









Electrochemistry Dictionary - A

- A: Symbol and abbreviation of ampere.
- Absorption: A process "to take in and incorporate." E.g., light can be "absorbed" by a material. In chemistry, a term often used to describe the dissolution of a gas into a liquid or solid. The dissolving gas is said to be "absorbed." Or a liquid substance can be "absorbed" by a solid. This is a bulk process, not to be confused with adsorption.
- AC: Abbreviation of alternating current. However this term is also used in connection with ac voltage, that is, an "alternating" voltage that will cause an "ac current" to flow in a conductor, and also in connection with ac power.
- Accumulator: See rechargeable battery.
- Acid: A compound that dissociates to produce hydrogen (H+) cations when dissolved in water. See also pH.
- Acidity: See pH.
- Activation overpotential (overvoltage): Contribution to the total overpotential due to the charge transfer step at the electrode interface.

- Active mass or material: The material in an electrochemical cell which takes part in the cell reaction. For example, the lead contained in the positive plate of a lead-acid battery.

- Active material utilization: The fraction of active material that reacts during discharge before the battery can no longer deliver the required current at a useful voltage.

- Active metal: A metal that is easily oxidized (corroded) in air. For example, sodium will violently react with air, aluminum will always have an air-formed oxide film on its surface, and

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iron is easily rusted. These metals have high negative standard electrode potentials and are high the on the electromotive series. Contrast with noble metal.

- Activation overpotential (polarization): The overpotential (alternatively called polarization) associated with the charge-transfer reaction elementary step in the overall electrode reaction.
- Activity : The activity of a dissolved species in solution is the "effective" concentration of that species. In an "ideal" solution, the molecules in the solution do not interact with each other and the concentration and the activity are identical. This is the case for very dilute solutions. In a "real" solution, there is a certain interaction between the molecules resulting in a diminished "activity" of the molecules toward the outside world, and the solution behaves like it would contain lower concentration of the dissolved species than it actually does. The activity can be expressed as the product of an "activity coefficient" and the concentration.
- Activity coefficient: See activity.
- Adsorbate: A material that is adsorbed.
- Adsorption: An increase of the concentration of a solute in the vicinity of a solid surface, over that in the bulk of the solution, due to the attractive interaction between the solid immersed into the solution and the solute. Adsorption on a solid from a gaseous phase also occurs. It is a surface process, not to be confused with absorption. Opposite: desorption.
- Ah: Symbol and abbreviation of ampere-hour.
- Alkali: See base.
- Alkalinity: See pH.
- Alkali production: See brine electrolysis.
- Alkaline battery: See Edison battery.
- Alkaline cell: A modern version of the Leclanche cell containing basic (potassium hydroxide) electrolyte. It has considerably improved characteristics and it is slowly replacing the Leclanche cell.
- Alternating current: See current. Abbreviated as "ac."
- Aluminum production: Aluminum metal is produced by electrolysis of aluminum oxide dissolved in a high-temperature molten-salt electrolyte. Aluminum is deposited as a liquid

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metal on the cathode of the electrolytic cell (the aluminum cations are reduced to liquid metal). This is the only large-scale industrial process for the production of aluminum.

- Amalgam: An alloy of mercury and another metal.
- Ammeter: Instrument used for the measurement of current.
- Amp: Symbol and abbreviation of ampere.
- Ampere: Measurement unit of current. Abbreviation: "A" or "amp".
- Ampere-hour: An alternative unit of electrical charge. One ampere-hour = 3,600 coulombs. Symbol: "Ah".
- Ampere-hour efficiency: See coulometric efficiency.
- Amperometry: An electroanalytical technique based upon the measurement of the current flowing through the working electrode of an electrochemical cell.
- Amperostat: See galvanostat.
- Analyte: A substance whose chemical composition is to be determined by chemical analysis.
- Anhydrous: A substance that does not contain water. The opposite of hydrous.
- Anion: A negatively charged ion.
- Anode: The electrode where oxidation occurs in an electrochemical cell. It is the positive electrode in an electrolytic cell, while it is the negative electrode in a galvanic cell. The current on the anode is considered a positive current according to international convention; however, in electroanalytical chemistry the anodic current is often considered negative. Contrast with cathode.
- Anode effect: A condition in an electrolytic cell that produces an abrupt increase in cell voltage and a decrease in current flow. It is usually caused by the temporary formation of an insulating layer on the anode surface. It occurs almost exclusively in molten salt electrolysis, such as in aluminum production.
- Anode mud: The insoluble residue that derives from the anodic dissolution of an impure metal such as copper during electrorefining. Also called "anode slime."
- Anode slime: See anode mud.
- Anodic partial current (density): See partial current density.
- Anodic (corrosion) protection: A process for corrosion

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protection of a metal or alloy achieved by impressing upon the metal an anodic current of sufficient magnitude to cause the formation of a passive film. Anodic protection is effective only for metals that are prone to passivate, such as stainless steel and titanium. See also an Encyclopedia Article and cathodic protection.

- Anodizing: A process to produce an oxide film or coating on metals and alloys by electrolysis. The metal to be treated is made the anode in an electrolytic cell and its surface is electrochemically oxidized. Anodization can improve certain surface properties, such as corrosion resistance, abrasion resistance, hardness, appearance, etc. One metal very often anodized is aluminum, all the above properties improve, furthermore, since the surface film is porous, the aluminum metal can even be colored by the application of pigments or dies in the pores.
- Anolyte: The electrolyte on the anode side of an electrochemical cell that is divided into compartments.
- Aqueous solution: A solution with water as the solvent.
- Atom, atomic structure (proton, neutron, electron): The smallest physical unit of a chemical element that can still retain all the physical and chemical properties of that element. Atoms combine to form molecules, and they themselves contain several kinds of smaller particles. An atom has a dense central core (the nucleus) consisting of positively charged particles (protons) and uncharged particles (neutrons). Negatively charged particles (electrons) are scattered in a relatively large space around this nucleus and move about it in orbital patterns at extremely high speeds. An atom contains the same number of protons as electrons and thus is electrically neutral (uncharged) and stable under most conditions.
- Atomic weight: The average relative weight of a chemical element as it occurs in nature referred to some element taken as a standard.
- Auxiliary electrode: See counter electrode.

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Electrochemistry Dictionary - B

- Background current (density): See residual current (density).
- Base: A compound that dissociates to produce hydroxyl (OH-) anions when dissolved in water (also called "caustic" or "alkali"). See also pH.
- Basicity: See pH.
- Bath: An electroplating solution is often called "bath."
- Battery: An assembly of two or more cells electrically connected to form a unit. For example, a 12V SLI battery is made up of six 2V cells in series. However, the term is also often used to indicate a single cell. A device that stores electrical energy using electrochemical cells. Chemical reactions occur spontaneously at the electrodes when they are connected trough an external circuit, producing an electrical current. The physical construction of the battery is such that it does not permit the intermixing and consequent direct reaction of the chemicals stored in it. Strictly speaking, a battery should consist of several, internally connected, electrochemical cells. (The individual cells in a battery can be series or parallel coupled, or a combination of both.) However, in present usage all storage devices (single cell and multiple cell) are called batteries.

- Battery charger: See charger.
- Battery management: The regulation of charging and discharging conditions (eg control of temperature, cut-off voltages, current).

- Binder: A polymeric material added to the active mass to increase its mechanical strength.

- Bioelectrochemistry: Electrochemistry of biological systems and biological compounds.
- Bipolar electrode: An electrode that is shared by two series-coupled electrochemical cells in such a way that one side of the (usually planar) electrode acts as an anode in one cell and the other side acts as a cathode in the other cell. In storage batteries and fuel cell stacks many cells are usually connected

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internally, and it is a very efficient design feature to use a single planar structure for electrodes in two neighboring cells and also as the electrical interconnection between them. An electrode assembly which functions as the anode of one cell on one side, and as the cathode of the next cell on the other side. Also known as a 'duplex' electrode, especially in Leclanché batteries.

