with a bowl full of 50 scoops of clear beads, which represent the 90% abundance of hydrogen in the universe. Then, add the following beads while telling your students what element they represent.

5 scoops of light blue beads (to represent 9% abundance of helium)
3 scoops of dark blue beads (to represent 0.08% abundance of oxygen)
2 scoops of black beads (to represent 0.03% abundance of carbon)
1 scoop of green beads (to represent 0.01% abundance of nitrogen)
1 scoop of orange beads (to represent 0.01% abundance of neon)
1 scoop of pink, purple, red, and yellow beads in roughly equal amounts
(to represent 0.01% abundance of magnesium, silicon, iron, and sulfur together)

Element Composition Key

Color Key

Hydrogen (H):	clear beads	**Carbon (C):**	black beads
Helium (He):	light blue beads	**Nitrogen (N):**	green beads
Oxygen (O):	dark blue beads	**Argon (Ar):**	white beads

Composition Key

Human Body

H	61.6%	1/2 C
O	26.3%	3 tbsp + 1 tsp
C	10.0%	1 tbsp
N	1.5%	1 tbsp

The Sun

H	92.1%	1/2 C + 3 tbsp + 1 tsp
He	7.8%	4 tsp

Earth's Atmosphere

N	78.0%	1/2 C + 1 tbsp
O	21.0%	2 tbsp + 2 tsp
Ar	1.0%	1/2 tsp

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Dawn Shaughnessy

1972–Present

United States

Nuclear Chemistry

Most known for discovering six new elements.

Discovering Elements
Dr. Dawn Shaughnessy currently leads the Nuclear and Chemical Sciences Division at Lawrence Livermore National Laboratory in California. Before working there, however, Shaughnessy led a team of scientists that discovered six new elements. One of these elements, named Livermorium in honor of the research lab, is now the heaviest known element. The number of protons in an atom determines an element's identity, so scientists try to create new elements by finding ways to force more protons into an atom's nucleus. One way to do this is using a particle accelerator, which slams atoms together at a high speed.

The Periodic Table
The periodic table is one of the most important tools a chemist can use. The table organizes elements according to atomic structure and properties. Scientists like Shaughnessy study the periodic table to make guesses about what elements have yet to be discovered and make predictions about how new elements can be created. An element's atomic number is the number of protons found in the nucleus. The highest atomic number found in naturally occurring elements is 92. Elements with atomic numbers 93 to 118 have to be made in laboratories.

Real-life Alchemy
Alchemy hasn't been practiced since medieval Europe, but Shaughnessy's work is as close as it gets. Rather than turning lead into gold, like alchemists sought to do, Shaughnessy found a way to turn the element plutonium into an element that hadn't been discovered yet: flerovium. In an interview with UC Berkeley, where Shaughnessy completed her Bachelor's degree in chemistry, she said that her work with nuclear chemistry "was like alchemy… you could take things, put them together, and make something totally new out of it."

Split Second
Creating new elements helps scientists have more knowledge about the world, yet studying them can be very difficult. Elements with such a high number of protons only last a few seconds before breaking apart! This means that many of the new elements Shaughnessy has helped create haven't been studied yet, as they have only existed for seconds at a time. When more protons are added to a nucleus, the atom becomes unstable, meaning that it falls apart quickly after struggling to maintain balance.

Information adapted from Gizmodo UK.

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Activity: Atom Smashers

Grades: K–5

Subject: Atoms, atomic structure, particle accelerators

Skills: Critical thinking, active listening, inference

Materials: Clear latex balloons, pennies

Next Generation Science Standards
ETS1.A: Defining and Delimiting Engineering Problems
PS3.C: Relationship Between Energy and Forces
PS3.A: Definitions of Energy

Background

A particle accelerator uses electric currents and magnetic fields to make atoms move at high speeds through circular pipes. When accelerators were first invented, they were often called atom smashers, because people wanted to use them to create collisions between two nuclei (the plural of nucleus is nuclei). The faster an object moves, the more energy it possesses, and when objects collide there is a transfer of energy.

Activity

1. Go over the background information with your students and read Dawn Shaughnessy's Biography (page 43 of this Guide). Tell them that they are going to make a simple model of a particle accelerator. For younger students, this can be done as a demonstration.

2. Have students place a penny inside of a latex balloon. Once it is inside, inflate the balloon and tie it off. Younger students may need help with this step.

3. Ask your students to shake the balloon left to right while holding onto its sides. The penny will start spinning around in the balloon extremely quickly. Note that balloons will pop after a few minutes of use due to the penny's motion.

Additional Information

Ask your students why they think particle accelerators are important in the world. Students should be able to understand that they help scientists make new discoveries, but accelerators are also used in the medical field to help diagnose medical patients and in industry to create items such as computer chips.

Activity: Collision Course

Grades: K–5

Subject: Elements, periodic table, forces

Skills: Critical thinking, counting, research

Materials: Black and white marbles (you will need more black than white), open floor space, periodic table (page 49)

Next Generation Science Standards
PS2.B: Types of Interactions
PS3.C: Relationship Between Energy and Forces

Background

In the last 75 years, scientists have added an additional 24 elements to the periodic table, which had previously only listed elements that could be found in nature. Regardless of how many neutrons and electrons an atom has, the periodic table defines an element based on the number of protons it has. For example, all atoms with six protons are carbon, no matter how many neutrons and electrons are present. Scientists create a new element by forcing more protons into an atom's nucleus.

Activity

1. Go over the background information with your students and read Dawn Shaughnessy's Biography (page 43 of this Guide).

2. Tell students they will be modeling the way elements are created using marbles. The black marbles represent protons, and the white marbles represent neutrons.

3. Break students into small groups and have them spread out on the floor (this can be done on a table, but marbles will often fall to the floor). Give each group a pile of both colors of marbles and a periodic table (page 49 of this Guide).

4. Have students group some or all protons and neutrons in a tight circle, being sure to leave at least one proton out. This circle represents the nucleus of an atom.

5. Have students count how many protons are in their nucleus. Then, tell them to find that number on the periodic table and to note what element they have formed.

