Intermediate General and Applied Science

Chemistry Module: Lecture Manual

Developed by Christine Miller © 2018

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Welcome and the Scientific Method

Learning Objectives

At the end of this unit, you will be able to:

- Describe the nature of science and the scientific method, including its limitations.
- List the stages in the cycle of the scientific method.
- Identify, in a given experiment:
  - The hypothesis
  - The independent variable
  - The dependent variable
  - The control(s)
- Describe some of the methods of dissemination of scientific research.

Science and its Limits

Science is	**Science is not**

Scientific Method

The **scientific method** is an organized way of learning about the world around us.

It generally begins with an _____, the formation of a _____, and the creation of an _____ specifically designed to determine if the hypothesis is correct or incorrect.

Experimental Design

- An experiment is an activity or procedure designed to test a _____.
- A hypothesis is typically an _____/_____ statement.
- A hypothesis is the starting point for designing an experiment.

In an experiment, there are two types of variables:

- An **independent variable** is what we _____.

- A **dependent variable** is what we _____.

Controls are an important part of experimental design. They serve one or both purposes of:

- Setting a standard to which other results are compared.
- Ensuring a fair test.

TRY IT OUT

Work with a partner and choose one of the following scenarios. Determine what a possible hypothesis may be, what sort of experimental design might work, and what your dependent variable, independent variable and controls might be.

Scenario 1	Scenario 2	Scenario 3
• Amy thinks her mom should only buy name-brand paper towels for cleaning up spills, but her mom thinks that the less expensive ones from the dollar store are just as good. How can you, as a good friend, help resolve this issue using the scientific method?	• You buy your goldfish some food and when you open the container, you see that the granules of food inside come in three different colours: red, orange and brown. You wonder if your fish have a preference for any of these colours. How can you use the scientific method to figure dthis out?	• The neighbour who lives to the left of your house firmly believes that her compost is the "best compost" for growing flowers. Your neighbour who lives to the right also believes his compost is the "best compost" for flowers. How can you use use the scientific method to settle this friendly competition once and for all?

We chose scenario _____. I worked with _____ and _____.

Hypothesis: (What do you think will happen?)

Experimental Design: (What do you plan to do?)

Independent Variable: (What will you manipulate?)

Dependent Variable: (What will you measure?)

Controls: (How will you keep it “fair”?)

Organizing Data

Once you have recorded your results, you need to organize your data in a way that makes sense to you and others. Then you need to see if your data shows any trends or relationships.

How would you organize your data?

Do it here:

Once you have organized your data and analyzed your results, you need to share them with the scientific community. This can be in the form of:

- _____
- _____
- _____
- _____
- _____

It is also important to consider with whom you are sharing your information. This may change the way in which you share your information based on who will be viewing it.

- **TALK IT OUT**

How would you present the ice cream preference data to your friends? The owner of an ice cream shop? A marketing executive promoting a particular flavor? Someone who has never tried ice cream?

Measurement

Learning Objectives

At the end of this unit, you will be able to:

- Define measurement.
- Match certain types of measurement with their appropriate units.
- Identify the purpose of measurement in the field of Chemistry.

Measurement is the process of comparing a _____ of an object to a _____.

Units

The referent is what we call a _____.

List some properties we can measure and their corresponding unit:

TRY IT OUT

How long is each line? What are the units? (The measurement is not to actual scale, but that is OK.)

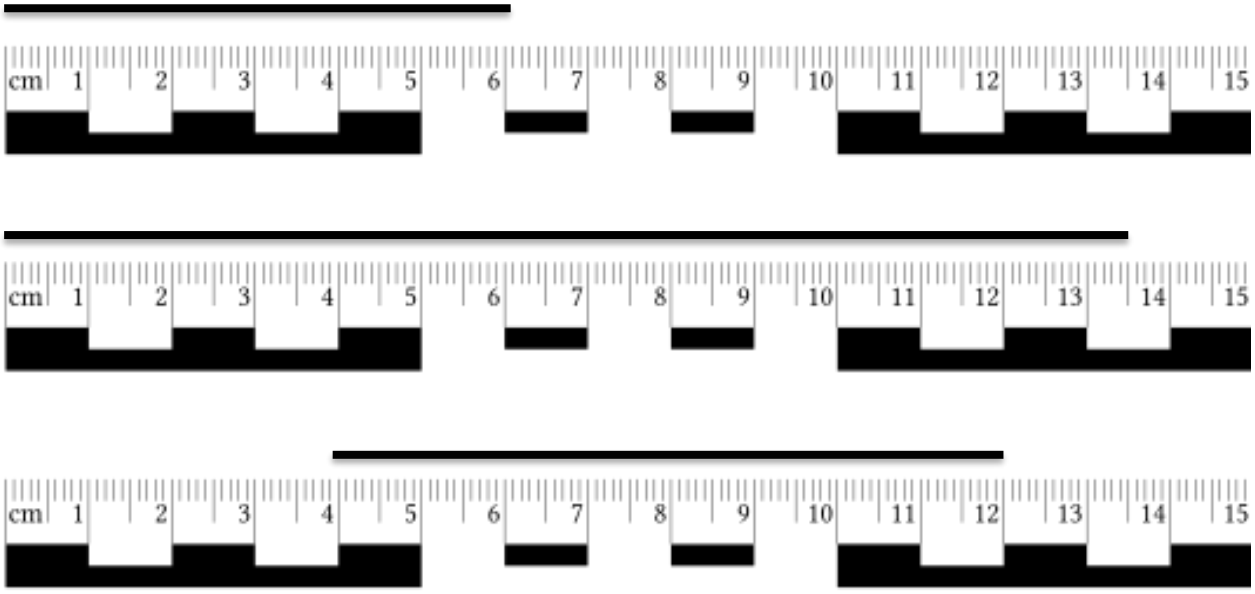
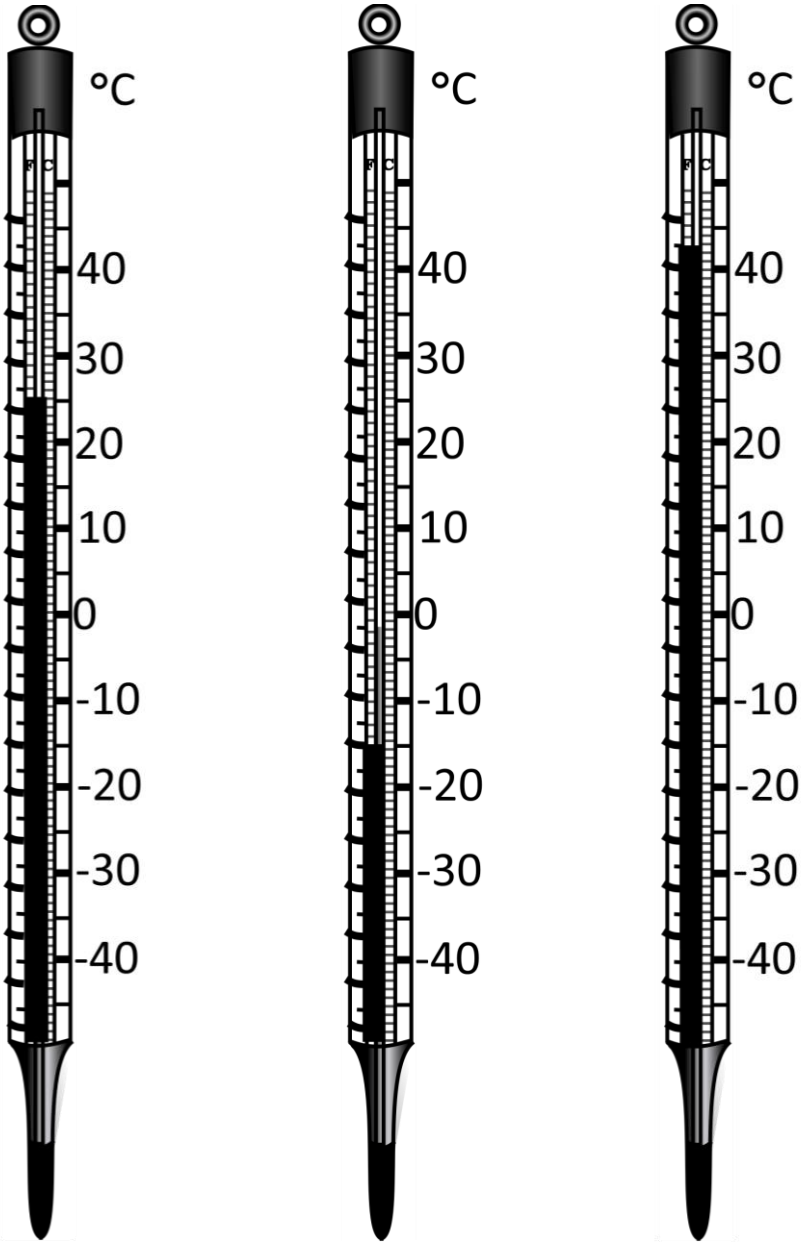