- Bipotentiostat: A potentiostat that controls the potential of two working electrodes independently in the same cell. Typically used in conjunction with a rotating-ring-disk electrode.
- Bleach production: See brine electrolysis.
- Boost charging: See trickle charging.
- Boundary layer: See hydrodynamic boundary layer.
- Brightening agent, brightener: Small amounts of (usually organic) compounds added to an electroplating solution that changes the mechanism of the plating to produce "bright" (mirror like) metal deposits.
- Brine electrolysis: Electrolysis of an aqueous solution of common table salt (sodium chloride), also called "brine," results in the production of chlorine gas at the anode and hydrogen gas at the cathode. Since the hydrogen is produced by breaking up water molecules, the solution is becoming basic around the cathode and a solution of sodium hydroxide (also called "caustic" or "alkali") is produced. If the electrolysis is carried out in a divided cell, the products are chlorine, caustic, and hydrogen. If the electrolysis is carried out in an undivided cell and the chlorine gas and the caustic are allowed to mix and react with each other, sodium hypochlorite (bleach) is produced if the cell operates close to room temperature, and sodium chlorate is produced if the cell is operated near the boiling point of water. Electrolysis is the only large-scale industrial process for the production of chlorine gas and these chlorine chemicals. Smaller scale cells are also used to produce chlorine-based disinfectants in municipal water-treatment plants and for swimming pools. The overall cell reaction is: $2NaCl + 2H_2O = Cl_2 + H_2 + 2NaOH$ Chlorine gas and sodium hydroxide react to form sodium hypochlorite and sodium chloride: $Cl_2 + 2NaOH = NaOCl + NaCl$

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+ H2O Sodium hypochlorite will react further at high temperature to form sodium chlorate and sodium chloride: 3NaOCl = NaClO3 + 2NaCl (although, sodium chlorate can also form by direct electrochemical oxidation).

- Buffer solution: A solution with a constant, specified pH. The pH of the solution "resists" any change: addition of small amounts of solvent or even acid or base will not appreciable change the pH. This is called "buffer capacity."
- Bus(bar): A typically not insulated (not covered with insulation) conductor used to carry a large current or to make a common connection between several circuits. A rigid metallic conductor which connects different elements of a battery; also, the conductor for an electrical system to which a battery terminal is attached.
- Button cell: Miniature cylindrical cell having a characteristic disc shape. See coin cell.

- Bypass current: See current leakage.

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Electrochemistry Dictionary - C

- C: Symbol and abbreviation of coulomb.
- Calomel electrode: A commonly used reference electrode. It is very similar to the silver/silver-chloride electrode both in construction and in theory of operation. The silver metal is replaced by mercury (electrical connection is made by an inert metal wire), the salt is mercury chloride, and the solution is saturated potassium chloride. Abbreviated as "SCE," for: "saturated calomel electrode." The equilibrium electrode potential is a function of the chloride concentration of the internal electrolyte ("filling solution"). The electrolyte is practically always saturated potassium chloride (hence the name: "saturated calomel electrode," SCE, "calomel" is an old name for mercurous chloride), producing a potential of 0.244 volt against the standard hydrogen electrode at 25 oC.
- Can, case: The external envelope of a cell or battery, or the box containing the cells and connectors.
- Capacitance: The capacitance value expresses the ability of a capacitor to store electrical charge. The unit of capacitance is the farad.
- Capacitive current (density): The current (or current density) flowing through an electrochemical cell that is charging/discharging the electrical double layer capacitance. This current does not involve any chemical reactions (charge transfer), it only causes accumulation (or removal) of electrical charges on the electrode and in the electrolyte solution near the electrode. There is always some capacitive current flowing when the potential of an electrode is changing, and the capacitive current is generally zero when the potential is constant. Also called "non-faradaic" or "double-layer" current. Contrast with faradaic current. Capacitive current can also flow at constant potential if the capacitance of the electrode is changing for some reason, e.g., change of electrode area or temperature.
- Capacitor: An electrical device which serves to store electricity or electrical energy. It has three essential parts: two electrical conductors, which are usually metal plates,

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separated and insulated by the third part called the dielectric. The plates are charged with equal amounts of positive and negative electrical charges, respectively. This is a "physical" storage of electricity as compared with the "chemical" storage in a battery.

- Capacity: See capacitance. The term "capacity" is also used in a somewhat different meaning for batteries: it expresses the total amount of electrical charge a battery is able to hold. It is usually expressed in ampere-hours.
- Capacity, rated: The value of the output capability of a battery, expressed in Ah, at a given discharge rate before the voltage falls below a given cut-off value, as indicated by the manufacturer.

- Capillary: A tube with very small bore.
- Catalysis: The phenomenon of increasing the rate of a chemical reaction by a chemical present in the reaction medium (hogeneous catalysis), or by a solid surface on which the reaction can occur (heterogeneous catalysis).
- Catalyst: A material that can cause catalysis.
- Cataphoresis: Alternative name for "electrophoresis." See electrokinetic effects.

- Cathode: The electrode where reduction occurs in an electrochemical cell. It is the negative electrode in an electrolytic cell, while it is the positive electrode in a galvanic cell. The current on the cathode is considered a negative current according to international convention; however, in electroanalytical chemistry the cathodic current is often considered positive. Contrast with anode.
- Cathodic partial current (density): See partial current density.
- Cathodic (corrosion) protection: A process for corrosion protection of a metal or alloy achieved by impressing upon the metal a cathodic potential of sufficient magnitude to decrease the corrosion rate. See also an Encyclopedia Article and anodic protection.
- Catholyte: The electrolyte on the cathode side of an electrochemical cell that is divided into compartments.

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- Caustic: See base. Sometimes it specifically refers to sodium hydroxide.
- Caustic production: See brine electrolysis.

- CCV: Stands for closed-circuit voltage.

- Cell: Electrochemical device which directly converts chemical and electrical energy.

- Cell constant: See conductivity cell.
- Cell divider: See separator

- Cell efficiency: The ratio of the electrical energy produced by a photovoltaic cell (under full sun conditions or 1 kW/m2) to the energy from sunlight falling upon the cell.
- Cell line: A series-coupled assembly of cells, a term used primarily in industrial electrolysis using electrolytic cells.
- Cell reaction: The overall chemical reaction occurring in the electrochemical cell. It is the sum of the two electrode reactions.

- Cell reversal: Inversion of the polarity of the terminals of a cell in a multicell battery. Cell reversal is usually due to over discharge, when differences in the capacity of individual cells result in one or more cells reaching complete discharge before the others.

- Cell voltage: The electrical potential difference between the two electrodes of an electrochemical cell. In case of a three-electrode cell, the potential difference between the working electrode and the counter electrode. "Cell voltage" usually refers to nonequilibrium conditions, that is when current is flowing through the cell (although this convention is not always followed). The "cell voltage" differs from the electromotive force (emf) (or open-circuit voltage (ocv)) of the cell by the amount of the overvoltage. The term "voltage" is usually reserved for the case when an electrochemical cell is under consideration, while the term "potential" is usually reserved for the case when an electrode is considered. (Of course, the latter case is still an "electrochemical cell"

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consisting of the electrode under consideration and a reference electrode.) Unfortunately, the terms "voltage" and "potential" are sometimes used interchangeably.

- Cementation: The process of spontaneous reduction of the ions of a metal by another metal above it in the electromotive series. For example, a piece of iron immersed in copper sulfate solution will be immediately covered by a thin film of copper. The iron is being anodically dissolved while copper is electroplated on its surface cathodically. Also called "metal displacement reaction."

- Chapman model of the double layer: See the Gouy-Chapman model of the double layer.

- Charge acceptance: The ability of a secondary cell or battery to convert the active material to a dischargeable form. It is measured by the capacity which can be subsequently delivered to a load as a result of the charging process. If the charge acceptance is 100% then all of the electrical energy input would become available for useful output.

- Charge carrier: The particle carrying the electrical charge during the flow of electrical current. In metallic conductors the charge carriers are electrons, while ions carry the charges in electrolyte solutions.
- Charge controller: A component that controls the flow of current to and from the battery subsystem to protect the batteries from overcharge and over discharge. The charge controller may also monitor system performance and provide system protection.
- Charge density: Charge referred to the unit area of the electrode. Charge divided by electrode area.
- Charge efficiency: See coulometric efficiency.
- Charger: An electrical device used to charge a rechargeable battery using household electricity.