6. Then, tell students to fire a proton into the nucleus by rolling it quickly towards the circle. Marbles will shoot various places and students should carefully collect all of these strays. Then, have students recount the number of protons in their circle. Do they have the same element?

7. Repeat steps 4–6 multiple times. Vary the speed with which a proton is fired into the nucleus. Discuss what technique makes the proton stick in the nucleus the best.

Activity continues on the following page.

Fun Fact

Stars create new elements in their cores. This process is called nuclear fusion. Eventually the star creates so many elements that its core is packed full of matter which causes the star to explode. This explosion creates even more elements.

Additional Information

In physics, a ***force*** is something that pushes or pulls an object. Chemistry, the study of matter, uses principles of physics to determine why matter behaves a certain way. To make an element, a chemist must use the perfect amount of force. The faster and heavier an object is, the more force it has. The first law of motion, discovered by Isaac Newton, explains that an object at rest will stay at rest, and an object in motion will stay in motion, until an outside force acts on it. Can your students see how this law relates to the marble activity? The proton and neutron marbles will stay motionless, or at rest, until the force of the extra proton moves them.

Background information adapted from the PBS article "How to Make an Element."

Group → / Period ↓	1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																		2 He
2	3 Li	4 Be												5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg												13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca		21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr		39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	*	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	**	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og
			*	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb		
			**	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No		

Link to periodic table: https://commons.wikimedia.org/wiki/File:Simple_Periodic_Table_Chart-blocks.svg

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Activity: Element Scavenger Hunt

Grades: 2–5

Subject: Elements, atoms

Skills: Critical thinking, inference

Materials: Shoe box or box with dividers, Element Scavenger List (page 53)

Next Generation Science Standards
PS1.A: Structure and Properties of Matter

Background

The periodic table is a list of the elements according to the structure of their atoms. The chart reads from left to right and top to bottom, and the elements are arranged by their atomic number. An atomic number is the number of protons in each atom. Elements are also placed in groups, arranged by columns that link elements together according to their properties. Some groups include noble gases, alkali metals, earth metals, transition metals, and nonmetals.

Activity

1. Go over the background information with your students and read *Women in Chemistry/Las mujeres en la química.*

2. Tell students that they will be going on an Element Scavenger Hunt. This can be done either at home or at school. Regardless, students will need to bring their items into the classroom after the search is completed.

3. Hand out the Element Scavenger Hunt List found on page 53 of this Guide. Tell students they should try to find one item from around their home (or whatever area you designate) for each element listed. If they cannot find all of the elements, that is okay. Consider having a prize for the student who finds the most.

4. Students will put their finds in a box and return to class. Have students break into groups to share their finds. If desired, have students label their finds and present them to the entire class.

Discussion

Ask students if they were surprised about how many elements were easy to find. Then ask them if the elements they found are pure or part of a compound. (This is a great activity to pair with Poundcakium, found on page 37 of this Guide, which demonstrates the difference between an element and compound.) Most of the items brought in will be compounds. Atoms are the building blocks of everything in the world, which means that the air we breathe, cats and dogs, mountains and rivers, are all made of atoms and elements.

Element Scavenger Hunt List

This is not an exhaustive list. There are many more elements, and many more items that could work for the elements on this list.

Iron (Fe):	Iron nails, iron pans, cereal, etc. Steel is a compound with iron inside, so steel wool, food cans, etc.
Copper (Cu):	Copper piping, pennies, electrical wire etc.
Gold (Au):	Gold nuggets, gold jewelry, gold leaf, etc.
Silver (Ag):	Silver jewelry, silver coins, silver leaf, etc.
Aluminum (Al):	Tin foil, knitting needles, drink cans, etc.
Carbon (C):	Coal, pencil lead, diamonds, etc.
Zinc (Zn):	US pennies made after 1982 have zinc in them.
Potassium (K):	Bananas, hardwood ashes, avocado, etc.
Chlorine (Cl):	Chlorine tablets for pools or water purification.
Sodium (Na):	Table salt.
Oxygen (O):	An empty bottle or jar with a cover
Flourine (F):	Toothpaste.
Calcium (Ca):	Bones, teeth, shells, etc.
Phosphorus (P):	The heads of matches.

This list was adapted from the article "Homeschool Nature Table."

Rosalind Franklin

1920–1958

England

Physical Chemistry

Most known for her X-ray photography and role in discovering the double helix structure of DNA.

A Tense Partnership
Dr. Rosalind Franklin was born in London in 1920. She studied chemistry at Cambridge, where she received her PhD. Franklin was recruited to research DNA with Maurice Wilkins in the late 1950s. The duo did not get along: while Wilkens was quiet and reserved, Franklin was headstrong and used debate as a tool to further her pursuits. Franklin and Wilkens were also given different instructions when hired by their laboratory. Wilkens thought Franklin was merely an assistant, while Franklin believed they had equal claims on the research. They joined with Francis Crick and James Watson to study the structure of DNA. Much of the controversy surrounding this group's research stems from the hostility between Wilkins and Franklin.

Double Helix
The double helix shape refers to the structure of DNA. The shape is typically described as a twisted ladder. The discovery of this shape by Franklin, Wilkins, Crick, and Watson led to the creation of modern molecular biology, an area of science which deals with understanding the relationship between genes and chemical processes within cells.

Controversy of a Photograph
There is much controversy surrounding the discovery of DNA's double helix structure. Franklin was an expert in using X-ray crystallography to take images of molecules. She applied this knowledge in her research to discover the structure of DNA. One particular image, known as Photo 51, captured an almost perfect image of DNA's double helix structure. Wilkens, Crick, and Watson used this image in an article and model they published without Franklin's knowledge or consent. The three men were awarded a Nobel Prize in 1962 for their work, while Franklin's work went largely unrecognized. It remains debated today whether Franklin should have also received the award, and if Franklin's image was stolen or not. She died of ovarian cancer at age 37.

