Metals and Non-Metals

Key Concepts

Elements can be classified as metals or non-metals on the basis of their properties.

Physical properties include:

appearance

density

melting and boiling point

conductivity of heat and electricity

tensile strength (resistance to bending)

malleability (ability to roll into sheets)

ductility (ability to draw into a wire)

Chemical properties include:

charge on ions formed from the element

type of bonding found in the element's oxides and chlorides

pH of the element's oxide

Metals are found on the left hand side of the Periodic Table while non-metals are found on the right hand side.

Properties of Metallic and Non-Metallic Elements

Property	Metallic Elements	Non-Metallic Elements
Appearance (physical property)	lustrous	dull
Density (physical property)	moderate to high	low to moderate
Physical State (25°C, 101.3kPa) (physical property)	solid (except liquid mercury)	solid, liquid or gas

Melting and Boiling Point (physical property)	moderate to high	wide range
Heat and Electrical Conductivity (physical property)	good	poor (except graphite)
Tensile Strength (resistance to bending) (physical property)	high	brittle
Malleability (roll into sheets) (physical property)	malleable	not malleable
Ductility (draw into wire) (physical property)	ductile	not ductile
Charge on Ions (in general)* (chemical property)	forms positive ions	forms negative ions
Bonding in oxides and chlorides (chemical property)	usually ionic**	covalent
pH of oxides (chemical property)	usually basic***	usually acidic

*some non-metals can form positive or negative ions, eg, H^+ and H^-
**some metal oxides are covalent, eg, Al_2O_3
***some metal oxides are amphoteric (both acidic and basic), eg, Al_2O_3

Examples of Metals and Non-metals

Property	Metal		Non-Metal	
	magnesium	zinc	oxygen	sulfur
Density (g/mL)	1.74	7.14	0.0013	2.07
Melting Point (°C)	650	419	-219	113
Electrical Conductivity (megaohm^{-1})	23	16	0	10^{-21}

Charge on Ion	2+	2+	2-	2-
Bonding in Oxides	MgO ionic	ZnO ionic	O_2 covalent	SO_2 covalent

Position of Metallic and Non-Metallic Elements in the Periodic Table

Metals	Metals occur on the left hand side of the Periodic Table.
Non-metals	Non-metals occur on the right hand side of the Periodic Table.
Semi-metals (metalloids)	Semi-metals with properties in between metals and non-metals occur between these two groups. (B, Si, Ge, As, Sb, Te)

metals				non-metals				H
								He
Li	Be		B	C	N	O	F	Ne
Na	Mg		Al	Si	P	S	Cl	Ar
K	Ca	Transition Metals	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Transition Metals	In	Sn	Sb	Te	I	Xe
Cs	Ba	Transition Metals	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Transition Metals						

Chemical and Physical Changes

Key Concepts

A chemical change involves the formation of atleast one new substance.

A chemical change is usually difficult to reverse.

A physical change does not involve the the formation of any new substances.

A physical change involves a change in the physical state or appearance of the substance.

A physical change is usually easy to reverse.

Physical Changes

No new substances are produced during a physical change.

Common physical changes include:

Physical Change	Example
Melting a Solid change of state	Ice, solid water, can be heated to form liquid water.
Freezing a liquid change of state	Liquid water can be frozen to form solid water, ice.
Boiling a liquid change of state	Liquid water can be heated to form water vapour, a gas.
Condensing a gas change of state	Water vapour can be cooled to form liquid water.
Dissolving a solid	Solid sodium chloride can be dissolved in liquid water to form sodium chloride solution.
Evaporating a solution	Sodium chloride solution can be gently heated to remove the water as water vapour leaving the solid sodium chloride behind.
Grinding a solid	Pieces of calcium carbonate can be ground down to form smaller pieces of calcium carbonate.
Changing the shape	A piece of copper wire can be hammered out into a flat sheet of copper.

Chemical Changes

A chemical change results in the formation of one or more new substances.