- Charge rate: The current applied to a rechargeable battery to restore its capacity. This rate is commonly expressed as a multiple of the rated capacity. See C-rate.

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- Charge retention: The ability of a charged cell to resist self-discharge.

- Charge, state of: The condition of a cell or a battery in terms of the remaining available capacity.

- Charge-transfer overpotential (polarization): See activation overpotential.
- Charge-transfer reaction: A chemical reaction where an electrical charge (usually an electron) is transferred from one reactant to another. See also heterogeneous charge-transfer reaction and homogeneous charge-transfer reaction. In case of an electrode reaction, the electrode itself is considered one of the "reactants." An electrode reaction is always a heterogeneous charge-transfer reaction.
- Charge-transfer resistance: A characteristic quantity for an electrode reaction indicative of its inherent speed: a large charge-transfer resistance indicates a slow reaction. See also non-ohmic resistance.
- Charge transport: The phenomenon of movement (transportation) of electrical charge from one part of the system to another, occurring through electromigration.
- Charging: A process to "fill" a rechargeable battery with electricity by applying a current to its terminals. The process will cause electrochemical reactions to occur in the battery, storing the electricity in chemical form. In contrast, during the charging of a capacitor the electricity is stored as electrical charges, without causing any chemical reactions to occur. Opposite: discharging.

- Chemical kinetics: See kinetics.
- Chlor-alkali production: See brine electrolysis.
- Chlorate production: See brine electrolysis.
- Chlorine-caustic production: See brine electrolysis.
- Chlorine gas production: See brine electrolysis.
- Chronoamperometry: An electrochemical measuring technique used for electrochemical analysis or for the determination of the kinetics and mechanism of electrode reactions. A fast-rising potential pulse is enforced on the working electrode of an electrochemical cell and the current

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flowing through this electrode is measured as a function of time. See also Cottrell equation.

- Chronocoulometry: An electrochemical measuring technique used for electrochemical analysis or for the determination of the kinetics and mechanism of electrode reactions. A fast-rising potential pulse is enforced on the working electrode of an electrochemical cell and the electrical charge passing through this electrode is measured as a function of time.
- Chronopotentiometry: An electrochemical measuring technique used for electrochemical analysis or for the determination of the kinetics and mechanism of electrode reactions. A fast-rising current pulse is enforced on the working electrode of an electrochemical cell and the potential of this electrode is measured against a reference electrode as a function of time. In an unstirred solution, the potential will rise to the electrode potential of the reaction requiring the least amount of energy to proceed, and it will increase in time due to the concentration overpotential developing as the concentration of the reactant is exhausted at the electrode surface. If the current is larger than the limiting current, eventually the diffusional process will not be able to provide the required flux for the current, and the electrode potential will sharply rise (at the transition time) until it reaches the electrode potential of the next available reaction in the solution, and so on. See also Sand equation.
- Clark electrode: An amperometric sensor assembly used for the measurement of dissolved oxygen concentration in water or aqueous solutions. It is a two-electrode electrochemical cell with the working electrode (typically positioned at the end of a tubular structure) separated from the test solution by a thin membrane permeable to oxygen. The oxygen diffusing through the membrane is reduced at the electrode and the current produced is proportional to the concentration of the dissolved oxygen (calibration required).
- Closed-circuit voltage: The voltage of a battery when it is discharging (on-load condition). Abbreviated as "ccv."
- Coin cell: A miniature non-rechargeable battery, in the shape and size of a small coin used to power small electronic devices, e.g. watches and hearing aids. Also called "button"

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cell. See also an Encyclopedia Article.

- Collector; current collector: Electronic conductor embedded in the active mass and connected to the bus bar or terminal.

- Combination electrode: An assembly that combines an ion-selective electrode and a reference electrode in one physical structure (typically in a tubular form).This can be conveniently used for the determination of ionic concentrations in test solutions. It is most often used for pH measurements.
- Combustion pile: See fuel cell.
- Compact layer: See the Helmholtz model of the double layer.
- Completely-polarizable electrode: Alternative expression for ideal polarizable electrode.
- Compliance limits: The maximum value of the current and voltage that a control instrument (e.g., galvanostat or potentiostat) is capable to provide.
- Concentration: The measure of the amount of dissolved material (solute) in a solution. It can be expressed in a variety of ways. Expressions in weight percent, and grams of solute per liter of solution are common. A more fundamental way to express concentration is used in chemistry: the "molar" concentration. A solution is considered one molar (1 M) if it contains as many grams of solute per liter of solution as is the molecular weight of the solute (the so called gram-mole). This provides an atomistically fundamental expression because one gram-mole of any material will contain the same (and very large) number of molecules. One gram-mole of hydrogen gas contains the exact same number of molecules as one gram-mole of table salt (sodium chloride), even though the latter is much heavier. In this dictionary, the term "concentration" always designates "molarity" unless otherwise specified.
- Concentration cell: A galvanic cell in which the chemical energy converted into electrical energy is arising from the concentration difference of a species at the two electrodes of the cell. An example is a divided cell consisting of two silver electrodes surrounded by silver nitrate solutions of different concentrations. Nature will tend to equalize the concentrations. Consequently, silver cations will be spontaneously reduced to silver metal at the electrode

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(cathode) in the higher concentration solution, while the silver electrode (anode) in the lower concentration solution will be oxidized to silver cations. Electrons will be flowing through the external circuit (from the anode or negative electrode to the cathode or positive electrode) producing a current, and nitrate anions will diffuse through the separator. This process will continue till the silver nitrate concentration is equalized in the two compartments of the cell.

- Concentration overpotential (polarization): The overpotential (alternatively called polarization) associated with the diffusional transport of the reactants to the electrode surface from the bulk of the electrolyte and the reverse transport of the products. The diffusion is an elementary step in the overall electrode reaction. Also called "diffusion overpotential" or "mass-transport overpotential."

- Condenser: See capacitor.
- Conditioning: For a rechargeable battery: see forming.
- Conductance (electrical): See conductivity.
- Conducting polymer: A polymeric material (e.g., plastics) having electronic conductivity.
- Conductivity (electrical): The measure of a material's capability to carry electrical current. The measurement unit of conductivity (conductance) is the siemens. The reciprocal of resistivity.
- Conductivity cell: A cell specially designed for the measurement of the conductivity of an electrolyte solution. It is a small vessel containing two metallic electrodes, the cell is filled with the solution to be measured. Also called "conductance cell." The measurement of the conductivity of an electrolyte solution is more complicated than a similar measurement with a metallic conductor. When measuring with dc current, one would have to take into consideration the electromotive force of the electrochemical cell, and the polarization of the electrodes. Therefore, the measurements are typically carried out with high frequency ac current and the electrodes in the conductivity cell are typically made of platinized platinum to avoid these complications. The cell geometry usually does not ensure that exactly and only one

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cubic centimeter of solution will carry the current; therefore, the cell has to be calibrated to obtain the specific conductance of the solution. The calibration is usually carried out with high purity potassium chloride solutions, and the resulting calibration constant is often called the "cell constant."

- Conductometry: An electroanalytical technique based upon the measurement of the conductivity an electrolyte solution.
- Conductor (electrical): A material that is capable to carry an electrical current. See also electronic conductor and ionic conductor.
- Constant-current technique/process: A technique used in electroanalytical chemistry or in the determination of the kinetics and mechanism of electrode reactions or a process carried out in an electrolytic cell that operates at constant current. See also chronopotentiometry.
- Constant-potential technique/process: A technique used in electroanalytical chemistry or in the determination of the kinetics and mechanism of electrode reactions or a process carried out in an electrolytic cell that operates at constant potential. See also chronoamperometry and chronocoulometry.
- Contact adsorption: Adsorption with the adsorbed molecule or ion being in direct contact with the solid surface.
- Convection: A mass-transport mechanism that involves bulk movement of a solution (contrast with diffusion that involves individual molecules or ions). We differentiate "forced" convection from "natural" convection. The simplest example of forced convection is mechanical stirring. If a non-uniform solution is stirred, the solute is "transported" from the high concentration parts of the solution to the low concentration parts till the solution becomes completely uniform. Other examples of forced convection are the "flow" of a solution through a pipe or a porous separator driven by pressure difference. "Natural" convection is very important in electrochemistry. It always occurs at the surface of an electrode carrying current in the absence of "forced" convection. As electrode reaction is proceeding, the buildup of reaction products and the consumption of reactants changes the density of the solution layer close to the electrode surface

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compared to that of the bulk solution. Eventually, this density difference will force the surface solution layer to sink or rise, setting up a "natural stirring" action close to the electrode surface which will tend to equalize the surface and bulk concentrations. As a "rule of thumb," natural convection starts after about a minute of current flow.