Sexism and Science
Many people believe Franklin's lack of recognition stemmed from sexism, defined as discrimination against a specific sex that is typically women. Franklin certainly lived in a time where women had to fight hard for representation in all areas of academics. Her own father, in fact, was very hesitant to let her pursue higher education—something he thought should be reserved for men. As an undergraduate at Cambridge she was unable to earn a Bachelor's degree, for they were only given to men. Rosalind was also Jewish, and watched as the British government capped the number of Jewish immigrants while she was at Cambridge during WWII.

Information adapted from the articles "Women in Science: Remembering Rosalind Franklin" and "Rosalind Franklin: A Crucial Contribution."

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Activity: DNA Model

Grades: 2–5

Subject: Subjects: DNA, models

Skills: Critical thinking, building

Materials: Twizzlers, toothpicks, four colors of mini gumdrops

Next Generation Science Standards
ETS1.B: Developing Possible Solutions
LS1.A: Structure and Function

Background

DNA, or deoxyribonucleic acid, is held within the nucleus of a cell. It has the important job of telling cells how to function and what to do. DNA is also what causes every individual to be different. This is because DNA carries genes, which control the traits of an organism, such as color, behavior, and more.

DNA is made up of four nucleotides, Adenine (A), Thymine (T), Cytosine (C), and Guanine (G). These four nucleotides are held together by a backbone of sugars and phosphates that give DNA its double helix structure. Adenine is always paired with Thymine, and Cytosine with Guanine.

Activity

1. Go over the background information with your students and read Rosalind Franklin's Biography (page 55 of this guide).

2. Each student should have two Twizzlers and all four colors of gumdrops. Have students sort gumdrops into piles based on color. Tell students to designate each color one of the four nucleotides. Remind them that Adenine and Thymine are always paired together and so are Cytosine and Guanine.

3. Then, tell students to push a toothpick through two gumdrops, keeping in mind that the gumdrops must stay in the correct pairs.

4. Next, have students push the two Twizzlers on either end of the toothpick. The result should look like a rung on a ladder.

5. Have students repeat steps 3–4 until they have a complete ladder. Remind them that the DNA model can have endless combinations, but the pairs must stick together.

6. Have students gently twist the top and the bottom of the model in opposite directions to form the double helix structure.

Discussion

Look up Photo 51, the first photo of DNA taken by Rosalind Franklin, and show your students. Discuss with them how similar it looks to the double helix structure they made.

Activity: Design a Dog

Grades: 3–5

Subject: DNA, cell biology, genetics, genetic variation

Skills: Identifying, researching, sorting, analysis, inference

Materials: Envelopes, genetic code key (page 61), DNA symbols (page 63), paper, and drawing materials

Next Generation Science Standards
LS3.A: Inheritance of Traits
LS3.B: Variation of Traits

Background

Genetics is the study of how genes and traits are passed down from one generation to the next. Genetics affects characteristics such as hair color, health, gender, and personality traits. Genetic information is carried in DNA, the blueprint and building blocks of all organisms. DNA is made up of four coding molecules, the order of which determines the genetic code. The DNA of humans is located in 23 pairs of chromosomes; one chromosome from each pair is inherited from each parent.

Activity

1. Go over the background information with your students and review Franklin's Biography (page 55 of this Guide).

2. Students will be broken into groups, but before the activity begins, prepare an envelope for each group. Each envelope should have three cards in it: one card for each of the three "DNA" symbols (page 63 of this Guide).

3. Hand out one genetic code key (page 61 of this Guide) and one envelope to each group. Each student should also be given a blank piece of paper on which to draw their dog.

4. Each group will draw one card from the envelope at a time, creating a pattern of three symbols. The pattern will correspond to a characteristic on the genetic code key. Return the cards to the envelope and repeat for each part of the dog: head, ears, body, tail, and color. Students will draw their dog according to the patterns they picked from the envelope, therefore each group will have a different-looking dog at the end.

5. End the activity with a discussion about genetic variation and DNA with help from the Teacher's Guide.

Discussion

Genetic variation is an important part of evolution. Natural selection, the process by which the organisms best adapted to their environment survive and reproduce, relies on genetic variation to ensure the survival of the population. Tell your students to imagine a world where every turtle had the same type of lumpy shell. What would happen if a disease that killed all lumpy-shelled turtles were to spread? Turtles would become extinct. Now imagine the same scenario but with turtles that have all kinds of shells: lumpy-shelled turtles might die, but some turtles would still survive. Genetic diversity makes living things more resilient to environmental changes.

This activity was adapted from Teach Genetics Utah.

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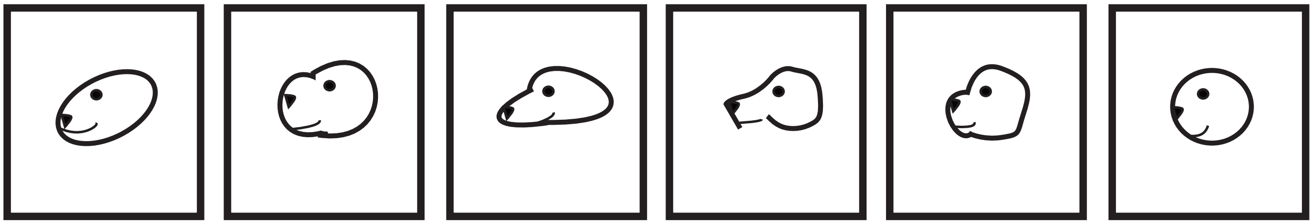
Design a Dog: Genetic Code Key