Image Source: File:Ruler Lineal 25 cm Zentimeter and Millimeters on DIN A4, by Erik Streb [CC0 1.0], via Wikimedia Commons

What is the temperature? What are the units?



_____ _____ _____

Image Source: Adapted from Advanced Thermometer, by Tom, from openclipart.org, [CC0 1.0].

Matter and Atoms

Learning Objectives

At the end of this unit, you will be able to:

- Define the term “matter.”
- Differentiate between what is and what is not matter.
- Describe the particle model of matter.
- Define the terms “atom” and “element.”
- Identify and describe the three types of subatomic particles.
- Compare properties of the three states of matter.
- Identify and describe different examples of mixtures.

Matter

Matter is anything that has both _____ and _____.

Which of the following are examples of matter?

- Helium
- Feathers
- Light
- Cement
- Vibrations
- Water
- Electricity (this is a tricky one!)

Particle Model of Matter

Particles are always _____.

Particles at a _____ temperature move _____ than particles at a _____ temperature.

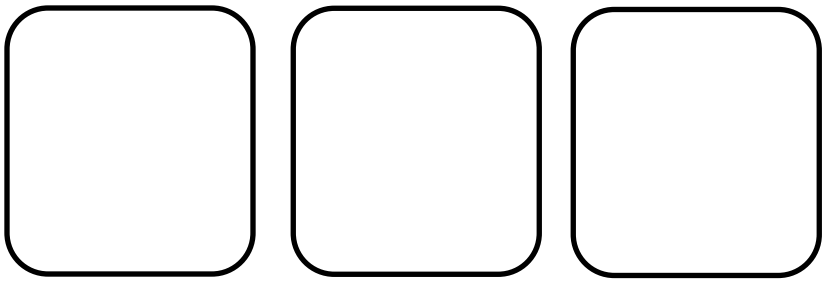
Particles in a _____ are closer together than the particles in a liquid, and particles in a liquid are closer together than the particles in a _____.

States of Matter

The three states of matter are:

- Solid
- Liquid
- Gas

DRAW IT OUT



Solid
Atoms are very close together and do not exhibit very much movement. Solids maintain their shape when placed in a container.

Liquid
Atoms are slightly spread out and move in a random pattern. Liquids take the shape of the bottom of any container they are placed in.

Gas
Atoms are very spread out and move very quickly in an extremely random manner. Gases take the shape of the entire container they are placed in.

A substance can change from one state to another depending on temperature changes, and how far apart the atoms are.

There are specific terms for each change in state:

As temperatures increase:

- solid → liquid = _____
- liquid → gas = _____
- solid → gas = _____

As temperatures decrease:

- gas → liquid = _____
- liquid → solid = _____
- gas → solid = _____

TRY IT OUT

- Your ice cream has now turned into ice cream soup. It has _____.
- You are boiling water for tea, and some of the water has come out of the kettle as steam. It has _____.
- You are making Jello. You add the powder to boiling water and then put it into the fridge for a few hours. It has _____.

- You are taking a very hot shower and now your mirror is covered in drops of water. The water in the air hit the cold surface of the mirror and has _____.

Atoms

Matter is made up of **atoms.**

Atoms are the smallest unit of matter that retain their _____.

Atoms of one kind differ from atoms of another kind.

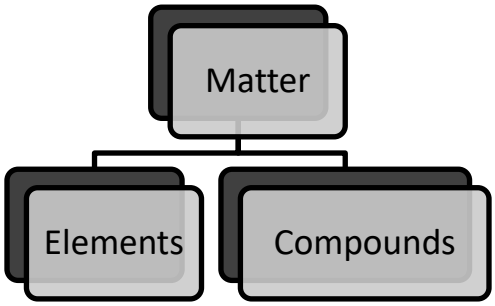
Atoms take up _____ and have _____.

Atomic Theory was developed in the early 1800s by John Dalton. It states:

- All matter is made up of small particles called atoms
- Atoms cannot be created, destroyed or divided into smaller particles
- All atoms of the same **element** have the same properties
- **Compounds** are created when atoms of different elements combine

Elements are made up of _____. You can't break them down into anything simpler.

Compounds are made up of _____. You can break compounds down into elements again through chemical processes.



Properties

Each element and compound has a unique set of **properties**. Properties are separated into two types: physical and chemical

Physical Properties	Chemical Properties
•	•
•	•
•	•
•	•
•	

Subatomic Particles

Atoms are made up of three types of subatomic particles:

- Protons
- Neutrons
- Electrons

Each of these particles has a particle mass, charge, and location

Protons

- **Protons** exist in the _____ of the atom
- They carry a _____ charge (1+)
- They have a mass of _____ atomic unit

The number of protons in an atom determines the type element that atom is.

For example, is an atom has 2 protons, it is a Helium atom, no matter how many neutrons or electrons it may have.

Neutrons

- **Neutrons** exist in the _____ of the atom
- Neutrons have _____ charge, they are considered neutral
- They have a mass of _____ atomic unit

Neutrons are a critical part of the nucleus of an atom because they provide a buffer so that positively charged protons don't repel each other and tear the nucleus apart.