There are a number of observations that we can make to detect a chemical change:

Observation	Example
a gas is evolved	when magnesium reacts with hydrochloric acid a new substance, hydrogen gas, is produced.
an odour is produced	When hydrochloric acid is added to iron sulfide, the pungent odour of "rotten eggs" is produced due to the formation of the new substance hydrogen sulfide gas.
a new solid is formed	When silver nitrate solution is added to sodium chloride solution, a new white solid of silver chloride is produced.
a colour change	When metallic iron reacts with oxygen in the presence of water, a new red coloured solid called rust is formed.
a temperature change	When sodium reacts with water the temperature of the water increases substantially due to the chemical reaction between the two reactants.
a solid disappears (that is not due to a physical change)	When solid sodium hydroxide is added to hydrochloric acid, the solid disappears due to a chemical reaction between the two reactants.

History of the Periodic Table of the Elements

Contributor	Date	Contribution	Comment
Aristotle	~330 BC	Four element theory: earth, air, fire & water	
Antoine	~1770-	Wrote the first extensive list of elements containing 33 elements.	Some of Lavoisier's elements were later

Lavoisier	1789	Distinguished between metals and non-metals.	shown to be compounds and mixtures.
Jöns Jakob Berzelius	1828	Developed a table of atomic weights. Introduced letters to symbolize elements.	
Johann Döbereiner	1829	Developed 'triads', groups of 3 elements with similar properties. Lithium, sodium & potassium formed a triad. Calcium, strontium & barium formed a triad. Chlorine, bromine & iodine formed a triad.	Forerunner to the notion of groups.
John Newlands	1864	The known elements (>60) were arranged in order of atomic weights and observed similarities between the first and ninth elements, the second and tenth elements etc. He proposed the 'Law of Octaves'.	Newlands' Law of Octaves identified many similarities amongst the elements, but also required similarities where none existed. He did not leave spaces for elements as yet undiscovered. Forerunner to the notion of periods.
Lothar Meyer	1869	Compiled a Periodic Table of 56 elements based on the periodicity of properties such as molar volume when arranged in order of atomic weight.	Meyer & Mendeleev produced their Periodic Tables simultaneously.
Dmitri Mendeleev	1869	Produced a table based on atomic weights but arranged 'periodically' with elements with similar properties under each other. Gaps were left for elements that were unknown at that time and their properties predicted (the elements were gallium, scandium and germanium). The order of elements was re-arranged if their properties dictated it, eg, tellerium is heavier than iodine but comes before it in the Periodic Table.	Mendeleev's Periodic Table was important because it enabled the properties of elements to be predicted by means of the 'periodic law': properties of the elements vary periodically with their atomic weights.

William Ramsay	1894	Discovered the Noble Gases.	In 1894 Ramsay removed oxygen, nitrogen, water and carbon dioxide from a sample of air and was left with a gas 19 times heavier than hydrogen, very unreactive and with an unknown emission spectrum. He called this gas Argon. In 1895 he discovered helium as a decay product of uranium and matched it to the emission spectrum of an unknown element in the sun that was discovered in 1868. (helios is the Greek for Sun). He went on to discover neon, krypton and xenon, and realised these represented a new group in the Periodic Table. Ramsay was awarded a Nobel Prize in 1904.
Henry Moseley	1913	Determined the atomic number of each of the elements. He modified the 'Periodic Law' to read that the properties of the elements vary periodically with their atomic numbers.	Moseley's modified Periodic Law puts the elements tellerium and iodine in the right order, as it does for argon and potassium, cobalt and nickel.
	1914	Predicted that there were 3 unknown elements between aluminium and gold and concluded there were only 92 elements up to and including uranium.	
Glenn Seaborg	1940	Synthesised transuranic elements (the elements after uranium in the periodic table)	In 1940 uranium was bombarded with neutrons in a cyclotron to produced neptuniun (Z=93). Plutonium (Z=94) was produced from uranium and deuterium. These new elements were part of a new block of the Periodic table called Actinides. Seaborg was awarded a Nobel Prize in 1951.