Head Shape

☆○⬢	○⬢☆	⬢☆○	⬢○☆	○☆⬢	☆⬢○

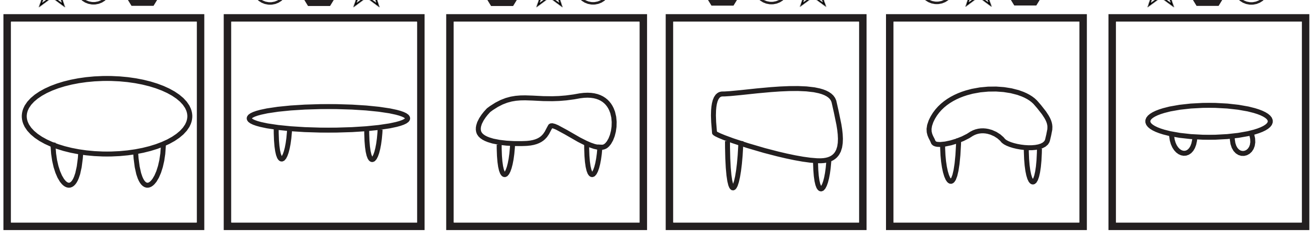


Ear Shape

☆○⬢	○⬢☆	⬢☆○	⬢○☆	○☆⬢	☆⬢○

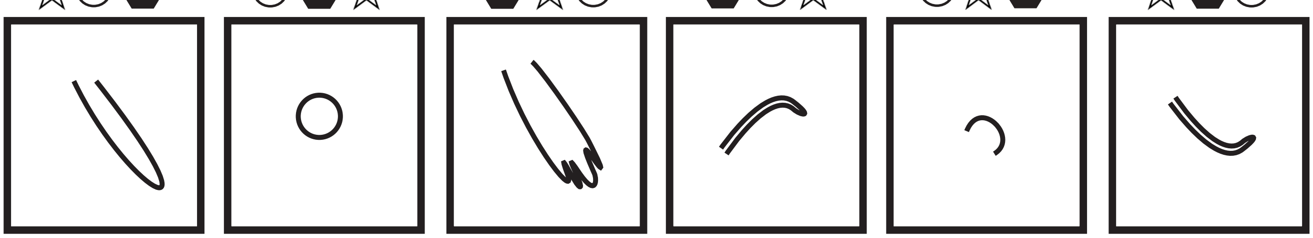
Body Shape

☆○⬢	○⬢☆	⬢☆○	⬢○☆	○☆⬢	☆⬢○



Tail Shape

☆○⬢	○⬢☆	⬢☆○	⬢○☆	○☆⬢	☆⬢○



Color

☆○⬢	○⬢☆	⬢☆○	⬢○☆	○☆⬢	☆⬢○
RED	BROWN	BLACK	YELLOW	BLACK AND WHITE SPOTS	GREY

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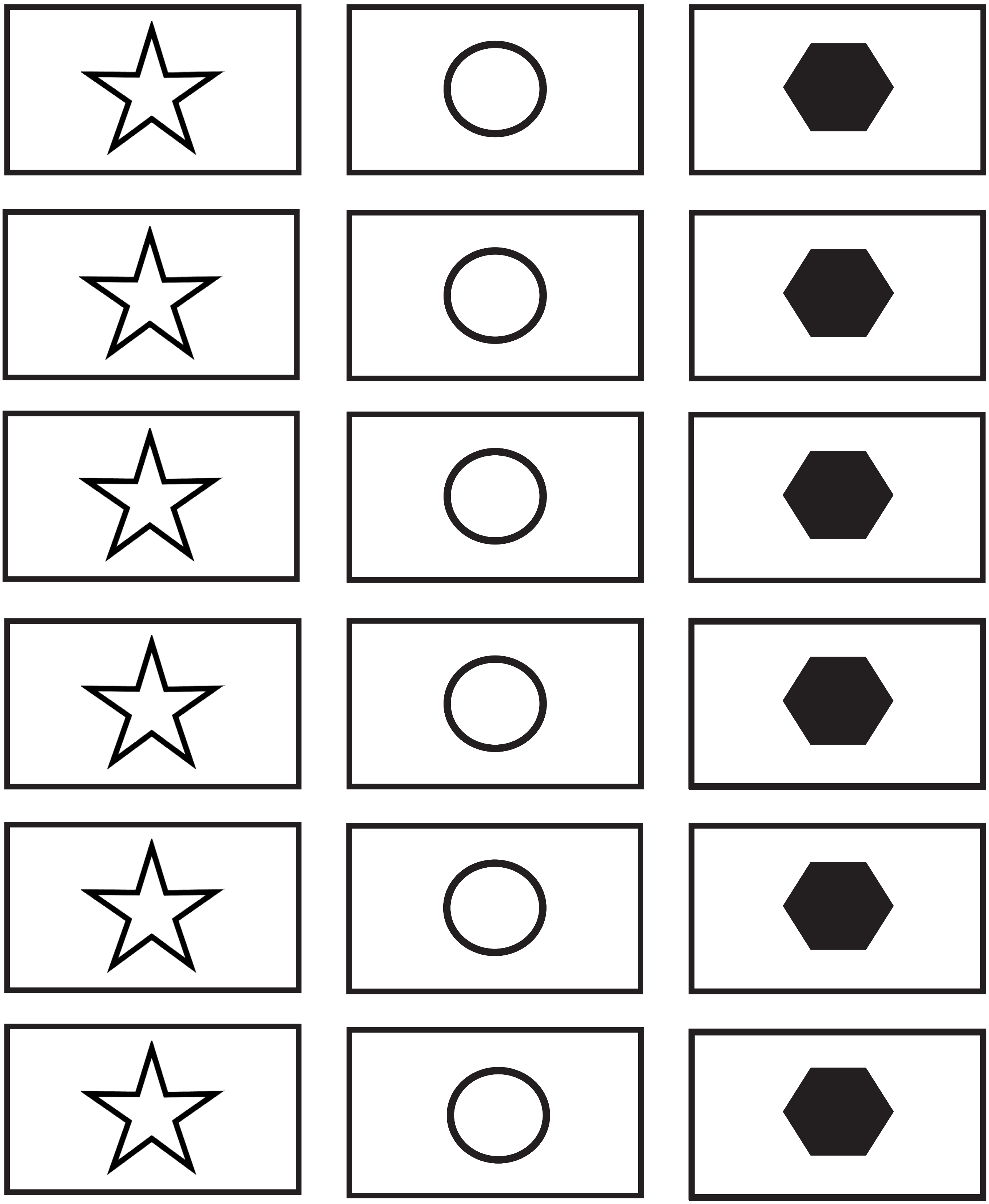
Design a Dog: "DNA" Symbols



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Ada Yonath

1939–Present

Israel

Bio-crystallography

Most known for her work on the structure of ribosomes.