- Conversion: See energy conversion.

- Corrosion: A chemical (often electrochemical) process that destroys structural materials. Typically it refers to corrosion of metals, but any other material (e.g., plastic or semiconductor) will also corrode. The simplest example of metallic corrosion is the rusting of iron in air. Iron is spontaneously oxidized by the oxygen in air to iron oxides (while the oxygen is being reduced). Metallic corrosion is very often an electrochemical process. It is always electrochemical when the metal is immersed in a solution, but even in atmospheric corrosion a thin film of condensed moisture often covers the surface. The metal in the corrosive solution essentially acts as a short-circuited galvanic cell. Different areas of the surface act as anode and cathode, at the anodic areas the metal is oxidized to an oxide while at the cathodic areas the dissolved oxygen is being reduced. The spontaneous complementary oxidation/reduction processes of "rusting" are spatially separated while an electrical current is flowing "internally" from one part of the corroding metal to another; the current is totally "wasted" as it produces no useful work but only generates heat. (A cell arrangement like this is often called a "local cell.") Corrosion products are typically oxides, but other products (e.g., sulfides) can also form depending on the environment. Corrosion always involves oxidation of the corroding material in the general sense of the term.
- Corrosion current (density): The current flowing in a corrosion "local cell" (often, but not always, under steady-sate conditions). The anodic and cathodic currents must be equal, but the current densities may be different depending on the area ratio. The corrosion current is closely related to the concept of corrosion potential. See also an Encyclopedia Article.

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- Corrosion inhibitor: A chemical that stops (or at least decreases the rate of) a corrosion process. The inhibitor can be added to an otherwise corrosive solution (often a very small concentration will accomplish the goal) or it can be incorporated in a coating applied to the metal surface. See also an Encyclopedia Article.
- Corrosion potential: The electrode potential of a corroding metal. It is a "mixed potential" with a value that is in between the equilibrium potentials of the anodic and cathodic corrosion reactions. The corrosion is a spontaneous, dynamic phenomena with electrode reactions taking place and a current flowing. Consequently, both reactions are polarized and their potentials approach each other; as a matter of fact, they must become equal to preserve a single potential for the metal. However, the two reactions are not necessarily equally polarized. The overpotential of the two electrode reactions will be generally different, and their values will be dictated by the requirement that the electrode potentials be equal (at the "corrosion potential") at one, uniquely defined current (the corrosion current). See the Tafel equation for a relation between overpotential and current. (The ir drops in the solution and the metal are ignored in the above discussion, this is justified by the close proximity of the anodic and cathodic areas on the corroding metal.)

- Cottrell equation: A relation between diffusion limited current density and time in a chronoamperometric experiment, assuming that the potential excursion is sufficiently large to immediately result in limiting current. The equation is valid only for planar electrodes in unstirred solution. The diffusion current density is inversely related to the square root of time, or expressing it differently: the product of i(t) × t0.5 is a constant. The constant is proportional to the concentration of the reactant and to the square root of the diffusion coefficient of the reactant. Because the equation was derived for an unstirred solution, it ceases to be valid once natural convection starts.

- Coulomb: Measurement unit of the electrical charge. Symbol:

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"C". The charge passing a given point during one second when the current. is one ampere.

- Coulombic efficiency: See coulometric efficiency.
- Coulometer: Instrument used for the measurement of electrical charge.
- Coulometric efficiency: For a rechargeable battery: the fraction, usually expressed as a percentage, of the electrical charge stored in a battery by charging that is recoverable during discharging. Inefficiencies arise from current inefficiencies. The coulometric efficiency is always larger than the energy efficiency. Also called "ampere-hour efficiency" "charge efficiency," and "coulombic efficiency."
- Coulometry: An electroanalytical technique based upon the measurement of the amount of electrical charge passed through the working electrode of an electrochemical cell.
- Coulostatic technique: An electrochemical measuring technique for electrochemical analysis or for the determination of the kinetics and mechanism of electrode reactions based on the control of the amount of charge flowing through the system.
- Coulter counter: Instrument used to count the number of small particles (e.g. biological cells) in a given volume of a suspension by monitoring decreases in electrical conductivity through a small orifice caused by the particles passing through the orifice.
- Counter electrode: An electrode in a three-electrode cell that is used only to make an electrical connection to the electrolyte so that a current can be applied to the working electrode. The processes occurring on the counter electrode are unimportant, it is usually made of inert materials (noble metals or carbon/graphite) to avoid its dissolution. This is the case for cells used for research or for electroanalytical purposes. Of course, for many practically used cells, the processes occurring on both electrodes can be very important. Also called "auxiliary" electrode.
- Counterion: The mobile ion in ion exchange. The ion with opposite charge to that of the fixed site on the ion-exchange resin. Contrast with fixed ion.

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- Couple: A somewhat ambiguous term. For a redox reaction, the combination of the oxidized and reduced species is often called the "redox couple." But it is also used to designate the combination of an anode and a cathode, especially for corrosion cells.
- C-rate: A charge or discharge current rate of a battery expressed in amperes. It is numerically a fraction or a multiple of the rated capacity of the battery expressed in ampere-hours. For example: for a 5-Ah rated capacity battery, C-rate is 5 A; C/5-rate is one A; 2C-rate is 10 A; and so on.
- Creep: The process by which liquid electrolytes, and in particular alkalies, can escape past rubber-metal or polymer-metal seals, or through minute cracks in a cell case or lid.

- Crystallization overpotential (polarization): The overpotential (alternatively called polarization) associated with the crystallization step in electrocrystallization. The crystallization is an elementary step in the overall electrode reaction.

- Current: The movement of electrical charges in a conductor; carried by electrons in an electronic conductor and by ions in an ionic conductor. "By definition" the electrical current always flows from the positive potential end of the conductor toward the negative potential end, independent of the actual direction of motion of the differently charged current carrier (or "charge carrier") particles. Two kinds of currents must be distinguished: "direct current (dc)" and "alternating current (ac)." Direct current is the unidirectional continuous flow of current, while alternating current is the oscillating (back and forth) flow of current. In electrochemistry, we almost always use direct current. Consequently, the term "current" always designates "dc" in this dictionary unless specifically stated to be "ac." The normal household current is an alternating current. The measurement unit of current is the ampere. As mentioned above, the "defined" current flows from the positive terminal of the current source, trough the load, to the negative terminal of the source. Consequently, inside the "source" (whether it is electromechanical or electrochemical)

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the current must flow from the negative terminal to the positive terminal since there must be a complete circuit. This concept is especially important in electrochemistry because an electrochemical cell can be either a current "source" (galvanic cell) or a "load" (electrolytic cell). Furthermore, a rechargeable battery operates as a "source" during discharge and as a "load" during charge. Current flowing through an electrochemical cell is usually the sum of the capacitive current and the faradaic current.

- Current collector: A structural part of a complicated electrode assembly. Its primary purpose is to conduct the electricity between the actual working (reacting) parts of the electrode and the terminals.
- Current compliance: See compliance limits.
- Current concentration: The ratio between of the current flowing through a compartment of an electrochemical cell and the volume of that compartment (e.g., anodic or cathodic current concentration). It is an often-used parameter in cell-design engineering.
- Current density: Current referred to the unit area of the electrode. Current divided by the true electrode area.
- Current distribution: The local current density on an electrode as a function of position on the electrode surface. Most processes operate best when the current distribution is "uniform." That is, when the current density is the same at all points on the electrode surface. See also primary, secondary, and tertiary current distribution.
- Current efficiency: The fraction, usually expressed as a percentage, of the current passing through an electrolytic cell (or an electrode) that accomplishes the desired chemical reaction. Inefficiencies may arise from reactions other than the intended reaction taking place at the electrodes, or side reactions consuming the product. The expected production can be theoretically calculated and compared with the actual production.
- Current leakage: Current that is bypassing bipolar electrodes in a series coupled cell assembly (due to insufficient sealing or improper piping around the bipolar electrode) and therefore is not producing the required chemical change (electrode

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reaction).

