

GLOSSARY

Absolute zero

temperature at which the volume of a gas would be zero according to Charles's law.

Accuracy

How closely a measurement aligns with a correct value

Acid

substance that produces H_3O^+ when dissolved in water

acid dissociation constant, (K_a)

is an equilibrium constant that gives numerical representation of an acid's strength in a solution based its degree of dissociation in water. The greater the K_a , the stronger the acid.

Acid-base reaction

reaction involving the transfer of a hydrogen ion between reactant species

acid-ionization constant, K_a

equilibrium constant for the ionization of a weak acid

acidic

describes a solution in which $[\text{H}_3\text{O}^+] > [\text{OH}^-]$

Actinide

Inner transition metal in the bottom of the bottom two rows of the periodic table

active electrode

electrode that participates in the oxidation-reduction reaction of an electrochemical cell; the mass of an active electrode changes during the oxidation-reduction reaction

activity series

A list of elements that will replace elements below them in single-replacement reactions.

Actual yield

amount of product formed in a reaction

Adhesive force

force of attraction between molecules of different chemical identities

Alkali metal

element in group 1

Alkaline batteries

primary battery that uses an alkaline (often potassium hydroxide) electrolyte; designed to be an exact replacement for the dry cell, but with more energy storage and less electrolyte leakage than typical dry cell

Alkaline earth metal

element in group 2

Alloy

solid mixture of a metallic element and one or more additional elements

Alpha particle (α particle)

positively charged particle consisting of two protons and two neutrons

Amontons's law

(also, Gay-Lussac's law) pressure of a given number of moles of gas is directly proportional to its kelvin temperature when the volume is held constant

Amphiphilic

molecules possessing both hydrophobic (nonpolar) and a hydrophilic (polar) parts

amphiprotic

Able to both donate and accept a proton, and thus able to react both as an acid and a base

amphoteric

species that can act as either an acid or a base

Amplitude

extent of the displacement caused by a wave (for sinusoidal waves, it is one-half the difference from the peak height to the trough depth, and the intensity is proportional to the square of the amplitude)

Analyte

chemical species of interest; in a titration experiment, it is the solution of unknown solution for which you would like to determine either the concentration or the equilibrium constant.

angular momentum quantum number

quantum number distinguishing the different shapes of orbitals; it is also a measure of the orbital angular momentum

Anion

negatively charged atom or molecule (contains more electrons than protons)

anode

electrode in an electrochemical cell at which oxidation occurs; information about the anode is recorded on the left side of the salt bridge in cell notation

Aqueous solution

solution for which water is the solvent

Arrhenius acid

An acid as a compound that dissolves in water to produce H^+ ions (hydronium ions, H_3O^+)

Arrhenius base

a compound that dissolves in water to yield hydroxide ions (OH^-)

Atmosphere

unit of pressure; $1 \text{ atm} = 101,325 \text{ Pa}$

atom

smallest particle of an element that can enter into a chemical combination

Atomic mass

average mass of atoms of an element, expressed in amu

Atomic mass unit (amu)

(also, unified atomic mass unit, u, or Dalton, Da) unit of mass equal to $1/12$ the mass of a ^{12}C atom

Atomic number (Z)

number of protons in the nucleus of an atom

atomic orbital

mathematical function that describes the behavior of an electron in an atom (also called the wavefunction), it can be used to find the probability of locating an electron in a specific region around the nucleus, as well as other dynamical variables

Aufbau principle

procedure in which the electron configuration of the elements is determined by “building” them in order of atomic numbers, adding one proton to the nucleus and one electron to the proper subshell at a time

autoionization

reaction between identical species yielding ionic products; for water, this reaction involves transfer of protons to yield hydronium and hydroxide ions

average rate

rate of a chemical reaction computed as the ratio of a measured change in amount or concentration of substance to the time interval over which the change occurred

Avogadro's law

volume of a gas at constant temperature and pressure is proportional to the number of gas molecules

Avogadro's number (N_A)

experimentally determined value of the number of entities comprising 1 mole of substance, equal to $6.022 \times 10^{23} \text{ mol}^{-1}$

Axial position

location in a trigonal bipyramidal geometry in which there is another atom at a 180° angle and the equatorial positions are at a 90° angle

Balanced equation

chemical equation with equal numbers of atoms for each element in the reactant and product

Bar

(bar or b) unit of pressure; $1 \text{ bar} = 100,000 \text{ Pa}$

Barometer

device used to measure atmospheric pressure

Base

substance that produces OH^- when dissolved in water

base dissociation constant, (K_b)

is an equilibrium constant that measures how completely a base dissociates into ions in water. The greater the K_b , the stronger the base.

base-ionization constant (K_b)

equilibrium constant for the ionization of a weak base

basic

describes a solution in which $[\text{H}_3\text{O}^+] < [\text{OH}^-]$

battery

galvanic cell or series of cells that produces a current; in theory, any galvanic cell

Binary acid

compound that contains hydrogen and one other element, bonded in a way that imparts acidic properties to the compound (ability to release H^+ ions when dissolved in water)

Binary compound

compound containing two different elements.

Blackbody

idealized perfect absorber of all incident electromagnetic radiation; such bodies emit electromagnetic radiation in characteristic continuous spectra called blackbody radiation

Bohr's model

structural model in which an electron moves around the nucleus only in circular orbits, each with a specific allowed radius; the orbiting electron does not normally emit electromagnetic radiation, but does so when changing from one orbit to another.