Information adapted from the article "Ada E. Yonath" on The Nobel Prize website.

Influence on Medicine

Dr. Ada Yonath was the fourth female to receive the Nobel Prize for Chemistry and the first Israeli woman to win in any category. It was Yonath's work on mapping the ribosome that won her the award. The ribosome plays an important role in the body's maintenance of health, which is why Yonath's work has led to developments in medicine, specifically in the creation of antibiotics and understanding of antibiotic resistance.

Humble Beginnings

Yonath was born into a very poor family in Jerusalem. Her family rented a single room in an apartment, which they shared with two other families. When she was 11, her father passed away, and she began to begin working while going to school. In exchange for her school's tuition, she taught students in math and chemistry and cleaned the chemistry lab.

Polar Bears

Part of Yonath's research was heavily influenced by a study done on polar bears. When polar bears go into hibernation, their ribosomes stack together in order to stay in good condition. Yonath believed that this was proof that ribosomes could crystalize. If they were complex enough to stack themselves, she believed that they would be able to crystallize. She was able to crystallize them by freezing the ribosomes at sub-zero temperatures.

Ribosomes

Yonath's research focused on protein synthesis, or the creation of proteins, in cells, which occurs in the ribosomes. When Yonath began her research, scientists did not know how ribosomes functioned or what their structure looked like. People believed the ribosome was too small and unstable to photograph with X-Rays, which Yonath planned to do. Yonath recalls that her project "was met with reactions of disbelief and even ridicule in the international scientific community." In order to accomplish her goal, Yonath had to create a new way of using X-rays, a technique she called cryo-bio-crystallography. Her new goal is to discover how ribosomes first came into existence.

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Activity: Polar Bear Blubber

Grades: 2–5

Subject: Nutrient density, habitats, anatomy, energy systems, kinetic energy, heat

Skills: Critical thinking, measuring

Materials: Bowl of ice water, tub of shortening (ex. Crisco) (varies by class size), paper towels or wet wipes

Next Generation Science Standards
LS3.2: Heredity: Inheritance and Variation of Traits

Background

To stay warm in the winter while they hibernate, polar bears must build up a large layer of fat. This layer is known as blubber, and can grow to be about 10 cm. thick. Fat is a concentrated food source for these animals. In hibernation, polar bears survive off of the energy that is stored in their blubber. To build up such a stockpile of energy, polar bears must eat a high calorie diet. One of their main food sources is seal blubber.

Activity

1. Apply a thick coat of Crisco around one pointer finger of each student, leaving the other pointer finger clean.

2. Have students dip both pointer fingers into ice water and keep them there for one minute.

3. After removing their fingers from the water, ask the students how their fingers feel and if they feel different from one another. The Crisco finger represents the blubber on a polar bear. The Crisco keeps the participant's finger warm, just like the blubber keeps the polar bear insulated.

Additional Information

Polar bears are not the only animals who survive off of stored energy in their blubber. The Blue whale has the longest known migration of any mammal. They spend summers in the waters near Alaska, eating 900–24,000 lbs. of krill each day. When they begin their journey to Mexico in the fall, the mothers weigh 30 tons, are coated in a 5–10 inch layer of blubber, and will not eat. These mothers will swim 24 hours a day, travel 10,000 miles, gestate a 2,000 pound baby, and produce 6 tons of breastmilk—all with NO food! Even if they wanted to eat, there wouldn't be any food available because the krill they feed on are only found in Alaska. For 270 days each year they live off of the energy stored in their blubber.

Activity: X-Rays with Ada

Grades: K-2

Subject: Chemistry, anatomy

Skills: Identifying, building

Materials: Black construction paper, white chalk, white crayons, cotton swabs, glue

Next Generation Science Standards
LS1.A: From Molecules to Organisms: Structures and Processes

Background

Dr. Ada Yonath is a pioneering woman in the field of chemistry. She was the fourth woman in history to win the Nobel Prize for Chemistry and the first Israeli woman to win the Nobel Prize in any category. She has done very important research into ribosomes that has been valuable to X-Ray technology.

Activity

1. Read *Women in Chemistry/Las mujeres en la química*, while paying close attention to Ada Yonath.

2. Pass out black construction paper and white chalk or white crayons to your students. Ask them to trace one of their arms from the tips of their fingers to their elbows. Then, tell them to color in the tracing with the chalk or crayon.

3. Use cotton swabs to act as bones and let them glue them in place. You can use a reference photo so your students know where they should place the Q tips, or you can see what they come up with on their own!

Discussion

Ask your students how Ada Yonath used X-rays and for what purpose. Then, ask them why doctors might use X-rays at a hospital. Ask your students how this activity differs from the type of X-rays that Ada Yonath created.

Activity adapted from *From ABCs to ACTs* https://fromabcstoacts.com/q-tip-x-ray-craft-for-preschoolers/

Section 3: Hands-on Activities

Eager for more? Chemistry is the perfect way to introduce children to the world of science. These activities will introduce students to the basic concepts of science through some of the many subjects in chemistry, laying a foundation for success when these concepts are reintroduced later in their education.

Activity: Sink or Float

Grades: K–5

Subject: Density, volume, mass

Skills: Critical thinking, measuring

Materials: Objects to sink or float, clear container, water, whiteboards, dry erase markers

Next Generation Science Standards
PS1.A: Structure and Properties of Matter

Background

Density is a measure of how heavy something is compared to its size. One way to consider an object's density is to place it in water. If it is less dense than water, it will float; if it is more dense than water, it will sink. In order to know how dense an object is, its ***volume*** and its ***mass*** must also be known. Volume is the amount of space something takes up; mass is the amount of matter there is in an object. The more matter an object has per unit of volume, the more dense it is.