Neutrons also affect atomic mass and play a role in radioactivity.

Electrons

- **Electrons** exist _____ the nucleus
- They carry a _____ charge (1-)

- They have such a small mass that it is considered _____

Electrons are crucial in the ability of atoms for form compounds. All chemical bonding is due to interactions between the nucleus and the electrons in neighboring atoms.

FILL IT OUT

	Protons	Neutrons	Electrons
Location			
Charge			
Mass			

Atoms and Ions

When the numbers of electrons and protons in a single atom are _____, then the atom has a neutral charge (no charge)

When the number of electrons and protons is _____, the atom is termed an **ion.**

An **ion** is an atom or molecule with a net electric charge due to the gain or loss of one or more electrons.

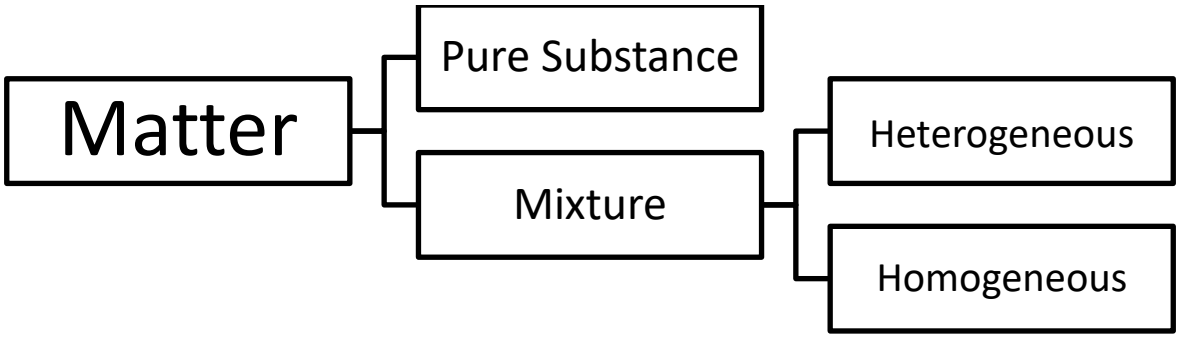
The Periodic Table

The **Periodic Table** is an organized way of displaying all known elements. It is made up of rows and columns; elements are placed from the top left in ascending order of the number of protons in their nucleus. We'll be revisiting the periodic table very soon!

Mixtures of Matter

Not only can matter be in a specific state, but it can also exist as a **pure substance** or as a **mixture**

- A pure substance is matter that contains _____
- A mixture is matter that contains _____



A specific mixture can be either **homogeneous** or **heterogeneous.**

- In a _____ mixture, particles are uniformly scattered, and the mixture will look uniform
- In a _____ mixture, particles are not uniformly scattered, and if the particles are large enough, you will be able to see the different particles in the mixture

The Periodic Table

Learning Objectives

At the end of this unit, you will be able to:

- Identify what type of information is presented in the periodic table.
- Explain how the periodic table organizes elements.
- Use the periodic table to determine information about a specific element.
- Use the periodic table to predict the properties of elements.
- Use the periodic table to draw Bohr and Lewis diagrams of specific elements.

Dmitri Mendeleev created the first periodic table of elements in 1869. He developed it based on 63 known elements, and by arranging these elements according to mass.

Periodic Table of the Elements

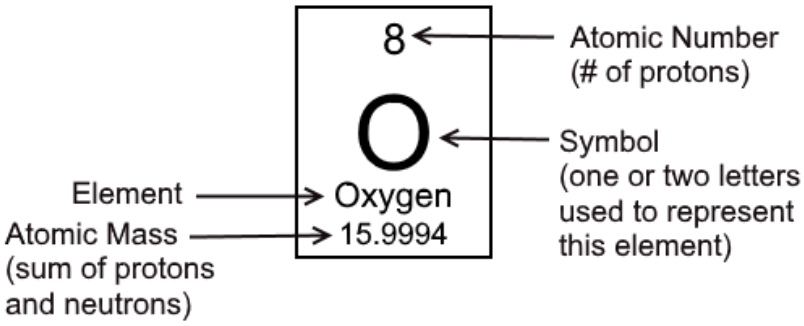
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H Hydrogen 1.008																	2 He Helium 4.003
2	3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Flourine 19.00	10 Ne Neon 20.18
3	11 Na Sodium 22.99	12 Mg Magnesium 24.31											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95
4	19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.88	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.39	31 Ga Gallium 69.72	32 Ge Germanium 72.61	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80
5	37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molyb-denum 95.94	43 Tc Technetium 98	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3
6	55 Cs Cesium 132.9	56 Ba Barium 137.3	*	72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.8	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Mg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium 209	85 At Astatine 210	86 Rn Radon 222
7	87 Fr Francium 223	88 Ra Radium 226	**	104 Rf Ruther-fordium 261	105 Db Dubnium 262	106 Sg Seaborgium 266	107 Bh Bohrium 264	108 Hs Hassium 277	109 Mt Meitnerium 268	110 Ds Darmstad-tium 281	111 Rg Roentgen-ium 272	112 Cn Conipern -icium 285						

*	57 La Lanthanum 138.9	58 Ce Cerium 140.1	59 Pr Praseo-dymium 140.9	60 Nd Neo-dymium 144.2	61 Pm Prometh-ium 145	62 Sm Samarium 150.4	63 Eu Europium 152.0	64 Gd Gadolinium 157.3	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 Lu Lutetium 175.0
**	89 Ac Actinium 227	90 Th Thorium 232.0	91 Pa Proactinium 231.0	92 U Uranium 238.0	93 Np Neptunium 237	94 Pu Plutonium 244	95 Am Americium 243	96 Cm Curium 247	97 Bk Berkelium 247	98 Cf Californium 251	99 Es Einsteinium 252	100 Fm Fermium 257	101 Md Mendel-evium 258	102 No Nobelium 259	103 Lr Lawren-cium 262

How to Read the Periodic Table

A scientist can use the periodic table to quickly find information about a particular element. Elements are listed in increasing order of atomic number.