Boiling point

temperature at which the vapor pressure of a liquid equals the pressure of the gas above it

Boiling point elevation

elevation of the boiling point of a liquid by addition of a solute

Boiling point elevation constant

the proportionality constant in the equation relating boiling point elevation to solute molality; also known as the ebullioscopic constant

bomb calorimeter

device designed to measure the energy change for processes occurring under conditions of constant volume; commonly used for reactions involving solid and gaseous reactants or products

Bond angle

angle between any two covalent bonds that share a common atom

Bond dipole moment

separation of charge in a bond that depends on the difference in electronegativity and the bond distance represented by partial charges or a vector

Bond distance

(also, bond length) distance between the nuclei of two bonded atoms

Bond energy

(also, bond dissociation energy) energy required to break a covalent bond in a gaseous substance

Bond length

distance between the nuclei of two bonded atoms at which the lowest potential energy is achieved

Born-Haber cycle

thermochemical cycle relating the various energetic steps involved in the formation of an ionic solid from the relevant elements

Boyle's law

volume of a given number of moles of gas held at constant temperature is inversely proportional to the pressure under which it is measured

Brønsted-Lowry acid

A compound that donates a proton to another compound

Brønsted-Lowry base

a compound that accepts a proton

Buret

device used for the precise delivery of variable liquid volumes, such as in a titration analysis

calories (cal)

unit of heat or other energy; the amount of energy required to raise 1 gram of water by 1 degree Celsius; 1 cal is defined as 4.184 J

calorimeter

device used to measure the amount of heat absorbed or released in a chemical or physical process

calorimetry

process of measuring the amount of heat involved in a chemical or physical process

Capillary action

flow of liquid within a porous material due to the attraction of the liquid molecules to the surface of the material and to other liquid molecules

cathode

electrode in an electrochemical cell at which reduction occurs; information about the cathode is recorded on the right side of the salt bridge in cell notation

cathodic protection

method of protecting metal by using a sacrificial anode and effectively making the metal that needs protecting the cathode, thus preventing its oxidation

Cation

positively charged atom or molecule (contains fewer electrons than protons)

cell notation

shorthand way to represent the reactions in an electrochemical cell

cell potential

created when two dissimilar metals are connected together and is a measure of the energy per unit charge available from the oxidation-reduction reaction

Celsius (°C)

Unit of temperature; water freezes at 0 °C and boils at 100 °C on this scale.

Chalcogen

element in group 16

Charles's law

volume of a given number of moles of gas is directly proportional to its kelvin temperature when the pressure is held constant

chemical change

change producing a different kind of matter from the original kind of matter

Chemical equation

symbolic representation of a chemical reaction

chemical property

behavior that is related to the change of one kind of matter into another kind of matter

Chemical symbol

one-, two-, or three-letter abbreviation used to represent an element or its atoms

chemical thermodynamics

area of science that deals with the relationships between heat, work, and all forms of energy associated with chemical and physical processes

chemistry

Study of the composition, properties, and interactions of matter

Clausius-Clapeyron equation

mathematical relationship between the temperature, vapor pressure, and enthalpy of vaporization for a substance

Coefficient

number placed in front of symbols or formulas in a chemical equation to indicate their relative amount

Cohesive force

force of attraction between identical molecules

Colligative property

property of a solution that depends only on the concentration of a solute species

Colloid

(also, colloidal dispersion) mixture in which relatively large solid or liquid particles are dispersed uniformly throughout a gas, liquid, or solid

Combustion analysis

gravimetric technique used to determine the elemental composition of a compound via the collection and weighing of its gaseous combustion products

Combustion reaction

vigorous redox reaction producing significant amounts of energy in the form of heat and, sometimes, light

common ion effect

effect on equilibrium when a substance with an ion in common with the dissolved species is added to the solution; causes a decrease in the solubility of an ionic species, or a decrease in the ionization of a weak acid or base

Complete ionic equation

chemical equation in which all dissolved ionic reactants and products, including spectator ions, are explicitly represented by formulas for their dissociated ions

composition reaction

A chemical reaction in which a single substance is produced from multiple reactants.

compounds

pure substance that can be decomposed into two or more elements

Compressibility factor (Z)

ratio of the experimentally measured molar volume for a gas to its molar volume as computed from the ideal gas equation

Concentrated

qualitative term for a solution containing solute at a relatively high concentration

Concentration

quantitative measure of the relative amounts of solute and solvent present in a solution

Condensation

change from a gaseous to a liquid state

conjugate acid

the product that results when a base accepts a proton

conjugate base

the product that remains after an acid donates a proton

Continuous spectrum

electromagnetic radiation given off in an unbroken series of wavelengths (e.g., white light from the sun)

coordinate covalent bond

(also, dative bond) bond formed when one atom provides both electrons in a shared pair

core electrons

electron in an atom that occupies the orbitals of the inner shells

Corrosion

degradation of metal through an electrochemical process

Covalent bond

attractive force between the nuclei of a molecule's atoms and pairs of electrons between the atoms

Covalent compound

(also, molecular compound) composed of molecules formed by atoms of two or more different elements

covalent radius

one-half the distance between the nuclei of two identical atoms when they are joined by a covalent bond

Crenation

process whereby biological cells become shriveled due to loss of water by osmosis

Critical point

temperature and pressure above which a gas cannot be condensed into a liquid

Cubic centimeter

Volume of a cube with an edge length of exactly 1 cm.

Cubic meter

SI unit of volume.

d orbitals

written as: *d* orbitals

region of space with high electron density that is either four lobed or contains a dumbbell and torus shape; describes orbitals with $l = 2$. An electron in this orbital is called a d electron

Dalton (Da)

alternative unit equivalent to the atomic mass unit

Dalton's atomic theory

set of postulates that established the fundamental properties of atoms

Dalton's law of partial pressures

total pressure of a mixture of ideal gases is equal to the sum of the partial pressures of the component gases.

decomposition reaction

A chemical reaction in which a single substance becomes more than one substance.

degeneracy

electron orbitals having the same energy levels

Density

Ratio of mass to volume for a substance or object.

Deposition

change from a gaseous state directly to a solid state

diatomic molecules

molecules that contain two identical atoms chemically bonded together

Diffusion

movement of an atom or molecule from a region of relatively high concentration to one of relatively low concentration (discussed in this chapter with regard to gaseous species, but applicable to species in any phase)

Dilute

qualitative term for a solution containing solute at a relatively low concentration

Dilution

process of adding solvent to a solution in order to lower the concentration of solutes

Dimensional analysis

(also, factor-label method) versatile mathematical approach that can be applied to computations ranging from simple unit conversions to more complex, multi-step calculations involving several different quantities

Dipole moment

property of a molecule that describes the separation of charge determined by the sum of the individual bond moments based on the molecular structure

dipole-dipole attraction

intermolecular attraction between two permanent dipoles

diprotic acid

A diprotic acid is an acid that yields two H^+ ions per acid molecule. Examples of diprotic acids are sulfuric acid, H_2SO_4 , and carbonic acid, H_2CO_3