Activity

1. Before the activity begins, fill a clear container with water and have the objects you plan to sink or float nearby.

2. Go over the background information with your students. Depending on their age level, stress the concepts of mass and volume. Students should aim to understand that matter is tightly packed together the more dense an object is.

3. Tell students that they will be guessing whether an object will sink or float in water. Remind them that if an object is more dense than water, it will sink; if it is less dense, it will float.

4. Hold up an object, making sure every student can see it. Have students write on their whiteboards "sink" or "float" based on their best guess. Then, instruct students to show their answers on the boards. Select a few students and ask why they guessed what they did. Try to lead them to use words such as density, volume, matter, and mass.

5. Drop the object in the water. Ask students if the object was more or less dense than water. If it sinks, it is more dense; if it floats, it is less dense.

6. Repeat steps 4 and 5 for as many objects as you have.

Expand the Activity

Roll a lump of clay into a ball and show it to the students. Ask them if they believe it will sink or float, then drop it into water in a clear container. Next, break the clay ball in half. Ask students if they think it will float now. Repeat the process until students become aware that changing an objects size does not affect how dense the material is.

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Activity: States of Matter Squares

Grades: K–5

Subject: States of matter

Skills: Critical thinking

Materials: Floor space, masking tape

Next Generation Science Standards
PS1.A: Structure and Properties of Matter

Background

The most common states of matter are solid, liquid, and gas. These are known as the ***three states of matter***. Typically, matter is only found in one form at normal earth temperatures. Water is unique, because it can be found on Earth in all three states. The main difference between the three states of matter is how fast its molecules move. A solid has tightly packed molecules, which cannot move much; the molecules in a liquid have more space and can move more; the molecules in a gas have the most room and move very quickly.

Activity

1. Before the activity begins, mark off a square on the floor that is 5 feet by 5 feet. Then, put an 8 feet by 8 feet square around that. If your group of students is small, make these dimensions smaller, so that the inner square is only large enough for the group to stand with little room between them.

2. Go over the background information with your students. Tell them that they will be modeling the molecules in different states of matter.

3. Instruct students to stand in the 5x5 square. They should be standing close together or touching.

4. Ask students the following: Do you have a lot of personal space? If you wanted to move, would you bump into someone? Would the person you bump into bump someone else?

5. Ask: What do you think would happen if everyone were moving at the same time? Try it carefully. Ask: What do you think would happen if you spread out and someone moved?

6. Instruct students to spread out in the 8 x 8 square. Can they move farther without hitting other students? Does it take more energy to bump into someone else?

7. Next, spread the students out so that they are equidistant from each other and taking up the space of the whole room.

8. Ask: What are the chances of you bumping into someone now? Tell students to move around without hitting people. Was that difficult?

9. Finally, ask students what changed during the activity. Answer: space. Ask what remained constant. Answer: the number of students.

Activity continues on the following page.

Discussion

Ask students what determines the different states of matter. It is a misconception that temperature is the cause. The motion of molecules is the determining factor. Ask students if they think gas has less molecules than a solid does. Encourage them to remember the activity. It is not the number of molecules but their density (how compact something is) which determines its state of matter. In each stage of the activity, the same number of students was used, and only the space changed.

Activity: Rule-breaking Fluid: Oobleck

Grades: K–5

Subject: States of matter, fluids

Skills: Critical thinking, measuring

Materials: Corn flour, food coloring, plastic spoon, plastic cups, 1/4 measuring cup, water

Next Generation Science Standards
PS1.A: Structure and Properties of Matter
PS2.B: Types of Interactions

Background

Though it is true that the most typical states of matter are solid, liquid, and gas, not all matter conforms to these labels. For example, liquids typically take on the shape of whatever container you put them in (picture water in differently shaped glasses). Liquids that don't follow this rule are called ***non-Newtonian fluids.*** These special fluids tend to get thicker and to behave like a solid when stress and force are applied to them, unlike regular liquids.

Activity

1. Go over the background information with your students. Tell them they will be making Oobleck, a type of non-Newtonian fluid. For younger students, this can be done as a demonstration.

2. Tell students to pour 1/4 cup of corn flour into their cup.

3. Have students slowly add water until the corn flour has become a thick paste. Add food coloring if desired. If the mixture is too watery, add more corn flour.

4. Then, instruct students to stir their mixture very slowly. It should be easy, like stirring a liquid.

5. Next, have students stir their mixture really fast. This should be almost impossible.

6. Have students take their concoction out and roll it into a ball while making sure to keep pressure on it. After the ball is formed, tell them to hold their hands out flat and watch the mixture return to a puddle.

Fun Fact!

Ketchup is a non-Newtonian fluid because it becomes runnier when shaken. Honey, toothpaste, and ketchup are all non-Newtonian fluids, also known as "soft solids" or "yield stress fluids."

Discussion

Ask students what they observed about the Oobleck. When did it behave more like a typical liquid? What happened when they applied force and stress? Students should observe that the mixture behaves like a liquid when at rest. They should also note that applying force—rubbing, tapping, hitting, or trying to move quickly through the mixture—causes it to behave like a solid.

This activity was adapted from the article "Non-Newtonian Fluid... It's Super Stuff."

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Activity: Bad Fruit

Grades: K–5

Subject: Chemical reactions, acids, oxidation

Skills: Critical thinking, observation, experimentation

Materials: Apple, knife, glass of water, three bowls, lemon juice

Next Generation Science Standards
PS1.B: Chemical Reactions

Background

Oxidation is a chemical reaction that happens when a chemical combines with oxygen. One type of oxidation occurs when the inside of fruit is exposed to the oxygen in the air. This is the reason that apples and avocados start to turn brown after you cut them open.

Activity

1. Go over the background information with your students.

2. Cut three, thin slices from the apple. Ask students to predict whether water, air, or lemon juice will best preserve the apple slice.

3. Then, put one apple slice in each bowl. Pour water into one bowl, just covering the apple. Pour lemon juice into the second bowl, just covering the apple. Leave the third slice in a bowl by itself.