Each square on the periodic table gives a certain set of facts about the element:



TRY IT OUT

What is the atomic number of Silicon? _____

What is the symbol for lead? _____

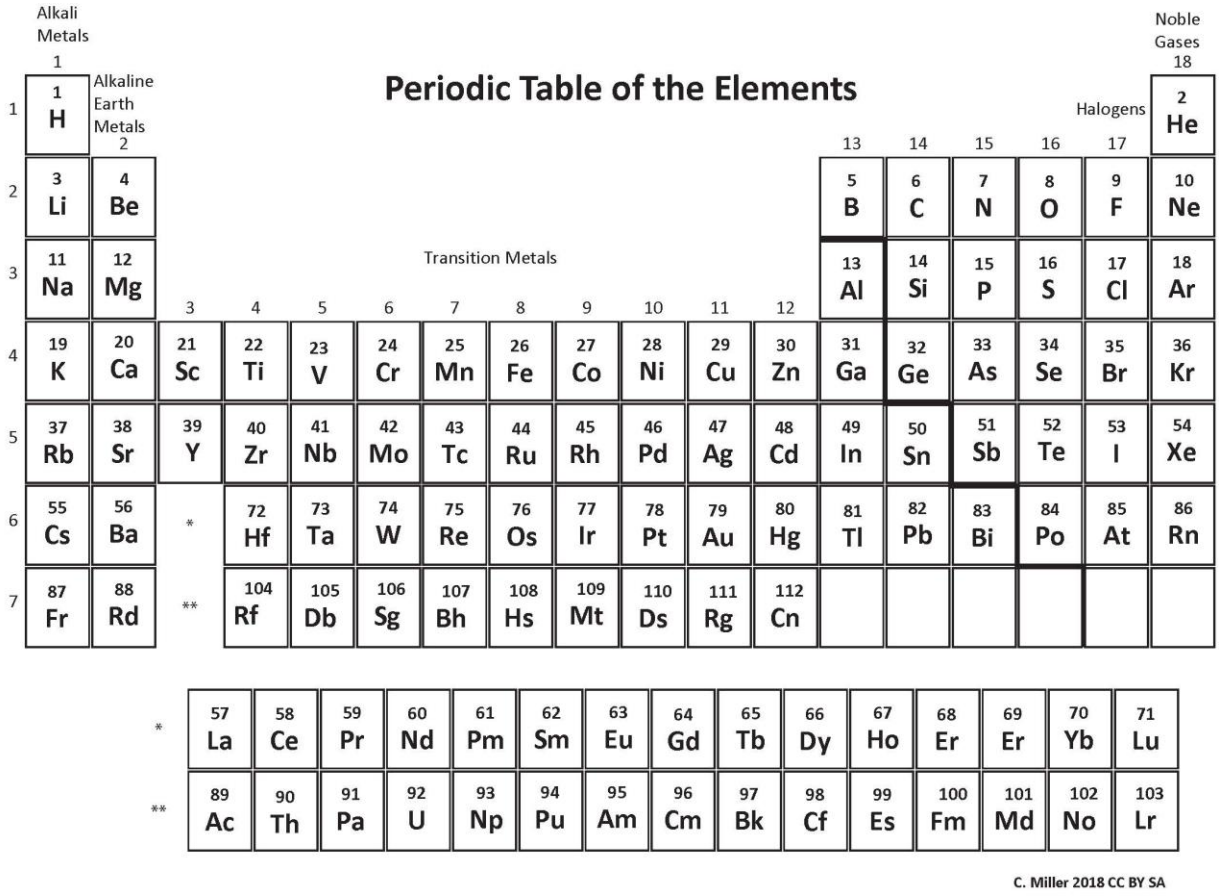
What is the atomic mass of Radon? _____

What is the name of the element with the atomic number 99? _____

Elements are arranged according to their properties and behaviours.

Columns in the periodic table form **groups.** **Groups** react with other elements in _____.

Rows in the periodic table form **periods.** Elements in the same **period** have _____.



Major Groups of the Periodic Table

Groups in the periodic table share behaviours—they react with other elements in the same way.

- **Alkali Metals**
  Colour this group red on your periodic table.
  - _____ family of the periodic table
  - Very reactive, many must be stored in _____, often reactive to _____
- **Earth Metals**
  Colour this group orange on your periodic table.
  - Second family of the periodic table
  - Sometimes called “alkaline”
  - Fairly reactive, do not dissolve in water, unchanged by heat
- **Halogens**
  Colour this group yellow on your periodic table.
  - 17^{th} family of the periodic table

    - Very _____ with most elements
    - Very corrosive and/or harmful
    - Examples: chlorine as an antiseptic
- **Noble Gases**
  Colour this group blue on your periodic table.
    - Odorless, colorless
    - Very stable, _____
    - Examples: helium in balloons, argon in fluorescent tubes

Atoms and Elements

Electron arrangement determines the _____of an atom.

Atoms can give away, take, or share electrons—when this happens we call it a chemical _____ or a chemical _____.

A **chemical reaction** results in a new substance _____.

When two elements react to produce something new, a chemical reaction has occurred.

Reminder

An Electron is a subatomic particle. It carries a charge of -1 and exists outside the nucleus

Electron Arrangement

- Electrons are always moving around the nucleus
- Electrons have a certain _____ they can occupy
- According to Bohr's model, electrons orbit the nucleus in a way similar to how _____
- Only a certain number of electrons can fit into one orbit
- Electrons always occupy the innermost (_____) orbital possible
- The number of electrons that can fit into the first orbital is 2.
- The second orbital can fit 8 electrons.
- The third and fourth orbitals can fit 18 electrons.

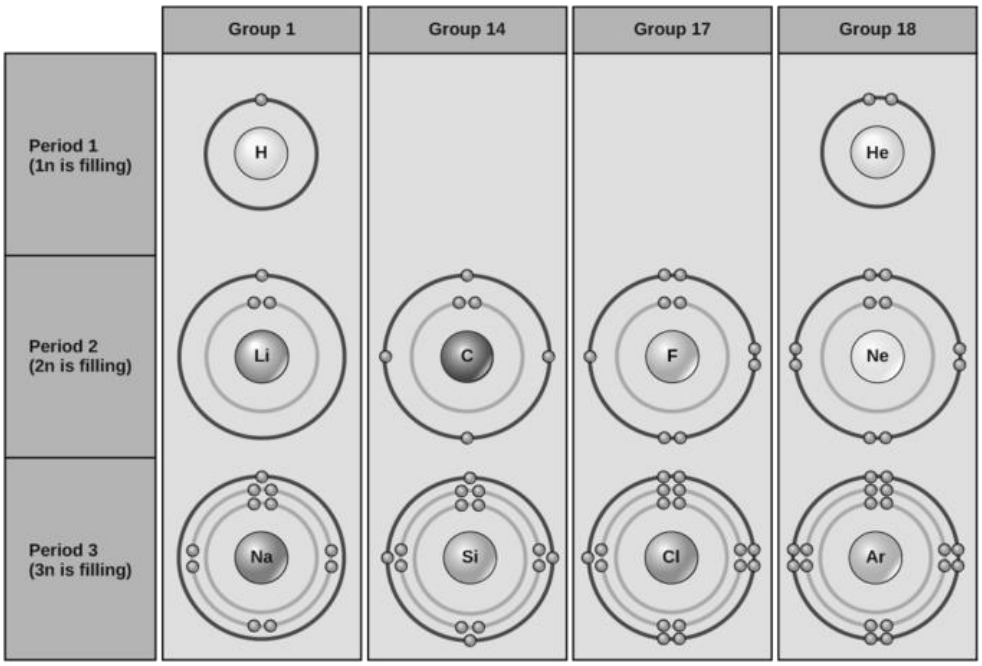
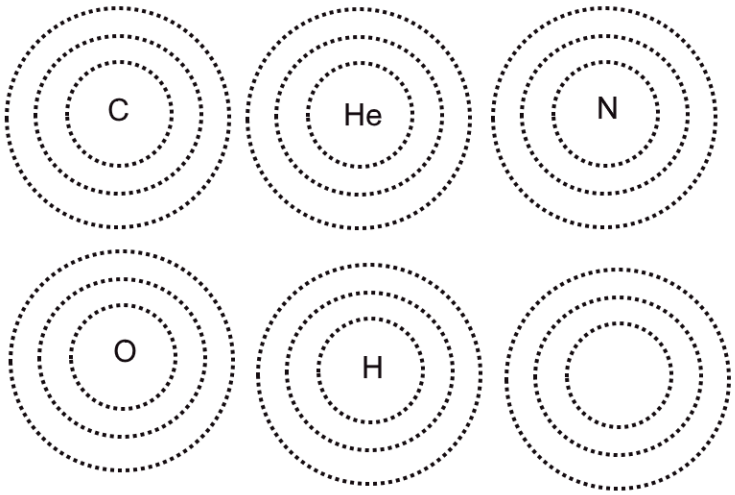