Dispersed phase

substance present as relatively large solid or liquid particles in a colloid

Dispersion force

(also, London dispersion force) attraction between two rapidly fluctuating, temporary dipoles; significant only when particles are very close together

Dispersion medium

solid, liquid, or gas in which colloidal particles are dispersed

Dissociation

physical process accompanying the dissolution of an ionic compound in which the compound's constituent ions are solvated and dispersed throughout the solution

Dissolved

describes the process by which solute components are dispersed in a solvent

Double bond

covalent bond in which two pairs of electrons are shared between two atoms

double-replacement reaction

A chemical reaction in which parts of two ionic compounds are exchanged.

dry cell

primary battery, also called a zinc-carbon battery; can be used in any orientation because it uses a paste as the electrolyte; tends to leak electrolyte when stored

Dynamic equilibrium

state of a system in which reciprocal processes are occurring at equal rates

effective nuclear charge, Z_{eff}

charge that leads to the Coulomb force exerted by the nucleus on an electron, calculated as the nuclear charge minus shielding

Effusion

transfer of gaseous atoms or molecules from a container to a vacuum through very small openings

electric charge

physical property of an object that causes it to be attracted toward or repelled from another charged object; each charged object generates and is influenced by a force called an electric force

electric forces

noncontact force observed between electrically charged objects

electrolysis

process using electrical energy to cause a nonspontaneous process to occur

electrolytes

substances that produce ions when dissolved in water and whose aqueous solutions can conduct electricity

electrolytic cells

electrochemical cell in which electrolysis is used; electrochemical cell with negative cell potentials

Electromagnetic radiation

energy transmitted by waves that have an electric-field component and a magnetic-field component

Electromagnetic spectrum

range of energies that electromagnetic radiation can comprise, including radio, microwaves, infrared, visible, ultraviolet, X-rays, and gamma rays; since electromagnetic radiation energy is proportional to the frequency and inversely proportional to the wavelength, the spectrum can also be specified by ranges of frequencies or wavelengths

Electron

negatively charged, subatomic particle of relatively low mass located outside the nucleus

electron affinity

energy required to add an electron to a gaseous atom to form an anion

electron configurations

electronic structure of an atom in its ground state given as a listing of the orbitals occupied by the electrons

Electron-pair geometry

arrangement around a central atom of all regions of electron density (bonds, lone pairs, or unpaired electrons)

Electronegativity

tendency of an atom to attract electrons in a bond to itself

electroplating

depositing a thin layer of one metal on top of a conducting surface

electrostatic attraction

phenomenon of two objects with opposite charges attracting each other

electrostatic repulsion

phenomenon of two objects with like charges repelling each other

elements

substance that is composed of a single type of atom; a substance that cannot be decomposed by a chemical change

Empirical formula mass

sum of average atomic masses for all atoms represented in an empirical formula

empirical formulas

simplest or most reduced ratio of elements in a compound

Emulsifying agent

amphiphilic substance used to stabilize the particles of some emulsions

Emulsion

colloid formed from immiscible liquids

End point

measured volume of titrant solution that yields the change in sample solution appearance or other property expected for stoichiometric equivalence (see *equivalence point*)

endothermic process

chemical reaction or physical change that absorbs heat

Energy

capacity to supply heat or do work

enthalpy (H)

sum of a system's internal energy and the mathematical product of its pressure and volume

enthalpy change (ΔH)

heat released or absorbed by a system under constant pressure during a chemical or physical process

Equatorial position

one of the three positions in a trigonal bipyramidal geometry with 120° angles between them; the axial positions are located at a 90° angle

equilibrium

in chemical reactions, the state in which the conversion of reactants into products and the conversion of products back into reactants occur simultaneously at the same rate; state of balance

equilibrium constant

value of the reaction quotient for a system at equilibrium

Equivalence point

volume of titrant solution required to react completely with the analyte in a titration analysis; provides a stoichiometric amount of titrant for the sample's analyte according to the titration reaction

Exact number

Number derived by counting or by definition

Excess reactant

reactant present in an amount greater than required by the reaction stoichiometry

Excited state

state having an energy greater than the ground-state energy

exothermic process

chemical reaction or physical change that releases heat

expansion work

work done as a system expands or contracts against external pressure

extensive property

property of a substance that depends on the amount of the substance

factor-label method

versatile mathematical approach that can be applied to computations ranging from simple unit conversions to more complex, multi-step calculations involving several different quantities

Fahrenheit

Unit of temperature; water freezes at 32 °F and boils at 212 °F on this scale

first law of thermodynamics

internal energy of a system changes due to heat flow in or out of the system or work done on or by the system

Formal charge

charge that would result on an atom by taking the number of valence electrons on the neutral atom and subtracting the nonbonding electrons and the number of bonds (one-half of the bonding electrons)

formula mass

sum of the average masses for all atoms represented in a chemical formula; for covalent compounds, this is also the molecular mass

Free radical

molecule that contains an odd number of electrons

Freezing

change from a liquid state to a solid state

Freezing point

temperature at which the solid and liquid phases of a substance are in equilibrium; see also *melting point*

Freezing point depression

lowering of the freezing point of a liquid by addition of a solute

Freezing point depression constant

(also, cryoscopic constant) proportionality constant in the equation relating freezing point depression to solute molality

Frequency (ν)

number of wave cycles (peaks or troughs) that pass a specified point in space per unit time

fuel cell

devices that produce an electrical current as long as fuel and oxidizer are continuously added; more efficient than internal combustion engines

Fundamental unit of charge

(also called the elementary charge) equals the magnitude of the charge of an electron (e) with $e = 1.602 \times 10^{-19} \text{ C}$

Galvanic cells

electrochemical cell that involves a spontaneous oxidation-reduction reaction; electrochemical cells with positive cell potentials; also called a voltaic cell

galvanized iron

method for protecting iron by covering it with zinc, which will oxidize before the iron; zinc-plated iron

gas

state in which matter has neither definite volume nor shape

Gel

colloidal dispersion of a liquid in a solid

Graham's law of effusion

rates of diffusion and effusion of gases are inversely proportional to the square roots of their molecular masses

Gravimetric analysis

quantitative chemical analysis method involving the separation of an analyte from a sample by a physical or chemical process and subsequent mass measurements of the analyte, reaction product, and/or sample

Ground state

state in which the electrons in an atom, ion, or molecule have the lowest energy possible

Group

vertical column of the periodic table

groups

vertical column of the periodic table

Half-reaction

an equation that shows whether each reactant loses or gains electrons in a reaction.

