

CHEMISTRY

1 Safety

In order to ensure safety, please note the following rules and regulations when using the laboratory:

(1) No food, drinks, or backpacks are allowed. (2) No running, throwing, or sitting on benches. (3) No shouting or loud voices. (4) No unnecessary movement between benches. (5) Safty goggles and laboratory coats must be worn at all times.

2 Matter

Matter can be classified into (1) pure substances and (2) mixtures. There are 2 types of pure substances: elements and mixtures, along with 2 types of mixtures: heterogeneous and homogenous.

An element is defined as a pures substance that can not be separated into simpler pieces. For example:

H : hydrogen

A compound is defined as a pure substance consisting of 2 or more elements held together by chemical bonds. For example:

H_3PO_3 : phosphoric acid

A heterogeneous mixture is defined as a mixture that is not uniform in composition. For example, cereal. Meanwhile, a homogenous mixture is defined as a mixture that is evenly and microscopically distributed throughout. For example, salt water.

Insert graphical representations here.

2.1 Observing Changes in Matter

The differences between physical and chemical changes are summarized in the following table:

Aspect	Physical Change	Chemical Change
Definition	Change in form or state	Formation of a new substance
Chemical composition	Remains the same	Changes
Reversibility	Often reversible	Usually irreversible
Energy change	Small energy change	Often large energy change
Examples	Melting ice, tearing paper	Rusting iron, burning wood
Evidence observed	Change in shape or phase	Color change, gas, heat, or light

Table 1: Comparison of Physical and Chemical Changes

2.2 Observing Substances and Reactions

Common words and phrases used for describing substances and chemical reactions are found in the table below:

State	Qualitative	Quantitative
Solids	Color, appearance (e.g. grainy, dull, shiny, crystalline, powdery), brittleness, hardness, malleability, ductility	Thermal and electrical conductivity, density, melting point, boiling point
Liquids	Color, appearance (e.g. clear, cloudy), viscosity (can also be quantitative)	Concentration, thermal and electrical conductivity, density, boiling point, melting point, refractive index
Gases	Color	Thermal and electrical conductivity, density, melting point, refractive index

Table 2: Qualitative and Quantitative Properties of Matter

Take note of the following when observing chemical reactions:

- Color changes (including intensity),
- Formation of a gas (i.e. bubbling), then describe the gas,
- Formation of a solid, then describe the solid,
- Formation of a liquid, then describe the liquid,
- Temperature change (exothermic or endothermic),
- Disappearance of any reactants (only use “melted” or “dissolved” if you are absolutely sure),
- Formation of sound or light,
- Production of smells (only test by wafting as instructed): strong, acrid, pungent, sweet, fruit.

Avoid words like “pretty”, “nice”, “clumpy”, “smelly”, and “colorful”.

2.3 The Modern Atomic Theory

In the 1700s, most scientists defined an element as a form of matter that could not be broken down into simpler substances but could combine with other elements to form compounds. However, they could not explain this phenomena.

2.3.1 Dalton

In 1808, Dalton theorized that: (1) an atom is the smallest piece of any element and that they were (2) smooth, solid spheres without an electrical charge. Furthermore, that (3) all atoms of any one element are identical and (4) compounds are created when atoms of different elements combine in a ratio. (5) Atoms can not be created, destroyed, or subdivided during chemical changes.

However, Dalton's theory could not explain static electricity, and thus it was revised as summarized in the following:

1. An atom is the smallest piece of any element and are smooth, solid spheres.
2. Each element has its own type of atom with a unique mass.
3. All atoms of one element are identical.
4. Compounds are created when elements combine in a ratio.
5. Atoms cannot be created, destroyed or subdivided during chemical changes.
6. Matter must contain positive and negative charges.
7. Opposite charges attract and like charges repel.
8. Atoms combine to form the particles of a compound through electrical attraction between charges.

2.3.2 J.J. Thomson

In the late 1800s, the negatively charged particle, the electron, was discovered by J.J. Thomson: "the raisin-bun" model. The key points of Thomson's theory can be summarized in the following points:

1. Atoms contain electrons.
2. Electrons have a negative charge and a tiny mass of around $\frac{1}{800}$ of a proton.
3. The remaining atom has a positive charge.
4. The electrons are randomly scattered in the positively charged atom.
5. Electrons can be removed or added to atoms to create charged atoms.

Insert graphical representations here.

2.3.3 Rutherford

Rutherford shot a gold foil with small, positively charged particles. Unexpectedly, most of the protons passed straight through while some bounced back. He concluded that all matter is concentrated in a very small space and that the atom was mostly empty. Rutherford's revisions can be summarized by the following:

1. The nucleus contains all the positive charge and most of the mass of the atom.
2. The nucleus contains positively charged protons and uncharged neutrons.
3. Neutrons have a very similar mass to protons.
4. The nucleus is small compared to the size of the atom.
5. The electrons orbit the nucleus and the size of the atom is determined by the size of the orbit of the electrons.

6. There is only empty space between the electrons and the nucleus.

Insert graphical representations here.

2.4 Emission Spectra

Definition: the pattern of light that is emitted when atoms absorb energy.

Each element has the ability to absorb and emit energy in the form of light in colors. This electromagnetic energy is seen in the form of visible light or distinct line(s). The resulting emission spectrum, sometimes referred to as a line spectrum, is specific to each element.

Insert graphical representations here.

Rutherford's model did not explain release of energy from atoms in defined "quantums".