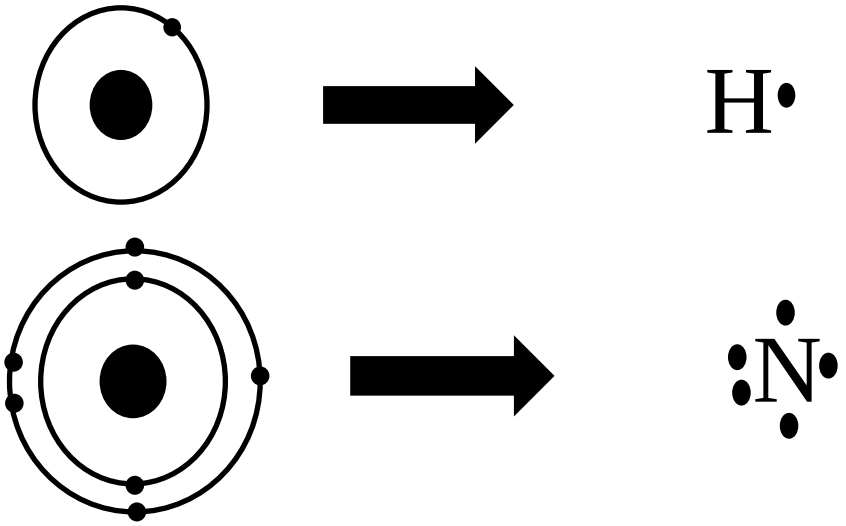
Image Source: Steven Telleen, April 3, 2018, Human Physiology. Open Stax. https://cnx.org/contents/HNrg06vQ@5.13:mPjp2GYc@1/Fundametals-of-Matter-Elements-and-Their-Relationships#fig-ch02_01_06 [CC BY 4.0]

TRY IT OUT



Lewis Diagrams

- Only show electrons in the outermost orbit.
- Electrons are represented by dots accompanying the chemical symbol.



TRY IT OUT

Group 1		Group 2	
Beryllium (4)	Be	Oxygen (8)	O
Magnesium (12)	Mg	Sulfur (16)	S
Calcium (20)	Ca	Selenium (34)	Se

Chemical Compounds

Learning Objectives

At the end of this unit, you will be able to:

- Differentiate between chemical and physical changes.
- Define the term “chemical reaction.”
- Describe the role electrons play in chemical reactions.
- Compare and contrast covalent and ionic bonds.
- Describe hydrogen bonds.
- Read a chemical formula and determine which and how many atoms make up the compound.
- Name inorganic compounds based on a given chemical formula.

Physical and Chemical Change

There are two ways that you can change a substance:

- _____: does not change the substance’s chemical make-up, and there is no rearrangement of atoms.
- _____: beginning material(s) are changed into a completely new compound due to a rearrangement of atoms.

Physical change is any change of phase or change in size of pieces in a sample.

Change of Phase	**Change in size of pieces**
Examples: • •	Examples: • •

Chemical change is a change in the identity of the matter, creating new substances with a new set of properties.

- The _____ all remain, but are _____ into new compounds.
- In this process, _____ are broken and/or made.
- This is called a _____.

Chemical Reactions

- In a _____, substances combine or degrade.
- The _____ are the starting materials for a chemical reaction.
- The _____ are the substances formed as a result of the reaction.

Chemical Equations

A _____ is the equation we write to describe the steps of the chemical reaction.

A chemical equation shows the chemicals _____ and _____ during a chemical reaction.

Chemical Reactions and Electrons

The chemical properties of a substance are ultimately determined by _____ of the atoms that make up the reactants.

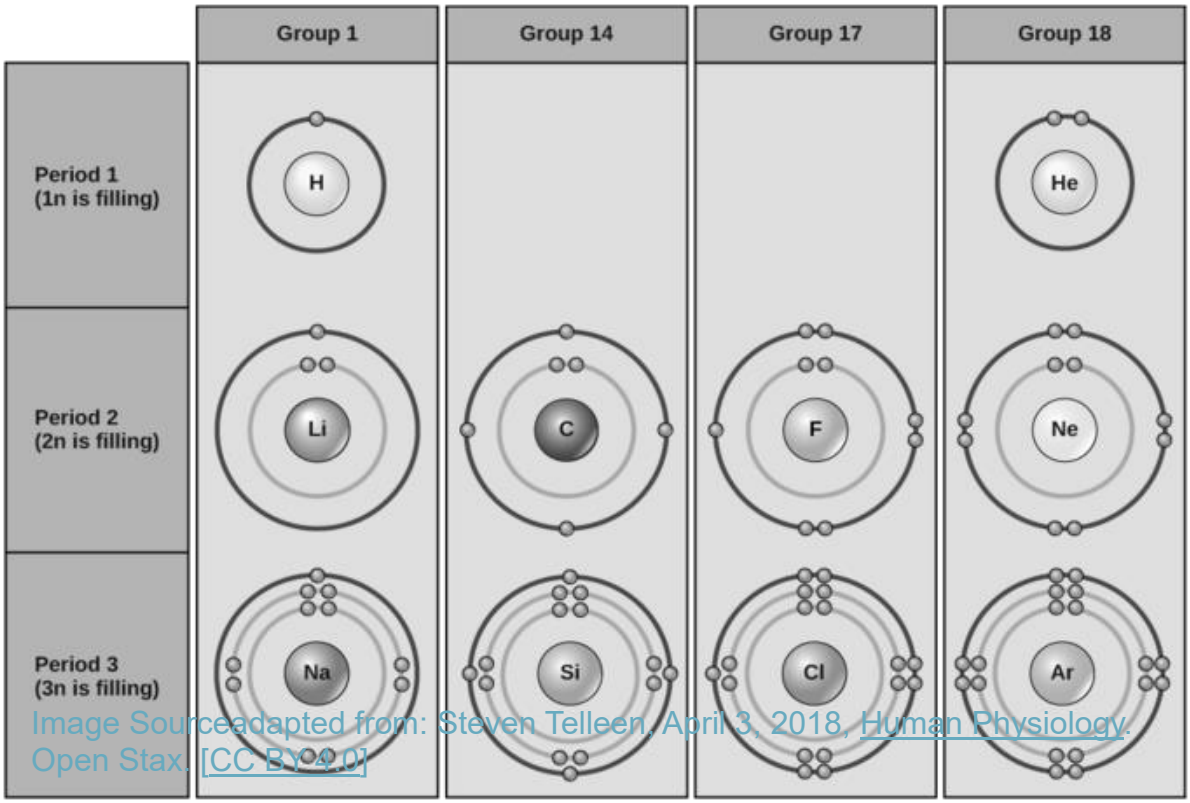
In a chemical reaction, atoms can be:

- _____
- _____
- _____

When this happens, a new substance is formed.