Halogen

element in group 17

Heat (q)

transfer of thermal energy between two bodies

heat capacity (C)

extensive property of a body of matter that represents the quantity of heat required to increase its temperature by 1 degree Celsius (or 1 kelvin)

Heisenberg uncertainty principle

It is fundamentally impossible to determine simultaneously and exactly both the momentum and the position of a particle.

Hemolysis

rupture of red blood cells due to the accumulation of excess water by osmosis

Henry's law

law stating the proportional relationship between the concentration of dissolved gas in a solution and the partial pressure of the gas in contact with the solution

Hertz (Hz)

the unit of frequency, which is the number of cycles per second, s^{-1}

Hess's law

if a process can be represented as the sum of several steps, the enthalpy change of the process equals the sum of the enthalpy changes of the steps

heterogeneous equilibrium

equilibria between reactants and products in different phases

heterogeneous mixture

combination of substances with a composition that varies from point to point

homogeneous equilibrium

equilibria within a single phase

homogeneous mixture

(also, solution) combination of substances with a composition that is uniform throughout

Hund's rule

Every orbital in a sublevel is singly occupied before any orbital is doubly occupied.

All of the electrons in singly occupied orbitals have the same spin (to maximize total spin).

hydrocarbons

compound composed only of hydrogen and carbon; the major component of fossil fuels

Hydrogen bonding

occurs when exceptionally strong dipoles attract; bonding that exists when hydrogen is bonded to one of the three most electronegative elements: F, O, or N

Hydrostatic pressure

pressure exerted by a fluid due to gravity

Hypertonic

of greater osmotic pressure

Hypervalent molecule

molecule containing at least one main group element that has more than eight electrons in its valence shell

Hypothesis

Tentative explanation of observations that acts as a guide for gathering and checking information

Hypotonic

of less osmotic pressure

Ideal gas

hypothetical gas whose physical properties are perfectly described by the gas laws

Ideal gas constant (R)

constant derived from the ideal gas equation $R = 0.08226 \text{ L atm mol}^{-1} \text{ K}^{-1}$ or $8.314 \text{ L kPa mol}^{-1} \text{ K}^{-1}$

Ideal gas law

relation between the pressure, volume, amount, and temperature of a gas under conditions derived by combination of the simple gas laws

Ideal solution

solution that forms with no accompanying energy change

Immiscible

of negligible mutual solubility; typically refers to liquid substances

Indicator

substance added to the sample in a titration analysis to permit visual detection of the end point

Induced dipole

temporary dipole formed when the electrons of an atom or molecule are distorted by the instantaneous dipole of a neighboring atom or molecule

Inert electrodes

electrode that allows current to flow, but that does not otherwise participate in the oxidation-reduction reaction in an electrochemical cell; the mass of an inert electrode does not change during the oxidation-reduction reaction; inert electrodes are often made of platinum or gold because these metals are chemically unreactive.

Inert gas

(also, noble gas) element in group 18

Inert pair effect

tendency of heavy atoms to form ions in which their valence s electrons are not lost

initial rate

instantaneous rate of a chemical reaction at $t = 0$ s (immediately after the reaction has begun)

Inner transition metal

(also, lanthanide or actinide) element in the bottom two rows; if in the first row, also called lanthanide, or if in the second row, also called actinide

Insoluble

of relatively low solubility; dissolving only to a slight extent

Instantaneous dipole

temporary dipole that occurs for a brief moment in time when the electrons of an atom or molecule are distributed asymmetrically

instantaneous rate

rate of a chemical reaction at any instant in time, determined by the slope of the line tangential to a graph of concentration as a function of time

Intensity

property of wave-propagated energy related to the amplitude of the wave, such as brightness of light or loudness of sound

intensive property

property of a substance that is independent of the amount of the substance

Interference pattern

pattern typically consisting of alternating bright and dark fringes; it results from constructive and destructive interference of waves

Intermolecular force

noncovalent attractive force between atoms, molecules, and/or ions

internal energy (U)

total of all possible kinds of energy present in a substance or substances

Ion

electrically charged atom or molecule (contains unequal numbers of protons and electrons)

Ion pair

solvated anion/cation pair held together by moderate electrostatic attraction

ion-dipole attraction

electrostatic attraction between an ion and a polar molecule

ion-product constant for water (K_w)

equilibrium constant for the autoionization of water

Ionic bond

electrostatic forces of attraction between the oppositely charged ions of an ionic compound

Ionic compound

compound composed of cations and anions combined in ratios, yielding an electrically neutral substance

ionization energy

energy required to remove an electron from a gaseous atom or ion; the associated number (e.g., second ionization energy) corresponds to the charge of the ion produced (X^{2+})

isoelectronic

group of ions or atoms that have identical electron configurations

Isotonic

of equal osmotic pressure

Isotopes

atoms that contain the same number of protons but different numbers of neutrons

joule (J)

SI unit of energy; 1 joule is the kinetic energy of an object with a mass of 2 kilograms moving with a velocity of 1 meter per second, $1 \text{ J} = 1 \text{ kg m}^2/\text{s}^2$ and $4.184 \text{ J} = 1 \text{ cal}$

K_c

equilibrium constant for reactions based on concentrations of reactants and products

Kelvin (K)

SI unit of temperature; $273.15 \text{ K} = 0 \text{ }^\circ\text{C}$

Kilogram (kg)

Standard SI unit of mass; 1 kg = approximately 2.2 pounds

kinetic energy

energy of a moving body, in joules, equal to $\frac{1}{2}mv^2$ (where m = mass and v = velocity)

Kinetic molecular theory

theory based on simple principles and assumptions that effectively explains ideal gas behavior

KP

written as: KP

equilibrium constant for gas-phase reactions based on partial pressures of reactants and products

Lanthanide

inner transition metal in the top of the bottom two rows of the periodic table

lattice energy

energy required to separate one mole of an ionic solid into its component gaseous ions