2.5 Bohr's Atomic Theory

This is the most recent atomic theory that we will observe in this study guide. Bohr's Atomic Theory can be summarized in the following bullet points:

1. Electrons are restricted to specific orbits (shells), which are specific distances from the nucleus.
2. The electrons can not occupy the space between these defined shells but can move to different shells.
3. An "excited" electron moves to a higher shell but moves back to a lower shell when it loses energy, correctly explaining the results in the emission spectra.
4. Electrons are stable when closer (possess less energy) to the nucleus and less stable when further away (possess more energy).

2.5.1 Bohr Diagrams

Bohr diagrams visualize the arrangement of electrons in different atoms. For the first twenty elements the maximum number of electrons per shell is as follows:

- 1st shell: 2e
- 2nd shell: 8e
- 3rd shell: 8e
- 4th shell: *remaining*

Insert graphical representations here.

3 Chemical Families

The table below summarizes the shared properties of chemical families:

Property	Metals	Metalloids	Non-metals
State at STP	Mostly solid	Solid	Solid, liquid, or gas
Appearance	Shiny (lustrous)	Variable	Dull
Conductivity	Good conductors	Semiconductors	Poor conductors
Malleability	Malleable	Brittle	Brittle if solid
Ductility	Ductile	Not ductile	Not ductile
Ion formation	Form cations	Variable	Form anions
Typical location	Left and center	Stair-step boundary	Right side
Examples	<i>Fe, Cu, Al</i>	<i>Si, B, As</i>	<i>O, S, Cl</i>

Table 3: Comparison of Chemical Families

Group	Reactivity	Key Features	Common Uses	Notes
Alkali metals (G1)	Extremely high	Soft, low density, form +1 ions	Batteries, fertilizers	Stored in oil; highly reactive; abundant in Earth's crust
Alkaline earth metals (G2)	High	Harder than G1, form +2 ions	Construction materials, fireworks	<i>Ca</i> and <i>Ba</i> react violently with water; <i>Ba</i> stored in oil; <i>Mg</i> burns brightly and reacts with CO_2 ; <i>Mg</i> fires cannot be extinguished with standard fire extinguishers
Halogens (G17)	Very high	Diatomic non-metals	Disinfectants, salt production	Brightly colored in the gaseous state
Noble gases (G18)	Very low	Full valence shell	Lighting, shielding gases	Chemically inert under standard conditions

Table 4: Properties and Uses of Selected Periodic Table Groups

4 Introduction to Formula Writing

4.1 Understanding Bohr Diagrams

To better understand formula writing, we will begin by observing Bohr diagrams. Observe the following Bohr models for *Li*, *F*, and *LiF*.

Insert graphical representations here.

When elements form compounds, they aim to attain a complete outer shell: a stable shell. This is completed through the gaining or losing of electrons. For example, as shown in Figure??, lithium will lose its single electron in its outer shell to fluorine, completing its outer ring.

4.2 Chemical Formulas

A chemical formula identifies a compound by indicating the elements it contains and the number of atoms of each element. Compounds form when elements combine in fixed, definite proportions. As a

result, a given compound always has the same elemental composition.

4.2.1 Ionic Compounds

The compound formed by joining lithium and fluorine is an example of an ionic compound. These are formed when a metal unites with a non-metal, where the metal generally loses electrons and the non-metal gains them. Any atoms that has lost or gained electrons are ions and the ion charge of an element indicates whether the atom will gain or lose electrons. For example:

Element	Ion Charge	Electron Movement
Barium (<i>Ba</i>)	2+	Lose 2e
Phosphorus (<i>P</i>)	3-	Gain 3e

Table 5: Properties and Uses of Selected Periodic Table Groups

4.2.2 The Criss-Cross Method

The criss-cross method is taught as a simple introductory method to write chemical formulas. For example:

Write the formula for phosphorus oxide:

1. Write the symbol of each element with the number of their ion charge: $K^{1+} + O^{2-}$
2. Criss-cross the ion charges with the numbers and write them as subscripts: K_2O_1
3. Simplify where applicable: K_2O

Answer: K_2O

4.3 Special Cases

In Grade 9, there are 2 special cases covered in the curriculum: polyatomic ions and multivalent elements.

4.3.1 Polyatomic Ions

Certain atoms group together into a compound but should be treated as a single element with an overall charge. For example:

Write the formula for magnesium bicarbonate:

Answer: $Mg(HCO)_3$

4.3.2 Multivalent Elements

Many metals have more than one ion charge. Roman numerals are used to indicate which ion charge to use. For example:

Write the formula for iron(II) chloride:

Answer: $FeCl_2$

4.4 Naming Ionic Compounds

To name an ionic compound, follow the following steps:

1. Metals are named first, as in formulas, and written as is on the periodic table (e.g. iron(II)). Note to include Roman numerals for multivalent elements.
2. Non-metals are written second with the ending changed to the suffix -ide (e.g. carbide).
3. Positive polyatomic ions are written first while negative polyatomic ions are written second. Their names are unchanged.
4. All ionic compounds should not be capitalized.

For example:

Write the IUPAC name for: CuF

Answer: copper(I) fluoride

Incorrect response example: Copper(1) Fluoride (there should be no capitals and multivalent elements should be expressed with Roman numerals).

5 Exothermic and Endothermic Reactions

The table below summarizes the definition and graphs of exothermic and endothermic reactions.

Type of Reaction	Definition	Graph
Exothermic	A chemical process during which energy is released (e.g. through light, heat, etc.)	Insert graphical representations here.
Endothermic	A chemical process in which energy is required to initiate	Insert graphical representations here.

Table 6: Exothermic and Endothermic Definitions and Graphs