- Current-potential plot: A common characterization of an electrode or an electrochemical cell. The current (or more often the current density) is plotted against the electrode potential or cell voltage. See also Tafel equation.
- Current source (supply): See electrical source (supply).
- Current-voltage plot: See current-potential plot.
- Current yield: See current efficiency.
- CV: Stands for "cyclic voltammetry," see voltammetry.
- Cycle: In voltammetry: a complementary pair of forward and reverse potential sweeps. For rechargeable batteries: a complementary discharging and charging processes.
- Cycle life: The number of times a rechargeable battery can be "cycled" (charged and discharged) before it loses its ability to accept charge. The processes occurring in the battery are not completely "chemically" reversible, and after repeated charging/discharging the battery will accept less and less charge till it becomes useless as a practical energy storage device. Some batteries can be recharged hundreds to thousands times.
- Cyclic voltammetry: See voltammetry.

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Electrochemistry Dictionary - D

- Daniell cell: A very early non-rechargeable battery. It consisted of a glass jar containing copper and zinc electrodes, each immersed in their respective acidic sulfate solutions. The two solutions were separated by a porous clay cylinder separator. It was a galvanic cell in which the spontaneous electrodissolution of zinc and electroplating of copper provided the electrical current. It was one of the earliest practical "laboratory" electrical sources; but, of course, it was not much use outside the laboratory.
- DC: Abbreviation of direct current. However this term is also used in connection with dc voltage, that is, a steady voltage that will cause a "dc current" to flow in a conductor, and also in connection with dc power.
- Decomposition potential (voltage): The electrode potential (cell voltage) at which a "measurable" electrolysis current begins to flow. This is a qualitative parameter since "measurable" is rather subjective.
- De-electronation: Alternative name of an oxidation process.
- Deferred-action battery: See reserve battery.
- Degreasing: Process for removal of grease, oil, etc from metal surfaces in preparation for electroplating. Typically, the metal is immersed in hot, strongly basic solution or in organic solvents to remove and dissolve these coatings. See also electrolytic degreasing.
- Deionization: See desalination.
- Demineralization: See desalination.
- Dendrite: A crystalline shape produced by skeletal growth ("dendritic growth") resulting in "tree-like" appearance (often with many branches) in metal deposition.
- Depolarizer: An archaic expression (hardly used any more) for a material added to a battery electrode for reducing the polarization upon application of a current. It usually completely changed the nature of the electrode reaction.
- Deposition/dissolution: See metal deposition/dissolution reactions.
- Depth of discharge: For a rechargeable battery: the fraction,

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usually expressed as a percentage, of the total electrical energy stored in a battery by charging that was recovered by discharging at a certain point of time. Contrast with state of charge.

- Desalination: A process to produce clean (potable) water from brackish or seawater. Electrodialysis is an electrochemical technique often used for this purpose.
- Desorption: The opposite process of adsorption. The removal of the excess concentration of the adsorbate from the vicinity of the solid surface.
- Dezincification: Corrosive removal of zinc from a brass surface, leaving rough copper.
- DHE: Stands for the dynamic hydrogen electrode.
- Diaphragm: See separator.
- Diffuse double layer: See the Gouy-Chapman model of the double layer. Often simply called the "diffuse layer." (The diffuse layer is not to be confused with the diffusion layer.)
- Diffuse-junction potential: See liquid-junction potential.
- Diffuse layer: See diffuse double layer.
- Diffusion: The movement of chemical species (ions or molecules) under the influence of concentration difference. The species will move from the high concentration area to the low concentration area till the concentration is uniform in the whole phase. Diffusion in solutions is the most important phenomenon in electrochemistry, but diffusion will occur also in gases and solids. The rate of diffusion (diffusional flux) is proportional to the gradient of the concentration in the solution, with the proportionality constant called the "diffusion coefficient."
- Diffusion layer: A thin liquid boundary layer at the surface of an electrode that is immobile. This is part of a rather simplified and not strictly correct model (originally proposed by the early electrochemist Nernst, and is often called the "nernstian hypothesis") that works surprisingly well in most cases. The electrolyte solution is divided into three distinct parts: the bulk solution and the two diffusion layers at the surfaces of the electrodes. The bulk solution is assumed to be so well stirred that the concentration of all species is uniform throughout. In this region, mass transport occurs only through

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convection. While in the diffusion layers mass transport occurs only through diffusion. Charge transport occurs through electromigration everywhere. The thickness of the diffusion layer can vary typically between the order of 0.01 centimeter in a stagnant solution and the order of 0.0001 centimeter in very well-stirred solution. (The diffusion layer is not to be confused with the diffuse layer.) While the concept of the diffusion layer is related to the concept of the hydrodynamic boundary layer, the two are not identical and neither is their thickness. The structure of the diffusion layer can be assumed to be relatively simple in the presence of a large excess of supporting electrolyte, which is usually the case in electroanalytical applications and in electrode kinetics research. Under these conditions, practically all the electrical current is carried by the ions of the supporting electrolyte, and the transport number of the reactant and the product is practically zero. When the current is initially turned on, the ions of the supporting electrolyte will migrate in the diffusion layer to/from the electrode (depending on their charge). However, since they do not take part in any electrode reaction, their concentration will increase/decrease at the electrode surface compared to that of their concentrations in the bulk solution. This will start the diffusion of these ions in a direction opposite to their migration. After steady-sate is reached, the diffusion will completely cancel the migration, and the net flux of these ions will be zero. They do not contribute to the mass transport in the diffusion layer; however, they are responsible for all the charge transport, that is, the resistance of the diffusion layer depends on the conductivity of the supporting electrolyte. On the other hand, the reactant and the product will diffuse to/from the electrode surface, and they will carry all the mass. The situation remains the same even if either the reactant or the product is an electrically neutral molecule. It is usually assumed that the concentration of all species changes linearly between the electrode surface and the edge of the diffusion layer. An example is the diffusion layer at the cathode surface during electroplating of copper from a solution containing a small amount of copper chloride and a large concentration of

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sulfuric acid. All the current is carried by the ions of the sulfuric acid (hydrogen cations and sulfate anions) but the only possible electrode reaction is the reduction of the copper ions since the reduction of hydrogen ions cannot occur at the prevailing electrode potential (copper is lower in the electromotive series than hydrogen). The situation is much more complex in the absence of supporting electrolyte. Then both the electromigrational and the diffusional flux of the reactant and product must be considered.

- Diffusion limited current density: See limiting current density.
- Diffusion overpotential (polarization): See concentration overpotential.
- Diffusion potential: See liquid-junction potential
- Dipole: A pair of equal and opposite electrical charges separated by a small distance. A dipole will align itself, if possible, in the presence of other electrical charges according to the attraction of opposite and repulsion of like charges. Externally electrically neutral chemical molecules can have a dipole inside. E.g., water is a triangular molecule with the oxygen at one corner and the two hydrogens at the other two corners. The internal charge distribution is such that the hydrogen side has a slight excess of positive charge and the oxygen end is correspondingly negative. A dipole is characterized by its "dipole moment," the product of the charge and the separation distance (coulomb times centimeter).
- Dipole moment: See dipole.
- Direct current: See current. Abbreviated as "dc."
- Discharge curve: A plot of cell or battery voltage as a function of time, or of discharge capacity, under a defined discharge current or load.

- Discharge rate: The current withdrawn from a battery. This rate is commonly expressed as a multiple of the rated capacity. See C-rate.
- Discharging: The opposite process of charging. In this process the battery or capacitor supplies electricity to a load (e.g., motor, light bulb). The term discharging is also used to

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describe the neutralization of an ion during an electrode reaction. E.g., a metal cation is said to be "discharged" to an electrically neutral metal atom during electroplating.