Law

Statement that summarizes a vast number of experimental observations, and describes or predicts some aspect of the natural world.

law of conservation of matter

when matter converts from one type to another or changes form, there is no detectable change in the total amount of matter present

Law of constant composition

(also, law of definite proportions) all samples of a pure compound contain the same elements in the same proportions by mass

Law of definite proportions

(also, law of constant composition) all samples of a pure compound contain the same elements in the same proportions by mass

law of mass action

when a reversible reaction has attained equilibrium at a given temperature, the reaction quotient remains constant

Law of multiple proportions

when two elements react to form more than one compound, a fixed mass of one element will react with masses of the other element in a ratio of small whole numbers

Le Châtelier's principle

when a chemical system at equilibrium is disturbed, it returns to equilibrium by counteracting the disturbance

lead acid battery

secondary battery that consists of multiple cells; the lead acid battery found in automobiles has six cells and a voltage of 12 V

Length

Measure of one dimension of an object

Lewis acid

any species that can accept a pair of electrons and form a coordinate covalent bond

Lewis acid-base adduct

compound or ion that contains a coordinate covalent bond between a Lewis acid and a Lewis base

Lewis base

any species that can donate a pair of electrons and form a coordinate covalent bond

Lewis structure

diagram showing lone pairs and bonding pairs of electrons in a molecule or an ion

Lewis symbol

symbol for an element or monatomic ion that uses a dot to represent each valence electron in the element or ion

Limiting reactant

reactant present in an amount lower than required by the reaction stoichiometry, thus limiting the amount of product generated

Line spectrum

electromagnetic radiation emitted at discrete wavelengths by a specific atom (or atoms) in an excited state

Linear

shape in which two outside groups are placed on opposite sides of a central atom

liquid

state of matter that has a definite volume but indefinite shape

Liter (L)

Also known as cubic decimeter. Unit of volume; $1 \text{ L} = 1,000 \text{ cm}^3$

Lithium ion batteries

very popular secondary battery; uses lithium ions to conduct current and is light, rechargeable, and produces a nearly constant potential as it discharges

London dispersion force

(also, dispersion force) attraction between two rapidly fluctuating, temporary dipoles; significant only when particles are very close together

Lone pair

two (a pair of) valence electrons that are not used to form a covalent bond

Macroscopic domain

Realm of everyday things that are large enough to sense directly by human sight and touch.

magnetic quantum number

quantum number signifying the orientation of an atomic orbital around the nucleus; orbitals having different values of m_l but the same subshell value of l have the same energy (are degenerate), but this degeneracy can be removed by application of an external magnetic field

Main-group element

(also, representative element) element in columns 1, 2, and 12–18

Manometer

device used to measure the pressure of a gas trapped in a container

mass

fundamental property indicating amount of matter

Mass number (A)

sum of the numbers of neutrons and protons in the nucleus of an atom

Mass percentage

ratio of solute-to-solution mass expressed as a percentage

mass-mass calculations

A calculation in which you start with a given mass of a substance and calculate the mass of another substance involved in the chemical equation.

mass-volume percent

ratio of solute mass to solution volume, expressed as a percentage

Matter

anything that occupies space and has mass

Mean free path

average distance a molecule travels between collisions

Melting

change from a solid state to a liquid state

Melting point

temperature at which the solid and liquid phases of a substance are in equilibrium; see also *freezing point*

Metal

element that is shiny, malleable, good conductor of heat and electricity

Metalloid

element that conducts heat and electricity moderately well, and possesses some properties of metals and some properties of nonmetals

Meter (m)

Standard metric and SI unit of length; 1 m = approximately 1.094 yards

Microscopic domain

Realm of things that are much too small to be sensed directly.

Milliliter (mL)

1/1,000 of a liter; equal to 1 cm³

Minerals

solid materials that occur in the earth

Miscible

mutually soluble in all proportions; typically refers to liquid substances

mixture

matter that can be separated into its components by physical means

Molality (m)

a concentration unit defined as the ratio of the numbers of moles of solute to the mass of the solvent in kilograms

Molar mass (g/mol)

the mass in grams of 1 mole of that substance

molar solubility

solubility of a compound expressed in units of moles per liter (mol/L)

Molarity (M)

unit of concentration, defined as the number of moles of solute dissolved in 1 liter of solution

Mole

the amount of a substance containing the same number of atoms as the number of atoms in a sample of pure ^{12}C weighing exactly 12 g

Mole fraction (X)

concentration unit defined as the ratio of the molar amount of a mixture component to the total number of moles of all mixture components

mole-mass calculation

A calculation in which you start with a given number of moles of a substance and calculate the mass of another substance involved in the chemical equation, or vice versa.

Molecular compound

(also, covalent compound) composed of molecules formed by atoms of two or more different elements

Molecular equation

chemical equation in which all reactants and products are represented as neutral substances

molecular formula

true formula for a compound; lists how many atoms of each element are in the compound

Molecular structure

structure that includes only the placement of the atoms in the molecule

molecule

bonded collection of two or more atoms of the same or different elements

monatomic ions

ion composed of a single atom

multiple equilibria

system characterized by more than one state of balance between a slightly soluble ionic solid and an aqueous solution of ions working simultaneously

Net ionic equation

chemical equation in which only those dissolved ionic reactants and products that undergo a chemical or physical change are represented (excludes spectator ions)

neutral solution

The solution in which the concentration of hydroxide ions equals the concentration of hydrogen ions
 $[H_3O^+] = [OH^-]$

Neutralization reaction

reaction between an acid and a base to produce salt and water

Neutron

uncharged, subatomic particle located in the nucleus

Nickel-cadmium

(NiCd battery) secondary battery that uses cadmium, which is a toxic heavy metal; heavier than lithium ion batteries, but with similar performance characteristics

Noble gas

(also, inert gas) element in group 18

Node

any point of a standing wave with zero amplitude

Nomenclature

system of rules for naming objects of interest

Non-polar covalent bond

(also, pure covalent bond) covalent bond between atoms of identical electronegativities

nonelectrolytes

are substances that do not readily ionize (do not produce ions) when dissolved in aqueous (water) solution or in molten state and are poor conductors of electricity.