Electron Arrangement

- Electrons are always orbiting around the _____.
- Electrons have a certain energy level they occupy. We can refer to this as an _____.
- Only a certain number of _____ can fit onto one orbit.
- Atoms have this innate desire for a _____ outer shell.



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Chemical Bonding Rules

Chemical bonding follows two general rules:

1. It MUST result in a _____.
2. It MUST result in _____ for all atoms involved.

These rules are satisfied as chemical compounds are created by donating, accepting or sharing electrons.

Bonding Makes Compounds

When two or more atoms have electrons interacting (being shared, donated or received), this makes a _____.

Compounds have different properties than the _____ that make them up.

Three Main Types of Chemical Bonding

FILL IT OUT

_____	_____	_____
• Transfer of electrons • One atom loses on or more electrons, the other gains	• One or more electrons are shared between atoms	• A weak attraction between two adjacent molecules • A hydrogen atom is shared between molecules

Ionic Bonds

Ionic bonds form as a result of the attraction between ions of opposite charge.

- _____ = an atom which has lost or gained an electron from/to the outer shell resulting in a + or – charge.
- Losing an electron = a _____ charged ion.
- Gaining an electron = a _____ charged ion.

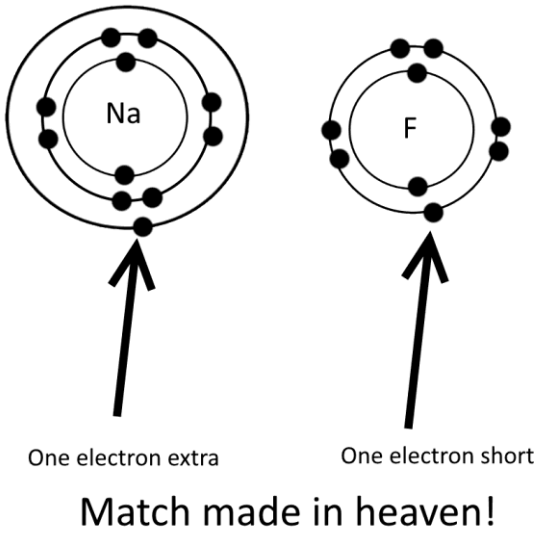
So, an ionic bond is created by the pull of 2 or more oppositely charged ions resulting in a neutral compound.

Ionic bonds form when electrons are donated and received between two or more atoms.

These bonds typically form between metals and non-metals.

This is because of the nature of the _____ of metals and non-metals.

In order to form ionic bonds, each atom needs to have a full outer shell of electrons. This often requires more than just two atoms.



DRAW IT OUT

Bohr Diagram:

Ca Cl

Lewis Diagram:

Ca Cl

Chemical formula:

TRY IT OUT

How many of each type of atom are needed to satisfy each outer shell?

Lithium + Sulfur _____
Magnesium + Bromine _____
Beryllium + Oxygen _____

Subscripts and Coefficients

Subscripts show how many of a particular _____ are present.

Circle the subscript: $CaCl_2$

How many of each atom is present?

Coefficients show how many of a particular _____ are present.

Circle the coefficient: $2CaCl_2$

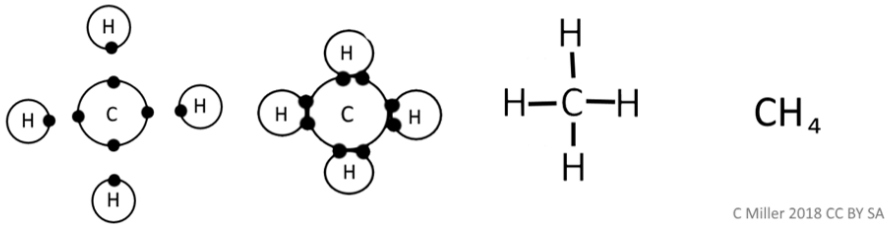
How many of each atom is present?

Covalent Bonds

Covalent bonds occur when two or more atoms share electrons.

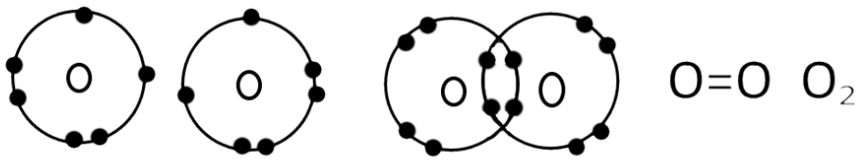
- One atom equally shares one or more of its electrons with another atom.
- Electron sharing is common between like atoms. Ex: Oxygen = O_2
- The resulting compound is neutral.

- One pair of shared electrons is a **single bond**



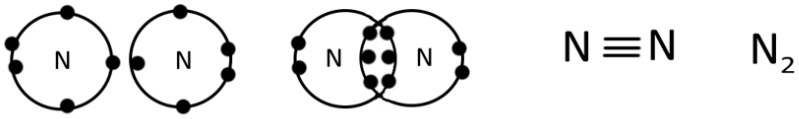
Strong

- Two pairs of shared electrons are a **double bond**



Stronger

- Three pairs of shared electrons are a **triple bond**



Strongest

FILL IT OUT

Ionic	vs.	Covalent

TRY IT OUT

Which of these chemical bonds are ionic? Which are covalent?

- NaCl
- O_2
- HCl
- $C_6H_{12}O_6$
- $MgBr_2$
- CO_2

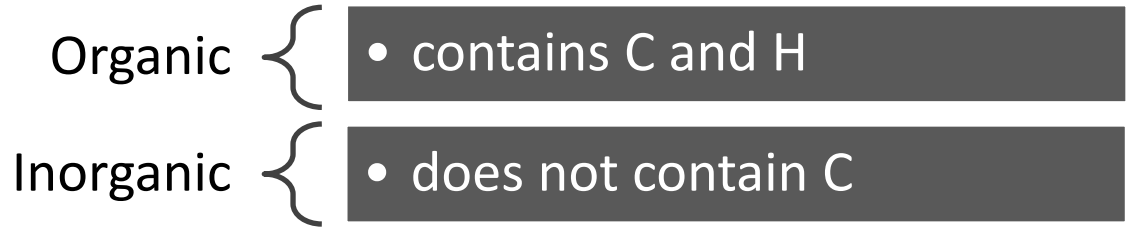
Compounds and Formulas

When we are talking about a particular compound, sometimes we will use the chemical formula—this formula gives more information about what atoms make up the compound than just its name.