4. Let the bowls sit for a minimum of 30 minutes. Then, ask students what they notice. Were their predictions correct?

How It Works

When water is poured onto the apple slice the air is slower to oxidize with the apple because the water is in the way. Still, the apple will turn brown because there is oxygen in water. Lemon juice is acidic, and contains the chemical ascorbic acid, which most people know as Vitamin C. Oxygen is drawn more to acid than it is the cells in the apple, so the Vitamin C is oxidized before the apple is. When the Vitamin C gets used up and oxidized, the apple will begin to turn brown.

Discussion

Ask students if they have heard of the term “preservatives.” A preservative is a substance which protects food, wood, and other materials from decay, making it last longer. Ask students if lemon juice is a preservative. Answer: yes. Many chemicals are used as preservatives. Some, like Vitamin C, are called antioxidants because they stop oxidation from occurring.

This activity was adapted from Fizzics Education.

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Activity: Colorful Currents

Grades: K–5

Subject: Density, heat, states of matter

Skills: Critical thinking, observation, experimentation

Materials: 2 glass bottles with the same wide openings, 2 different food colors, hot water, cold water, tray, index card, ice or freezer

Next Generation Science Standards
PS1.A: Structure and Properties of Matter
PS3.B: Conservation of Energy and Energy Transfer

Background

When heat is added to a substance, the molecules and atoms vibrate faster, which makes the space between atoms increase. This is why heat causes things to expand. If matter reaches a high temperature, molecules can expand so much that the matter becomes a liquid or a gas.

Activity

1. Go over the background information with your students. Tell them that this activity is a demonstration.

2. Fill one glass bottle to the top with water. Chill it with ice or in the freezer, but do not freeze it. This step is not essential, but it makes the activity much more clear.

3. Fill a second bottle with hot water. Using hot water from the tap will work fine.

4. Place both bottles on the tray. Add food coloring to the bottles, making them different colors.

5. Ask your students what they think will happen when you combine the water from the two bottles.

6. Keeping the index card as flat as possible, place it on top of the cold water bottle so that the water is sealed off from escaping.

7. Carefully turn the cold water upside down while gently pushing the index card upwards to keep the water sealed off. You should be able to take your hand off of the card without it falling off.

8. Carefully place the cold water directly on top of the hot water bottle. Make sure that the openings line up and gently slide the index card out. The cold water should sink to the bottom while the hot water rises. Ask your students why this might be happening.

9. As time goes on, the colors should mix together. How long does this take? This happens because, over time, the water becomes the same temperature.

Activity continues on the following page.

How It Works

Hot water rises and cold water falls because hot water is less dense than cold water. Because the hot water is less dense, it floats to the top while the cold water falls to the bottom of the bottles.

Expand the Activity

Have students bring in a metal ring that fits them well. Put the rings into a freezer or ice chest. After they have cooled, have the students try their rings on. They will be tight. Then, set the rings in the sun, under a heating lamp, or in a bowl of very warm water. When the students try the rings on this time, they will be loose because the metal has expanded.

This activity was adapted from Fizzics Education.

Activity: Charged Atoms

Grades: K–5

Subject: Atoms, charges, attractions

Skills: Critical thinking, experimentation

Materials: Balloons, paper, paper hole punches

Next Generation Science Standards
PS2.B: Types of Interactions
PS3.B: Conservation of Energy and Energy Transfer

Background

Atoms are made up of protons, neutrons, and electrons. Protons have a positive charge, electrons have a negative charge, and neutrons are neutral. Because matter is made of atoms, everything is made up of charges. One basic rule of charges is that opposites attract each other. This means that negative and positive charges attract. In contrast, like charges (negative to negative or positive to positive) repel each other. Most often, positive and negative forces are balanced in matter, which makes that object neutral.

Activity

1. Go over the background information with your students. Depending on the age group, this can be done individually, in groups, or as a demonstration.

2. Using the paper punch, create 20-30 small paper circles. The activity will be more clearly seen if the paper and the balloon are contrasting colors.

3. Blow up a balloon and tie it off. Ask students what they think will happen to the charge of the balloon when it is rubbed on someone's head.

4. After accepting responses, rub the balloon on a clean, dry head of hair.

5. Place the balloon close to the paper circles without touching them. If the paper does not jump to the balloon, try again after repeating step 4.

How It Works

Rubbing certain materials together can transfer electrons, which are negative charges. This is what happens when there is a buildup of static electricity. If you rub your shoes on the carpet, your body picks up extra electrons, which cling to your body until they can be released. The shock that often follows is what happens when the extra electrons leave your body.

The balloon and paper work the same way. When the balloon is rubbed on a head, the balloon picks up electrons from hair and the balloon is negatively charged. Opposites attract, so the positively charged atoms in the paper jump towards the negatively charged balloon when they get close together. The attraction between the negative and positive forces was so powerful that the paper defied gravity to cling to the balloon.

This activity was adapted from the article "Charged Atoms Science Experiment."

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Activity: Biographical Report

Grades: 2–5

Subject: Chemistry, research, biographies, presenting and sharing information

Skills: Researching, presenting, organizing

Materials: Chemist Biography (page 87)

Next Generation Science Standards
ETS1.B: Developing Possible Solutions

Common Core English Language Arts
CCSS.ELA-LITERACY.CCRA.R: Key Ideas and Details
CCSS.ELA-LITERACY.CCRA.SL Presentation of Knowledge and Ideas

Background

Now that your students have read *Women in Chemistry/Las mujeres en la química*, they are ready to create reports of their own. The ability to research, organize, and present information is vital to academic success. Children who develop these skills from a young age are better prepared for the future.

A ***biography*** is an account of someone's life told by someone else. A life story can be presented in many different ways, but the most common is through writing. There are many famous people, both in history and modernity, who have made important scientific contributions to the world. A biographical report is one way to explore and learn more about these people; it helps ensure their accomplishments do not go unrecognized. New solutions and problems are discovered by learning and building upon what people have already done.

Activity

1. Read *Women in Chemistry/Las mujeres en la química* and go over the background information with the students. Let them know that they will be making a biographical report about a chemist of their choice.

2. Have the students choose and research their own chemist, filling out the biographical report template, provided on page 87, as they go.