Nonmetal

element that appears dull, poor conductor of heat and electricity

Normal boiling point

temperature at which a liquid's vapor pressure equals 1 atm (760 torr)

Nucleus

massive, positively charged center of an atom made up of protons and neutrons

nutritional calorie (Calorie)

unit used for quantifying energy provided by digestion of foods, defined as 1000 cal or 1 kcal

Octahedral

shape in which six outside groups are placed around a central atom such that a three-dimensional shape is generated with four groups forming a square and the other two forming the apex of two pyramids, one above and one below the square plane

Octet rule

guideline that states main group atoms will form structures in which eight valence electrons interact with each nucleus, counting bonding electrons as interacting with both atoms connected by the bond

orbital diagrams

pictorial representation of the electron configuration showing each orbital as a box and each electron as an arrow

Osmosis

diffusion of solvent molecules through a semipermeable membrane

Osmotic pressure (Π)

opposing pressure required to prevent bulk transfer of solvent molecules through a semipermeable membrane

overpotential

difference between the theoretical potential and actual potential in an electrolytic cell; the “extra” voltage required to make some nonspontaneous electrochemical reaction to occur

Oxidation

process in which an element's oxidation number is increased by loss of electrons

Oxidation number

(also, oxidation state) the charge each atom of an element would have in a compound if the compound were ionic

Oxidation-reduction reaction

(also, redox reaction) reaction involving a change in oxidation number for one or more reactant elements

Oxidizing agent

(also, oxidant) substance that brings about the oxidation of another substance, and in the process becomes reduced

Oxyacid

compound that contains hydrogen, oxygen, and one other element, bonded in a way that imparts acidic properties to the compound (ability to release H⁺ ions when dissolved in water)

Oxyanions

polyatomic anion composed of a central atom bonded to oxygen atoms

p orbitals

written as: *p* orbitals

dumbbell-shaped region of space with high electron density, describes orbitals with $l = 1$. An electron in this orbital is called a p electron

Partial pressure

pressure exerted by an individual gas in a mixture

Partially miscible

of moderate mutual solubility; typically refers to liquid substances

parts per billion (ppb)

ratio of solute-to-solution mass multiplied by 10⁹

parts per million (ppm)

ratio of solute-to-solution mass multiplied by 10⁶

Pascal (Pa)

SI unit of pressure; 1 Pa = 1 N/m²

passivation

It is a widely-used metal finishing process to prevent corrosion

Pauli exclusion principle

specifies that no two electrons in an atom can have the same value for all four quantum numbers

Percent composition

percentage by mass of the various elements in a compound

percent ionization

ratio of the concentration of the ionized acid to the initial acid concentration, times 100

Percent yield

measure of the efficiency of a reaction, expressed as a percentage of the theoretical yield

Period

(also, series) horizontal row of the periodic table

Periodic law

properties of the elements are periodic function of their atomic numbers.

Periodic table

table of the elements that places elements with similar chemical properties close together

pH

logarithmic measure of the concentration of hydronium ions in a solution

pH scale

The pH scale measures how acidic an object is.

Phase diagram

pressure-temperature graph summarizing conditions under which the phases of a substance can exist

Photon

smallest possible packet of electromagnetic radiation, a particle of light

physical change

change in the state or properties of matter that does not involve a change in its chemical composition

physical property

characteristic of matter that is not associated with any change in its chemical composition

plasma

gaseous state of matter containing a large number of electrically charged atoms and/or molecules

Pnictogen

element in group 15

pOH

logarithmic measure of the concentration of hydroxide ions in a solution

Polar covalent bond

covalent bond between atoms of different electronegativities; a covalent bond with a positive end and a negative end

Polar molecule

(also, dipole) molecule with an overall dipole moment

Polarizability

measure of the ability of a charge to distort a molecule's charge distribution (electron cloud)

polyatomic ions

ion composed of more than one atom

polymorphs

the ability of a substance to crystallize into different crystalline forms

position of equilibrium

concentrations or partial pressures of components of a reaction at equilibrium (commonly used to describe conditions before a disturbance)

potential energy

energy of a particle or system of particles derived from relative position, composition, or condition

Pounds per square inch (psi)

unit of pressure common in the US

Precipitate

insoluble product that forms from reaction of soluble reactants

Precipitation reaction

reaction that produces one or more insoluble products; when reactants are ionic compounds, sometimes called double-displacement or metathesis

Precision

How closely a measurement matches the same measurement when repeated

Pressure

force exerted per unit area

Primary batteries

single-use nonrechargeable battery

principal quantum number

quantum number specifying the shell an electron occupies in an atom

Product

substance formed by a chemical or physical change; shown on the right side of the arrow in a chemical equation

Proton

positively charged, subatomic particle located in the nucleus

pure substance

homogeneous substance that has a constant composition

Quantitative analysis

the determination of the amount or concentration of a substance in a sample

Quantization

occurring only in specific discrete values, not continuous

quantum mechanics

the study of matter and its interactions with energy on the scale of atomic and subatomic particles. It includes the work of Schrodinger, Heisenberg and other scientists.

Quantum number

integer number having only specific allowed values and used to characterize the arrangement of electrons in an atom

Raoult's law

the partial pressure exerted by a solution component is equal to the product of the component's mole fraction in the solution and its equilibrium vapor pressure in the pure state

rate expression

mathematical representation relating reaction rate to changes in amount, concentration, or pressure of reactant or product species per unit time

Rate of diffusion

amount of gas diffusing through a given area over a given time

rate of reaction

measure of the speed at which a chemical reaction takes place

Reactant

substance undergoing a chemical or physical change; shown on the left side of the arrow in a chemical equation

reaction quotient

ratio of the product of molar concentrations (or pressures) of the products to that of the reactants, each concentration (or pressure) being raised to the power equal to the coefficient in the equation

Reducing agent

(also, reductant) substance that brings about the reduction of another substance, and in the process becomes oxidized

Reduction

process in which an element's oxidation number is decreased by gain of electrons

Representative element

(also, main-group element) element in columns 1, 2, and 12–18

Resonance

situation in which one Lewis structure is insufficient to describe the bonding in a molecule and the average of multiple structures is observed

Resonance forms

two or more Lewis structures that have the same arrangement of atoms but different arrangements of electrons

Resonance hybrid

average of the resonance forms shown by the individual Lewis structures

reversible reaction

chemical reaction that can proceed in both the forward and reverse directions under given conditions

Root mean square velocity (urms)

measure of average velocity for a group of particles calculated as the square root of the average squared velocity

Rounding

Procedure used to ensure that calculated results properly reflect the uncertainty in the measurements used in the calculation

s orbitals

spherical region of space with high electron density, describes orbitals with $l = 0$. An electron in this orbital is called an s electron

sacrificial anodes

more active, inexpensive metal used as the anode in cathodic protection; frequently made from magnesium or zinc

Salt

Ionic compound that can be formed by the reaction of an acid with a base that contains a cation and an anion other than hydroxide or oxide. A neutral chemical compound held together by an ionic bond consisting of positively charged cations and negatively charged anions.