FILL IT OUT

Compounds

There are two main categories of chemical compounds:



Name of Compound	Formula of Molecule	Elements Present	# of Atoms of Each
Water	H_20		
Carbon Dioxide	CO_2		
Glucose	C_6H12O_6		
Propane	C_3H_8		
Hydrochloric Acid	HCl		
Sodium Acetate	$NaC_2H_3O_2$		

FILL IT OUT

Name of Compound	Formula of Molecule	Organic or Inorganic
Water	H_20	
Carbon Dioxide	CO_2	
Glucose	C_6H12O_6	
Propane	C_3H_8	
Hydrochloric Acid	HCl	
Sodium Acetate	$NaC_2H_3O_2$	

Naming Inorganic Compounds

When naming a compound made of a metal and a non-metal you can follow these rules:

- The _____ name goes first.
- The _____ name goes second, but remove the original ending and add “ide.”

Ex: Na+ Cl = sodium chlor<u>ide</u>

TRY IT OUT

NO: _____

CaF_2: _____

KCl: _____

NaBr: _____

$MgCl_2$: _____

$CaCl_2$: _____

Chemical Equations

Learning Objectives

At the end of this unit, you will be able to:

- State the four conservation laws that apply to chemical reactions.
- Recognize if a chemical equation is balanced or not.
- Accurately follow the steps required to balance a chemical equation.

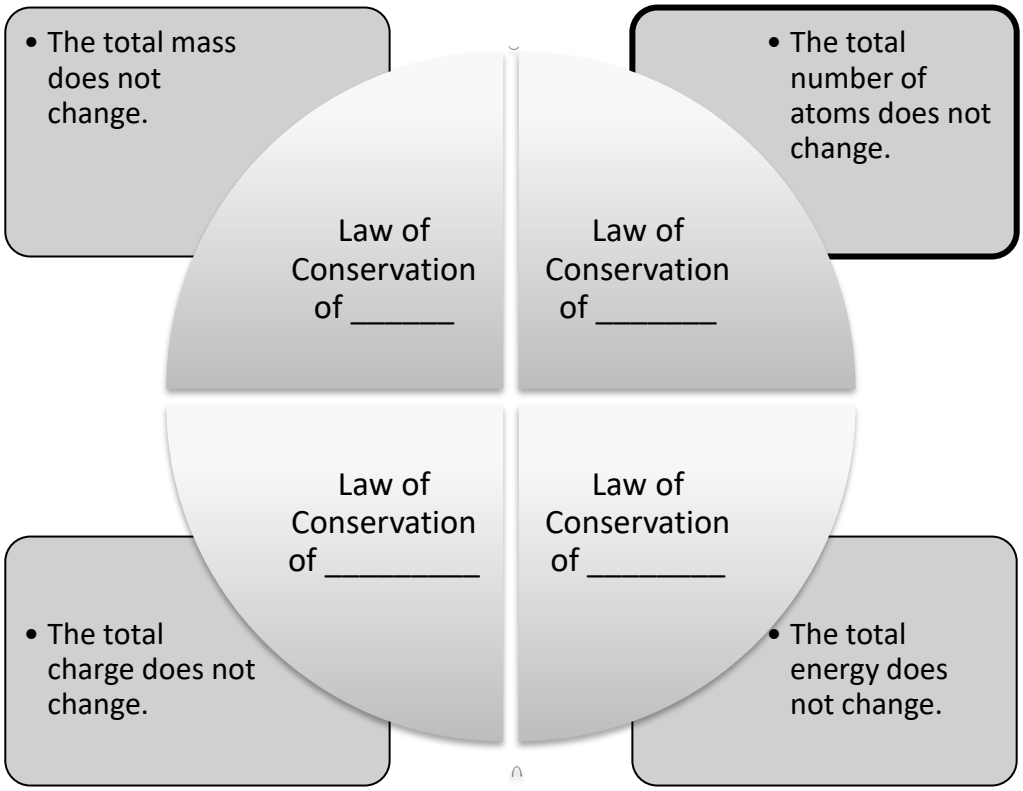
A **chemical equation** is the equation we write to describe the steps of the chemical reaction.

A chemical equation shows the chemicals used up and produced during a chemical reaction.

$H_2O_2 \rightarrow H_2O + O_2$

Chemical Reactions

There are four important conservation laws in chemical reactions in a closed system:



A chemical equation is balanced when the **mass, atoms,** and **electrical charge** are conserved (_____).

FILL IT OUT

H_2S + $PbCl_2$ → PbS + HCl

Left	Right
Pb	Pb
Cl	Cl
S	S
H	H

Balancing Chemical Equations

- Start with an atom that occurs in a compound on each side of the equation. Chose **one** of these as your starting point.
- Start with a metal.
- Save O and H for last.
- Do NOT change subscripts, only coefficients.
- Once a coefficient is added, you must check the other side of the equation to balance the atoms.
- Keep placing coefficients until the equation is balanced.
- A blank is a co-efficient of 1.

TRY IT OUT

___CH_4 + ___ O_2 → ___ CO_2 + ___ H_2O

Left	Right
C	C
O	O
H	H

___ Cr + ___ O_2 → ___ Cr_2O_3

Left	Right
Cr	Cr
O	O

___ CaC_2 + ___ O_2 → ___ Ca + ___ CO_2

Left	Right
Ca	Ca
C	C
O	O

___ Al_2O_3 → ___ Al + ___ O_2

Left	Right
Al	Al
O	O

___ Fe + ___ H_2O → ___ Fe_3O_4 + ___ H_2

Left	Right
Fe	Fe
O	O
H	H

___ C_2H_6 + ___ O_2 → ___ CO_2 + ___ H_2O

Left	Right
C	C
O	O
H	H

___ KNO_3 → ___ KNO_2 + ___ O_2

Left	Right
K	K
N	N
O	O

___ C_2H_6 + ___ O_2 → ___ CO2 + ___ H_2O

Left	Right
C	C
O	O
H	H

___ Na + ___ ZnI_2 → ___ NaI + ___Zn

Left	Right
Na	Na
Zn	Zn
I	I

Acid-Base Chemistry

Learning Objectives

At the end of this unit, you will be able to:

- Define pH and describe the pH scale.
- Use indicators to determine if a substance is an acid or a base.

Acids

- Define the term acid.
- List common properties of acids.
- List three examples of acids.

Bases

- Define the term base.
- List common properties of bases.
- List three examples of bases.

Acids and Bases

Many of the things you use on a daily basis are **acids** or **bases.**

- The main difference between acids and bases is whether they will form _____ ions (acidic) or _____ ions (basic) when dissolved in water.
- Acids share many of the same properties with other acids. Similarly, bases share many of the same properties with other bases.