- Disinfection of water: See brine electrolysis.
- Dissociation: The process that may occur when a chemical compound is dissolved in a solvent (e.g., water). The molecules of the compound will break up ("dissociate") into two or more ions resulting in an ionically conducting electrolyte solution. E.g., the common table salt (sodium chloride) will dissociate into a single charged sodium cation and a single charged chloride anion.
- Dissolved-oxygen electrode: See Clark electrode.
- Divided cell: An electrochemical cell in which the electrolyte is divided into two or more compartments by separators. Such separation may be necessary for two reasons. The solutions around the anode and the cathode may be different and it may be desirable to keep them from intermixing. Alternatively, it may be desirable to keep the products of the reactions at the anode and the cathode separated.
- Divider: See separator.
- DME: Stands for dropping-mercury electrode.
- Donnan equilibrium: See Donnan potential.
- Donnan potential: The electrical potential difference between two solutions separated by an ion-exchange membrane in the absence of any current flowing through the membrane. The concept of the Donnan potential is analogous to that of the equilibrium electrode potential. Consider two table salt (sodium chloride) solutions of different concentrations separated by a cation-exchange membrane. The concentration difference will set up a diffusional force driving the sodium chloride from the higher concentration solution into the lower concentration solution through the membrane. However, the ion-exchange membrane will permit only the passage of the positively charged sodium cations. Consequently, excess positive electrical charges will accumulate on the low concentration solution side of the membrane, while excess negative electrical charges will accumulate on the high concentration side because of the negatively charged chloride anions that are left behind. This charge separation will induce

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an electrical potential difference that will drive the electromigration of the sodium ions in the direction opposite to that of the diffusion. The overall result will be that the net movement of the sodium ions into the lower concentration solution will slow and eventually stop when the two opposing forces are equal end the two opposing fluxes are equal. In this so called "Donnan equilibrium," the diffusional flux of the sodium ions in one direction will be equal to the electromigrational flux in the opposite direction, resulting in net zero mass transport and zero charge transport. The electrical potential difference across the membrane under these equilibrium conditions is the "Donnan potential."

- Dorn potential (effect): Alternative name for "sedimentation potential." See electrokinetic effects.
- Double-junction reference electrode: A reference-electrode assembly (for example a silver/silver-chloride electrode) that is encased into a secondary containment vessel (typically a glass tubing) filled with an electrolyte not containing chloride ions (often a high concentration potassium nitrate solution). This second "internal electrolyte" of the reference electrode assembly and the external electrolyte into which the whole assembly is immersed are in ionic contact through a second separator (e.g., a porous ceramic plug). The purpose of this arrangement is the avoidance of chloride ion contamination of the test solution (many electrode reactions are strongly catalyzed by chloride ions) at the price of increased liquid-junction potential.
- Double layer: See electrical double layer.
- Double-layer capacitance: The measure of the ability of an electrical double layer to store electrical charge as a capacitor.
- Double-layer current (density): See capacitive current (density).
- Double-layer range (or window): The electrode potential range where an electrode behaves as an ideal polarized electrode. In this potential range, the electrode potential is not positive enough that any species in the solution could be oxidized and the potential is not negative enough that any species could be reduced. In practical situations, there is

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almost always a small residual current flowing that is faradaic in nature.

- Drain: Withdrawal of current from a cell or battery.

- Dropping-mercury electrode: A working electrode arrangement for electroanalytical techniques, such as polarography. Mercury is flowing continuously through a capillary tubing forming a small droplet (typical diameter about 0.1 cm) exposed to the solution. The old drop falls off and a new drop forms typically every few (3-6) seconds. The advantage of this self-renewing electrode is that the effect of impurities in the solution is minimized. Typically a new drop will form before impurities have a chance to adsorb on the surface of the old drop to such an extent as to influence the charge-transfer reaction. Abbreviated as "dme."
- Dry cell: An early name for the non-rechargeable battery that is still used occasionally. The early non-rechargeable batteries were laboratory devices (see, e.g. the Daniell cell). To produce a practical device, the electrolyte solution was "immobilized" by some gelling agent, and the whole cell was sealed to permit its use in any position. Hence the name: "dry cell." See also Leclanche cell. A cell in which the electrolyte is immobilized, being either in the form of a paste or gel or absorbed in a microporous separator material.
- Dry charged cell: A cell which is in its fully charged state but without electrolyte.

- Dry-charged battery: See reserve battery.
- Duplex electrode: Type of electrode system used in flat Leclanché multicell batteries, formed by zinc coated on one side with carbon. It acts as the cathode current collector for one cell and as the anode for the adjacent cell. (see 'bipolar electrode').

- Dynamic equilibrium: See exchange current density.
- Dynamic hydrogen electrode: A pseudo-reference electrode assembly, simulating a reversible hydrogen electrode with an approximately 20 to 40 mV more negative potential. While its potential is less defined, it has the advantage of not requiring a hydrogen gas supply. It is typically a glass tube containing

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two internal electrodes, at least one of which is a platinized platinum electrode, immersed in the same electrolyte solution as is the electrolyte in the working cell, with the two electrolytes in ionic contact through a separator. A small, constant current is enforced between the two electrodes with the platinized platinum being the cathode, carrying typically 1 mA/cm2 current density, resulting in a small amount of hydrogen evolution. This cathode is then used as the reference electrode.

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Electrochemistry Dictionary - E

- Edison battery: A rechargeable battery developed by Edison. In the charged state, the active material of the positive electrode is nickel oxide while that of the negative electrode is metallic iron, with a basic (potassium hydroxide) electrolyte. During discharging, the nickel oxide is converted to a lower oxidation state oxide, while the iron is converted to iron oxide. It is still used today.
- Electrical current: See current.
- Electrical double layer: The structure of charge accumulation and charge separation that always occurs at the interface when an electrode is immersed into an electrolyte solution. (For a simple example see equilibrium electrode potential.) The excess charge on the electrode surface is compensated by an accumulation of excess ions of the opposite charge in the solution. The amount of charge is a function of the electrode potential. This structure behaves essentially as a capacitor. There are several theoretical models that describe the structure of the double layer. The three most commonly used ones are the Helmholtz model, the Gouy-Chapman model, and the Gouy-Chapman-Stern model.
- Electrical energy: A form of energy. It expresses the ability of an electrical source to carry out useful work or generate heat. E.g., this energy can be used to drive an electrical motor and carry out some mechanical work, or to generate heat with an electrical heater. The electrical energy is usually expressed in units of watt-hour, symbol: "Wh". See also electrical power.
- Electrical potential: The electrical potential difference between two point in a circuit is the cause of the flow of a current. It is somewhat analogous to the difference in height in a waterfall that causes the water to fall, or the difference in pressure in a pipeline that causes the gas to flow. In electrochemistry we typically cannot measure "absolute" potentials, only the "difference" of potential between two points. For similar concepts, see electromotive force (emf) and voltage. These terms are sometimes used interchangeably. However, in electrochemistry "emf" usually refers to the

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potential difference between the two electrodes of an electrochemical cell when there is no current flowing through the cell, "voltage" refers to same with current flowing, and "potential" is usually used in connection with electrodes (see electrode potential). The measurement unit of the potential is the volt.

- Electrical power: The rate at which an electrical source can supply electrical energy. E.g., a battery may be able to store a large amount of energy, but if it has a small power capability it can provide the energy (do some work) only slowly, and it will take a long time to discharge. Another battery with the same energy storage capability but larger power will provide the energy (do work) faster, but will also be discharged faster. Electrical power is expressed usually in units of watt, symbol: "W". Unfortunately, the terms "power" and "energy" are often used interchangeably in everyday language (and sometimes also in the technical literature) even though they are quite distinct concepts, e.g., when we talk about "energy source" or "power source," we usually mean the same thing. Not only electrical sources but also loads are characterized by a power rating, e.g., an electrical motor or a light bulb is characterized by the power it needs to operate it. The power of a source (or the power need of a load) can be calculated as the product of the current and voltage (watt = ampere × volt). One watt means that one watt-second (coulomb × volt) energy is provided (used) every second. In more practical units, one watt means that one watt-hour (ampere-hour × volt) energy is provided (used) every hour.
- Electrical source (supply): A source of electrical power (electrical energy), a device that supplies electrical current. It can be electrochemical (battery or fuel cell) or an electromechanical device (dynamo) or a specialized electronic instrument. Also called "power source (supply)." Specialized sources can be called "voltage source" or "current source," indicating the characteristic of the electrical power that can be controlled by that device.
- Electroacoustics (electroacoustic effect): The electrokinetic effects arising when soundwaves cause oscillation of small particles suspended in a liquid; particularly, effect analogous

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to sedimentation potential.