Saturated

of concentration equal to solubility; containing the maximum concentration of solute possible for a given temperature and pressure

Scientific method

Path of discovery that leads from question and observation to law or hypothesis to theory, combined with experimental verification of the hypothesis and any necessary modification of the theory.

Scientific Notation

method to simplify very large and very small numbers by utilizing a base 10 exponential methodology

Second (s)

Standards fixed by international agreement in the International System of Units (*Le Système International d'Unités*)

Secondary batteries

battery that can be recharged

selective precipitation

process in which ions are separated using differences in their solubility with a given precipitating reagent

Semipermeable membrane

a membrane that selectively permits passage of certain ions or molecules

Series

(also, period) horizontal row of the period table

shells

set of orbitals with the same principal quantum number, n

SI units (International System of Units)

Standards fixed by international agreement in the International System of Units (*Le Système International d'Unités*)

significant digits

(also, significant figures) all of the measured digits in a determination, including the uncertain last digit

Significant figures

(also, significant digits) all of the measured digits in a determination, including the uncertain last digit

Single bond

bond in which a single pair of electrons is shared between two atoms

Single-displacement reaction

(also, replacement) redox reaction involving the oxidation of an elemental substance by an ionic species

single-replacement reaction

A chemical reaction in which one element is substituted for another element in a compound.

solid

state of matter that is rigid, has a definite shape, and has a fairly constant volume

Solubility

extent to which a solute may be dissolved in water, or any solvent

solubility product (K_{sp})

equilibrium constant for the dissolution of a slightly soluble electrolyte

Soluble

of relatively high solubility; dissolving to a relatively large extent

Solute

solution component present in a concentration less than that of the solvent

solution

Another name for a homogeneous mixture

Solvation

exothermic process in which intermolecular attractive forces between the solute and solvent in a solution are established

Solvent

solution component present in a concentration that is higher relative to other components

species (chemical)

can be a group of atoms, molecules, ions etc. that are chemically identical

specific heat capacity (c)

intensive property of a substance that represents the quantity of heat required to raise the temperature of 1 gram of the substance by 1 degree Celsius (or 1 kelvin)

Spectator ion

ion that does not undergo a chemical or physical change during a reaction, but its presence is required to maintain charge neutrality

spin quantum number

number specifying the electron spin direction, either $+1/2$ or $-1/2$

Spontaneous process

physical or chemical change that occurs without the addition of energy from an external source

standard cell potential

the cell potential when all reactants and products are in their standard states (1 bar or 1 atm or gases; 1 M for solutes), usually at 298.15 K; can be calculated by subtracting the standard reduction potential for the half-reaction at the anode from the standard reduction potential for the half-reaction occurring at the cathode

Standard conditions of temperature and pressure (STP)

273.15 K (0 °C) and 1 atm (101.325 kPa)

Standard enthalpy of combustion

heat released when one mole of a compound undergoes complete combustion under standard conditions

standard enthalpy of formation

enthalpy change of a chemical reaction in which 1 mole of a pure substance is formed from its elements in their most stable states under standard state conditions

standard hydrogen electrode (SHE)

the electrode consists of hydrogen gas bubbling through hydrochloric acid over an inert platinum electrode whose reduction at standard conditions is assigned a value of 0 V; the reference point for standard reduction potentials

Standard molar volume

volume of 1 mole of gas at STP, approximately 22.4 L for gases behaving ideally

standard state

set of physical conditions as accepted as common reference conditions for reporting thermodynamic properties; 1 bar of pressure, and solutions at 1 molar concentrations, usually at a temperature of 298.15 K

Standing wave

(also, stationary wave) localized wave phenomenon characterized by discrete wavelengths determined by the boundary conditions used to generate the waves; standing waves are inherently quantized

state function

property depending only on the state of a system, and not the path taken to reach that state

static electricity

buildup of electric charge on the surface of an object; the arrangement of the charge remains constant (“static”)

Stock system

The system of indicating a cation’s charge with roman numerals.

Stoichiometric factor

ratio of coefficients in a balanced chemical equation, used in computations relating amounts of reactants and products

Stoichiometry

relationships between the amounts of reactants and products of a chemical reaction

stress

change to a reaction's conditions that may cause a shift in the equilibrium

Strong acid

acid that reacts completely when dissolved in water to yield hydronium ions

Strong base

base that reacts completely when dissolved in water to yield hydroxide ions

Strong electrolyte

a substance that dissociates or ionizes completely when dissolved in water and can conduct electricity.

structural formula

shows the atoms in a molecule and how they are connected

Sublimation

change from solid state directly to gaseous state

subshell

set of orbitals in an atom with the same values of n and l

Supercritical fluid

substance at a temperature and pressure higher than its critical point; exhibits properties intermediate between those of gaseous and liquid states

Supersaturated

of concentration that exceeds solubility; a nonequilibrium state

Surface tension

energy required to increase the area, or length, of a liquid surface by a given amount

surroundings

all matter other than the system being studied

Symbolic domain

Specialized language used to represent components of the macroscopic and microscopic domains, such as chemical symbols, chemical formulas, chemical equations, graphs, drawings, and calculations.

system

portion of matter undergoing a chemical or physical change being studied

Temperature

intensive property of matter that is a quantitative measure of “hotness” and “coldness”

Tetrahedral

shape in which four outside groups are placed around a central atom such that a three-dimensional shape is generated with four corners and 109.5° angles between each pair and the central atom

Theoretical yield

amount of product that may be produced from a given amount of reactant(s) according to the reaction stoichiometry

Theory

Well-substantiated, comprehensive, testable explanation of a particular aspect of nature.