3. When all of the students have finished their reports, have them present their chemist to the class.

Discussion

The goal of this discussion is to have students recognize that a biographical report is just one way to present information. A book, such as *Women in Chemistry/Las mujeres en la química*, is another way. Ask students how they decided to choose the information that they did. Was there a lot of information to choose from? By choosing the most important information, they put together a short report; the more information you choose to include, the longer their report would be. Is a report the best way to present a biography? For example, would a movie or drawing be just as good, better, or worse?

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Worksheet: Chemist Biography

Photograph or drawing

Biography of: ______________________________

Born: ______________ **Died:** ______________

Field in Chemistry: ______________________________

(The study of ______________________________**).**

Most Known For: ______________________________

____

Early Life:

Education:

Scientific Contributions:

Fun Facts:

Quotes:

Time Line of Major Events:

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Activity: Scientific Method

Grades: 3–5

Subject: Scientific method, accuracy, research, experimentation

Skills: Researching, presenting, organizing

Materials: Experiment Template (page 91)

Next Generation Science Standards
LS1.D: Information Processing
ETS1.A: Defining and Delimiting an Engineering Problem

Common Core English Language Arts
CCSS.ELA-LITERACY.CCRA.R: Key Ideas and Details
CCSS.ELA-LITERACY.CCRA.SL: Presentation of Knowledge and Ideas

Background

The ***scientific method*** is the process of experimentation that almost all scientists use to observe and test their subjects. In science, accuracy is important; following these steps ensures that other scientists can repeat an experiment and make sure that the results are reliable. The method has six basic steps:

Observe and Ask Questions: What do you notice in the world that interests you? The questions you ask will help determine which mystery to solve.

Make a Hypothesis: A hypothesis is a possible answer to the question you propose. A hypothesis must be testable, meaning that you can prove it correct or incorrect through experimentation.

Experiment: In this stage, the hypothesis is tested. If you think plants will grow better with mineral water than distilled water, you would get two plants and water one plant with mineral water and the other with distilled water. Then you would wait and see which plant grew the best.

Analyze the Data: A scientist records information as their experiment progresses. Once you have all of the data, you can analyze it to discover if your hypothesis was correct or incorrect.

Repeat: To ensure results are not accidental, the experiment should be repeated several times.

Share the Results: A scientific discovery isn't useful if it isn't shared with the world. Making sure that the scientific method was followed will help other scientists see the value and accuracy of an experiment and test the hypothesis themselves.

Activity

1. Go over the background information with the students.

2. Select, or have your students select, an experiment to conduct. For a younger group, the entire class can complete the experiment together, while older groups can work individually or in smaller divisions. Give them the Experiment Template provided (page 91 of this Guide).

3. Have students present their reports to the class.

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Experiment Template

Question: ____________________

____

____

Hypothesis: ____________________

____

____

Materials

Method (What steps did you follow?)

Data (What did you observe?)

Conclusion

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Expanded Glossary

Accuracy: Free from mistakes or errors.

Alchemist: Someone in ancient times who tried to turn ordinary metals into gold or silver or find one cure that would work for all sicknesses.

Atoms: The building blocks that put together our universe. Different kinds of atoms are made by combining different numbers of protons, neutrons, and electrons.

Atomic Number: The number of protons in each atom; used to sort elements on the periodic table.

Biography: An account of someone's life, written by someone else.

Cells: The basic structural unit for all organisms. Cells hold the biological equipment to keep an organism alive and successful.

Chemical Reaction: A process where the structure of something, like a molecule, is rearranged.

Chemical Structure: The way the atoms are arranged in a substance.

Chemistry: The study of matter and the changes that happen to it.

Density: A measure of how heavy something is compared to its size; determined by dividing an object's mass by its volume.

DNA (Deoxyribonucleic Acid): The written plan in the cells of living things (like plants, animals, and people) that tells each cell, and by extension, the body, how to grow and function.

Electrons: Very teeny particles with a negative electric charge. Electrons travel around the nucleus of every atom.

Element: A basic substance made of one type of atom that cannot usually be separated into simpler substances.

Experiment: A test to collect information about the world to see if a hypothesis is correct.

Force: A strength or energy that pushes or pulls an object.

Genetics: The study of genes and heredity, which helps explain why you look the way you do. This subject is closely related to cell biology, as genes are located in cells.

Hypothesis: An educated guess that a person makes to explain something they think is true or will happen.

Mass: A measure of how much matter is in an object. Mass is usually measured in kilograms (1 kg = a little over 2 pounds). Mass is different from weight because the mass of an object never changes, but its weight will change based on its location in the universe.

Matter: Anything that takes up space and has mass.

Molecule: A group of atoms that are bonded together.

Neutrons: Very teeny particles with no electric charge, found in the nucleus of most atoms.

Non-Newtonian Fluid: Liquids that do not conform to typical liquid behavior, such as flowing to take the shape of whatever container it is in.

Nobel Prize: A set of very prestigious annual international awards recognizing academic, cultural, and scientific advances. The awards are named for Swedish scientist Alfred Nobel, and were first awarded in 1895.

Precision: The closeness of two or more measurements to each other. It is possible to be very precise, but not very accurate and it is also possible to be accurate without being precise.

Periodic Table: A chart that arranges chemical elements. It is organized by the element's atomic number. The atomic number comes from how many protons the element has.

Proteins: Chain-like molecules that are made up of small substances called amino acids. Muscles, organs, and the immune system are mostly made of proteins.

Protons: Very teeny particles with a positive electric charge. Protons are in the nucleus of every atom.

Ribosomes: Sphere-shaped structures inside a cell that read the cell's mRNA (messenger Ribonucleic Acid) and make proteins.

Scientific Method: The standardized process of experimentation that almost all scientists use to observe and test their subjects.

States of Matter: Solid, liquid, and gas are the three most common states of matter.

Volume: The amount of space something takes up.

X-Ray: Invisible waves of energy that can pass through solid objects. X-ray images can show the inside of an object, like a suitcase or a person's body.

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