- Electroactive substance: A species in solution that can take part in an electrode reaction or that can be adsorbed on the electrode.
- Electroadsorption: See electrosorption.
- Electroanalytical chemistry: The application of electrochemical cells and electrochemical techniques for chemical analysis. The analyte is dissolved in the electrolyte of the cell, and one can perform either "qualitative" analysis (determination of the type of constituents present) or "quantitative" analysis (determination of the amount of a given constituent).
- Electrocatalysis: The phenomenon of increasing the rate of an electrode reaction by changing the electrode material. The rate of the electrode reactions (the magnitude of the exchange current density) can strongly depend on the composition and morphological structure of the electrode surface. This is called the "electrocatalytic effect."
- Electrocatalyst: A material that can cause electrocatalysis.
- Electrochemical capacitor: A device that stores electrical energy using electrochemical cells. Large surface area electrodes are used resulting in large double layer capacitance, and much of the storage capacity is due to the charging/discharging of the double layer. Some surface oxidation/reduction also occurs, but in contrast to reactions occurring in batteries, this is limited to a monolayer or two on the electrode surfaces. Consequently, the device behaves more like a capacitor than a battery. It is also called "supercapacitor" and "ultracapacitor". It is not to be confused with electrolytic capacitors. Electrochemical capacitors typically have much larger power density but much smaller energy density than batteries.
- Electrochemical cell: A device that converts chemical energy into electrical energy or vice versa when a chemical reaction is occurring in the cell. Typically, it consists of two metal electrodes immersed into an aqueous solution (electrolyte) with electrode reactions occurring at the electrode-solution surfaces. See also galvanic cell and electrolytic cell. It consist of two electronically conducting phases (e.g., solid or liquid

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metals, semiconductors, etc) connected by an ionically conducting phase (e.g. aqueous or non-aqueous solution, molten salt, ionically conducting solid). As an electrical current passes, it must change from electronic current to ionic current and back to electronic current. These changes of conduction mode are always accompanied by oxidation/reduction reactions. An essential feature of the electrochemical cell is that the simultaneously occurring oxidation-reduction reactions are spatially separated. E.g., in a spontaneous "chemical reaction" during the oxidation of hydrogen by oxygen to water, electrons are passed directly from the hydrogen to the oxygen. In contrast, in the spontaneous electrochemical reaction in a galvanic cell the hydrogen is oxidized at the anode by transferring electrons to the anode and the oxygen is reduced at the cathode by accepting electrons from the cathode. The ions produced in the electrode reactions, in this case positive hydrogen ions and the negative hydroxyl (OH^-) ions, will recombine in the solution to form the final product of the reaction: water. During this process the electrons are conducted from the anode to the cathode through an outside electrical circuit where the electrical current can drive a motor, light a light bulb, etc. The reaction can also be reversed, water can be decomposed into hydrogen and oxygen by the application of electrical power in an electrolytic cell.

- **Electrochemical cleaning:** See electrolytic degreasing.
- **Electrochemical degreasing:** See electrolytic degreasing.
- **Electrochemical double layer:** See electrical double layer.
- **Electrochemical drilling:** See electrochemical machining.
- **Electrochemical equivalent:** The weight of a substance (in grams) produced or consumed by the passage of one coulomb in an electrochemical reaction. The gram-equivalent weight divided by the Faraday constant.
- **Electrochemical grinding:** A combination of electrochemical machining and mechanical grinding. Used when the products of electrochemical dissolution are not easily soluble and must be removed physically from the surface. Used with a metal-bonded and diamond-impregnated grinding wheel. Also called "electrolytic grinding" and "electrogrinding."

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- Electrochemical irreversibility: See irreversible electrode reaction.
- Electrochemical machining: A process to produce metallic objects with a technique that is essentially precision electrodissolution. The metal to be machined is made the anode in an electrolytic cell while the cathode (or "tool") is made of inert material and is machined to be the "mirror image" of the desired shape. A very small gap (typically, less than 0.1 cm) is maintained between the electrodes and a large current density is applied with a fast flowing electrolyte. One of the advantages of this production technique is that very complicated shapes can be produced with a single operation from very hard alloys that would be very difficult, if not impossible, to machine with any other metal cutting technique. Some typical applications are the production of turbine blades and the drilling of holes with very large depth-to-diameter ratio. The cathodic reaction is typically hydrogen evolution.
- Electrochemical nose: An instrument which comprises a sampling system, an array of chemical/electrochemical gas sensors with differing selectivity, and a computer with an appropriate pattern-classification algorithm, capable of qualitative and/or quantitative analysis of simple or complex gases, vapors, or odors. See also an Encyclopedia Article.
- Electrochemical pickling: See electrolytic pickling.
- Electrochemical polishing: See electropolishing.
- Electrochemical reaction: An oxidation/reduction reaction that occurs in an electrochemical cell. The essential feature is that the simultaneously occurring oxidation-reduction reactions are spatially separated. E.g., in a spontaneous "chemical reaction" during the oxidation of hydrogen by oxygen to water, electrons are passed directly from the hydrogen to the oxygen. In contrast, in the spontaneous electrochemical reaction in a galvanic cell two separate electrode reactions occur. The hydrogen is oxidized at the anode by transferring electrons to the anode and the oxygen is reduced at the cathode by accepting electrons from the cathode. The overall electrochemical reaction is the sum of the two electrode reactions. The ions produced in the electrode reactions, in this

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case positive hydrogen ions and the negative hydroxyl (OH-) ions will recombine in the solution to form the final product of the reaction: water. During this process the electrons are carried from the anode to the cathode through an outside electrical circuit where the electronic current can drive a motor, light a light bulb, etc. The reaction can also be reversed, water can be decomposed into hydrogen and oxygen by the application of electrical power in an electrolytic cell.

- Electrochemical reversibility: See reversible electrode reaction.
- Electrochemical series: See electromotive series.
- Electrochemical shaping: A variety of electrochemical techniques used to "shape" metal objects. These include: electrochemical machining, electrochemical drilling, electrochemical grinding, and electropolishing.
- Electrochemical switching: An electrochemically switchable molecule displays a different reactivity toward some other chemical species depending whether the switchable molecule is oxidized or reduced. Consequently, the reactivity of the molecule can be controlled by electrochemical oxidation/reduction. This phenomenon is primarily important in bioelectrochemistry.
- Electrochemical synthesis: See electrosynthesis.
- Electrochemiluminescence: Light emission by excited species produced in an electrode reaction. Also called: "electrogenerated chemiluminescence."
- Electrochromatography: A "chromatographic" separation method with the "mobile," liquid phase forced through the "immobile" phase by the application of an electrical potential difference, that is, by electroosmosis. In some cases, the separation is enhanced by electrophoresis. Chromatography is an analytical (see electroanalytical) separation technique based on the different attraction of the sample components to an immobile/stationary phase through which the sample solution is forced through by a flow of solvent. The sample components are adsorbed/desorbed on the surface of the stationary phase as they are flushed through by the solvent; consequently, they move with speeds inversely proportional to their adsorption strengths and become separated: the least-

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strongly adsorbed component is flushed out first and the most-strongly adsorbed last. A variety of stationary phases can be employed; the most common ones are: paper, thin layer of gelatinous material, or a column (or capillary) packed with small particles.