Thermal energy

kinetic energy associated with the random motion of atoms and molecules

thermochemistry

study of measuring the amount of heat absorbed or released during a chemical reaction or a physical change

titrant

is the "known" solution which has a precise and accurate concentration. It is placed in the buret during a titration experiment

titration

a technique where a solution of known concentration is used to determine the concentration of an unknown solution. Typically, the titrant (the know solution) is added from a buret to a known quantity of the analyte (the unknown solution) until the reaction is complete.

Titration analysis

quantitative chemical analysis method that involves measuring the volume of a reactant solution required to completely react with the analyte in a sample

Torr

unit of pressure

Transition metal

element in columns 3–11

Trigonal bipyramidal

shape in which five outside groups are placed around a central atom such that three form a flat triangle with 120° angles between each pair and the central atom, and the other two form the apex of two pyramids, one above and one below the triangular plane

Trigonal planar

shape in which three outside groups are placed in a flat triangle around a central atom with 120° angles between each pair and the central atom

Triple bond

bond in which three pairs of electrons are shared between two atoms

Triple point

temperature and pressure at which the vapor, liquid, and solid phases of a substance are in equilibrium

Tyndall effect

scattering of visible light by a colloidal dispersion

Uncertainty

Estimate of amount by which measurement differs from true value

Unified atomic mass unit (u)

alternative unit equivalent to the atomic mass unit

Unit

Standard of comparison for measurements

Unit conversion factor

Ratio of equivalent quantities expressed with different units; used to convert from one unit to a different unit

Unsaturated

of concentration less than solubility

valence electrons

electrons in the outermost or valence shell (highest value of n) of a ground-state atom; determine how an element reacts

valence shell

outermost shell of electrons in a ground-state atom; for main group elements, the orbitals with the highest n level (s and p subshells) are in the valence shell, while for transition metals, the highest energy s and d subshells make up the valence shell and for inner transition elements, the highest s, d, and f subshells are included

Valence Shell Electron-Pair Repulsion theory (VSEPR)

theory used to predict the bond angles in a molecule based on positioning regions of high electron density as far apart as possible to minimize electrostatic repulsion

Van der Waals equation

modified version of the ideal gas equation containing additional terms to account for non-ideal gas behavior

Van der Waals force

attractive or repulsive force between molecules, including dipole-dipole, dipole-induced dipole, and London dispersion forces; does not include forces due to covalent or ionic bonding, or the attraction between ions and molecules

van der Waals forces

attractive or repulsive force between molecules, including dipole-dipole, dipole-induced dipole, and London dispersion forces; does not include forces due to covalent or ionic bonding, or the attraction between ions and molecules

van't Hoff factor (i)

the ratio of the number of moles of particles in a solution to the number of moles of formula units dissolved in the solution

Vapor pressure

(also, equilibrium vapor pressure) pressure exerted by a vapor in equilibrium with a solid or a liquid at a given temperature

Vapor pressure of water

pressure exerted by water vapor in equilibrium with liquid water in a closed container at a specific temperature

Vaporization

change from liquid state to gaseous state

Vector

quantity having magnitude and direction

Viscosity

measure of a liquid's resistance to flow

voltaic cells

another name for a galvanic cell

Volume

Amount of space occupied by an object

Volume percentage

ratio of solute-to-solution volume expressed as a percentage

Wave

oscillation that can transport energy from one point to another in space

Wave-particle duality

term used to describe the fact that elementary particles including matter exhibit properties of both particles (including localized position, momentum) and waves (including nonlocalization, wavelength, frequency)

Wavelength (λ)

distance between two consecutive peaks or troughs in a wave

Weak acid

acid that reacts only to a slight extent when dissolved in water to yield hydronium ions

Weak base

base that reacts only to a slight extent when dissolved in water to yield hydroxide ions

Weak electrolyte

a substance that ionizes only partially when dissolved in water, thus producing an aqueous solution that conducts electricity poorly.

Weight

force that gravity exerts on an object

work (w)

energy transfer due to changes in external, macroscopic variables such as pressure and volume; or causing matter to move against an opposing force

ANCILLARY RESOURCES FOR FACULTY

Suggested Additional Resources

If you are faculty looking for additional resources to support your course delivery using this textbook, there are several options:

- Image PowerPoint Banks (created as part of this project; available below)
- OpenStax Instructor resources for *Chemistry 2e* – OpenStax (<https://openstax.org/details/books/chemistry-2e?Instructor%20resources>)
- Homework System: LibreADAPT for OpenStax's *Chemistry 2e*
- PhET Teaching Resources with suggested activities for simulations

Image PowerPoint Banks

These accessible images banks were created from the text. All numbered figures and tables are included. Attribution and alt-tags are included for each image. If copying or modifying these files, be sure to maintain attribution statements and run the Accessibility checker to ensure files are still accessible.

- | | | |
|-------------|--------------|--------------|
| • Chapter 1 | • Chapter 7 | • Chapter 13 |
| • Chapter 2 | • Chapter 8 | • Chapter 14 |
| • Chapter 3 | • Chapter 9 | • Chapter 15 |
| • Chapter 4 | • Chapter 10 | • Chapter 16 |
| • Chapter 5 | • Chapter 11 | • Chapter 17 |
| • Chapter 6 | • Chapter 12 | • Chapter 18 |

Organic Chemistry Supplemental

Most introductory chemistry courses either contain some organic chemistry learning or are followed by a discrete organic chemistry course. There are several organic chemistry resources available through LibreTexts (https://chem.libretexts.org/Bookshelves/Organic_Chemistry). By January 2024, we hope to release a supplemental text to our Enhanced Introductory College Chemistry text that focuses on organic chemistry and related topics.

Future Updates: Roadmap

In the next released revision, the following updates are proposed:

- Relocation of Indigenous Perspectives and Scientists in Action examples and updated figure numbering
- Updates to media library to reflect alt-tags and captions in chapters

Questions, Comments or Suggestions?

Please let us know if you are using this text or have questions, comments or suggestions. Email our team at OER [at] georgiancollege.ca