TRY IT OUT

Substance	Acid or Base: Guess	Acid or Base: Actual
Lemon		
Soap		
Water		
Bleach		
Cola		
Coffee		

Acids

- Sour taste
- React with ionic compounds to form H+ ions
- pH < 7
- Turn litmus paper red

Bases

- Bitter taste
- React with compouds to form OH- ions
- pH > 7
- Turn litmus paper blue

Image sources: Lemons, by oksmith [CC0 1.0]; Bar of Soap, by laurianne [CC0 1.0]

pH Scale

The pH scale is a tool for comparing the acidity or basicity of a substance.

The scale ranges from 0-14.

- 1-6 is considered _____ (more H+ ions than OH- ions).
- 8-14 is considered _____ (more OH- ions than H+ ions).
- 7 is considered _____ (equivalent amounts of H+ and OH- ions).

DRAW IT OUT

pH Scale

The “p” in pH stands for “power” meaning that pH scale is a power scale. Each step away from neutral is 10x stronger than the last.

For example:

- If pH rises from 8 to 9 on the pH scale, the substance is now 10x more basic than before (10x more OH- ions).
- If pH drops from 5 to 3, the substance is now 100x more acidic (100x more H+ ions).

This means that a small change in the **number** of the pH can have a large effect on the properties of the substance.

Lemon juice has a pH of 2 and you can eat it. Battery acid has a pH of one and you *should not* eat it!

Measuring pH

There are several substances that undergo a colour change when exposed to an acid or a base.

These materials are called _____. They indicate a change in _____.

Litmus paper is a common indicator for determining general pH.

- Red litmus paper will turn blue in the presence of a _____.
- Blue litmus paper will turn blue in the presence of an _____.

If you want more specific information about pH than just whether a substance is acidic or basic you can use:

- **pH paper** is strips of paper that change a variety of colours based on the pH of a substance.
- **Digital pH meters** are probes that measure the electrical property of a solution to determine pH.

Chemical Reactions

Learning Objectives

At the end of this unit, you will be able to:

- Identify different types of chemical reactions based on their chemical equations, including:
  - Synthesis
  - Decomposition
  - Single Replacement
  - Double Replacement
  - Neutralization
  - Combustion
- Identify factors that affect rate of reaction.
- Describe energy transformations that take place during chemical reactions, including:
  - Exothermic reactions
  - Endothermic reactions

Types of Chemical Reactions

We can categorize chemical reactions into six main types:

1. **Synthesis** (makes something)
2. **Decomposition** (breaks something)
3. **Single replacement** (one type of atom changes place)
4. **Double replacement** (two types of atoms change place)
5. **Neutralizing** (an acid and base neutralize each other)
6. **Combustion** (reaction with oxygen which releases heat)

Synthesis

In a synthesis reaction, two or more reactants combine to create a _____.

The general formula to represent a synthesis reaction is:

_____.

Real world examples:

$2Na + Cl_2 \rightarrow 2NaCl$
What did this make?
When would you use it?

$2H_2 + O_2 \rightarrow 2H_2O$
What did this make?
When would you use it?

Decomposition

In a decomposition reaction, a single reactant breaks down to create multiple_____.

The general formula to represent a decomposition reaction is:

_____.

Real world examples:

$2Al_2O_3 \rightarrow 4Al + 3O_2$
What did this make?
When would you use it?

$CaCO_3 \rightarrow CaO + CO_2$
What did this make?
When would you use it?

Single Replacement

In a single replacement reaction, a reactive element and a compound produce another element and another compound.

The general formula to represent a single replacement reaction is:

_____.

Real world examples:

$2Al + Fe_2O_3 \rightarrow Al_2O_3 + 2Fe$
What did this make?
When would you use it?

$3C + 2Cr_2O_3 \rightarrow 4Cr + 3CO_2$
What did this make?
When would you use it?

Double Replacement

In a double replacement reaction, two compounds react to form two different compounds.

The general formula to represent a double replacement reaction is:

_____.

Real world examples:

$HCL + NaHCO_3 \rightarrow NaCl + H_2CO_3$
What did this make?
When would you use it?

Neutralization

In a neutralization reaction, an acid and a base react with one another to produce _____. This is a special type of double replacement reaction.

The general formula to represent a double replacement reaction is:

_____.

Real world examples:

$HCL + NaHCO_3 \rightarrow NaCl + H_2CO_3$
What did this make?
When would you use it?

Combustion

In a combustion reaction, a hydrocarbon or carbohydrate is reacted with oxygen in order to produce an _____.

The general formula to represent a combustion reaction is:

_____.

Real world examples:

$CH_4 + 2O_2 \rightarrow CO_2 + H_2O$
What did this make?
When would you use it?

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
What did this make?
When would you use it?

Reaction Type Summary

Reaction Type	Formula	Identifiers
Synthesis	A + B → AB	One product only
Decomposition	AB → A + B	One reactant only
Single Replacement	A + BC → B + AC	One element and one compound
Double Replacement	AB + CD → AD + CB	Two compounds
Neutralization	HA + BOH → BA + H_2O	Acid and base, water as product
Combustion	C_xH_y + O_2 → CO_2 + H_2O	Organic compound with oxygen

Determining Reaction Type

We can often look at the formula of a chemical reaction and determine which of the six types it is. Some things to look for are:

- How many reactants are there?
- How many products are there?
- Was oxygen a reactant?
- Was water a product?
- Were H and OH present in the reactants?

TRY IT OUT

I_2 + 2K → 2 KI

2HCl + MG $(OH)_2$ → $MgCl_2$ + 2 H_2O

Al + $NiBr_3$ → Ni + $AlBr_3$

$2HF \rightarrow H_2 + F_2$

Equation	Type	How do you know?
$Ag + Br \rightarrow AgBr$		
$HCl + Pb(OH)_2 \rightarrow PbCl + H_2O$		
$CaS + NaOH \rightarrow CaOH + NaS$		
$C_4H_{10} + O_2 \rightarrow CO_2 + H_2O$		
$CsI \rightarrow Cs + I$		
$F_2 + NaI \rightarrow I_2 + NaF$		
$AlCl_3 + CuNO_3 \rightarrow AlNO_3$		

Rate of Reaction

Chemical reactions occur at different speeds.

Reaction rate is the measure of how quickly a reaction occurs. It is a measure that combines information about how fast a reactant is being used up (or how quickly a product is being formed) per unit of time.

There are four ways to increase the rate at which a reaction takes place:

1. Increase _____
2. Increase _____
3. Increase _____
4. Increase _____

Energy in Chemical Reactions

In a chemical reaction, bonds are _____.

Molecules tend to want to stay together, so it requires an _____ to break chemical bonds. Conversely, when chemical bonds are formed, _____.

Energy can be absorbed or released in many forms: heat, light, sound, etc. Chemical reactions are categorized based on whether there is an overall _____ of energy.

Endothermic Reactions	Exothermic Reactions
• **Absorb** energy, and require a large input of energy to occur • Example: baking soda in cookie dough in the oven	• **Release** energy and require a small amount of energy to begin, and then releases a large amount of energy • Example: burning natural gas in a furnace