- Electroclean: See electrolytic degreasing.
- Electrocoating: See electrophoretic deposition.
- Electroconcentration: Process for increasing the concentration of a trace component in a sample. It can be achieved by a variety of techniques, e.g.: electrochromatography, electrodialysis, electroplating, electroosmosis, and electrophoresis.
- Electrocrystallization: See electroplating. Electroplating typically will result in a crystalline metal deposit; therefore, the two terms can be used interchangeably. The term "electroplating" is mostly used in technological applications, and the term "electrocrystallization" is often used in research studies.
- Electrode: The two electronically conducting parts of an electrochemical cell. See also anode and cathode. These can be simple metallic structures (rods, sheets, etc) or much more complicated, composite structures. E.g., the electrodes in a rechargeable battery will also "contain" the chemicals being converted during its operation. The term "electrode" is also used to denote complex assemblies that include an electrode in a small vessel, which contains an electrolyte and is equipped with an ion-permeable separator. Reference electrodes are such assemblies.
- Electrode kinetics: The application of kinetics to electrode reactions. Not to be confused with electrokinetics.
- Electrode of the first kind: A simple metal electrode immersed in a solution containing its own ion (e.g., silver immersed in a silver nitrate solution). The equilibrium potential of this electrode is a function of the concentration of the cation of the electrode metal in the solution (see Nernst equation). Contrast with electrode of the second kind and electrode of the third kind.
- Electrode of the second kind: A metal electrode assembly with the equilibrium potential being a function of the

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concentration of an anion in the solution. Typical examples are the silver/silver-chloride electrode and the calomel electrode. Contrast with electrode of the first kind and electrode of the third kind. The assembly consists of a metal, in contact with a slightly soluble salt of this metal, immersed in a solution containing the same anion as that of the metal salt (e.g., silver---silver chloride---potassium chloride solution). The potential of the metal is controlled by the concentration of its cation in the solution, but this, in turn, is controlled by the anion concentration in the solution through the solubility product of the slightly soluble metal salt.

- Electrode of the third kind: A metal electrode assembly with the equilibrium potential being a function of the concentration of a cation, other than the cation of the electrode metal, in the solution. These have been used, with limited success, in sensors for metal ions for metals that are not stable in aqueous solutions, e.g., calcium and magnesium. Contrast with electrode of the first kind and electrode of the second kind. The assembly consists of a metal in contact with two slightly soluble salts (one containing the cation of the solid metal, the other the cation to be determined, with both salts having a common anion) immersed in a solution containing a salt of the second metal (e.g., zinc metal---zinc oxalate---calcium oxalate---calcium salt solution). The potential of the metal is controlled by the concentration of its cation in the solution, but this is controlled by the anion concentration in the solution through the solubility product of the slightly soluble metal salt, which, in turn is controlled by the concentration of the cation of the second slightly soluble salt. These electrodes are very sluggish and unstable due to a series of equilibria to be established to produce a stable potential.
- Electrode potential: The electrical potential difference between an electrode and a reference electrode. We cannot measure the "absolute" potential of an electrode; therefore, the electrode potential must always be referred to an "arbitrary zero point," defined by the potential of the reference electrode. Consequently, it is very important always to note the type of reference electrode used in the measurement of the electrode potential. See also equilibrium

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electrode potential.

- Electrode reaction: A chemical "half" (or "partial") reaction occurring at the electrode surface. It is called a "half" (or "partial") reaction because only the oxidation or the reduction part of the overall cell reaction occurs at any one electrode. See also electrochemical reaction. Many electrode reactions can proceed either as oxidation or as reduction, depending on the direction of the current flowing through the electrode/electrolyte interface. See, e.g. metal deposition/dissolution or redox reactions. An electrode reaction always occurs in several series and parallel elementary reaction steps. Even in the simplest case there are three steps in series: (1) the reactant must be transported to the electrode surface from the bulk of the electrolyte (usually predominantly by diffusion, but it can also occur by electromigration), (2) a charge-transfer reaction occurs, and (3) the product must be transported from the electrode surface to the bulk of the electrolyte.
- Electrodeposition: A process for depositing solid materials on an electrode surface using electrolysis. It is a somewhat loosely used term that is applied to many technologies. There are a number of metal deposition technologies. However, not only metals but also different compounds can be electrodeposited. This is used most often for the formation of oxides (such as manganese dioxide and lead dioxide) by anodic oxidation of dissolved salts. Deposition can also be achieved electrophoreticly. See also an Encyclopedia Article on electroplating.
- Electrodics: The part (sub-discipline) of electrochemistry that deals with phenomena occurring at the surface of electrodes, particularly charge-transfer reactions. See also ionics.
- Electrodissolution: The reverse reaction of metal deposition.
- Electrodialysis: A process to move ions from one solution into another using an electrolytic cell. An example is the electrochemical desalination of seawater. In its simplest form, the cell is separated into three compartments by appropriate ion-exchange membranes with electrodes placed in the two outer compartments, and all compartments are fed seawater. As an electrical current is forced through the cell, anions will

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move from the central compartment through an anion-exchange membrane into the anode compartment and the cations will move through an cation-exchange membrane into the cathode compartment. Since the ion-exchange membranes are appropriately ion selective, the ions cannot move from the edge compartments to the central compartment, resulting in a desalinated effluent from that compartment. In practice, more than one cell will be connected in series, and the process will be carried out in several stages since it would not be efficient to remove all the salt in one step. This process is also used to remove industrial pollutants from waste streams.

- Electroendosmosis: See electroosmosis.
- Electroextraction: See electrowinning.
- Electroflotation: An electrolytic process for particle separation. An aqueous solution containing dispersed solid particles is electrolyzed to produce hydrogen and oxygen gas bubbles, the rising bubbles carry particles adhering to them to the surface where they can be skimmed off. This process is routinely used in processing minerals (ores) for separating the light and heavy particles, and in waste treatment to remove solids.
- Electroforming: A process to produce metallic objects with a technique that is essentially precision electroplating. The metal is deposited onto a "mandrel" or "former" of suitable shape to a desired thickness, followed by the removal of the mandrel to produce a free standing metal object. One of the advantages of this production technique is that very complicated shapes can be produced with a single operation. It is often used to produce very precise optical elements, and solid-state electronic devices (integrated circuit boards, computer chips). Other applications are the production of flat or perforated metal sheets, seamless perforated metal tubes, and metal bellows. Two very prominent past applications of this technique were the production of "stampers" for the old-fashioned musical (phonograph) records and "electrotypes" for the printing industry. Practically any metal or alloy that can be electroplated can also be used for electroforming. The preparation of the removable mandrel is an important step in this process. One example is the use of machined copper or

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brass that is surface treated to permit electroplating that will closely follow the mandrel surface but will not permit strong adhesion of the electroformed piece.

- Electrogalvanizing: See galvanizing.
- Electrogenerated chemiluminescence: See electrochemiluminescence.
- Electrogenerated species: A chemical species produced at an electrode surface by a charge-transfer reaction.
- Electrogravimetry: An electroanalytical technique in which the substance to be determined (usually a metal) is deposited out on an electrode which is weighed before and after the experiment. The potential of the electrode must be carefully chosen to ensure that only the metal do be determined will deposit. Under favorable conditions, two or more metals can be determined by successive depositions at different potentials.
- Electrogrinding: See electrochemical grinding.
- Electrokinetic effects (electrokinetics): Phenomena that arise due to a charge separation caused by the relative motion of a solid and liquid phase. A portion of the Gouy-Chapman diffuse layer is sheared off as the two phases move relative to each other, resulting in a charge separation. The hydrodynamic boundary layer remains attached to the solid surface while the rest of the liquid moves separately; consequently, electrokinetic effects arise when the "diffuse double layer" is thicker that the "hydrodynamic boundary layer." The electrical potential difference between the bulk solution and the "shear plane" is the "electrokinetic potential," often called the "zeta potential." Two types of effects arise: an electrical potential difference will arise between the two phases if they move relative to each other due to an external force (streaming potential and sedimentation potential) or a movement of the two phases will arise relative to each other if an electrical potential is applied parallel to the phase boundary (electroosmosis and electrophoresis). Accordingly, "electrokinetics" includes the following four "electrokinetic effects:" Streaming potential arises when liquid is flowing by a solid surface, e.g., when liquid is forced through a capillary tubing or porous solid by a pressure differential. Sedimentation

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potential arises when small suspended particles move through a liquid (e.g., forced by gravity). This can occur in "dispersions" (suspended solid particles) or "emulsions" (suspended immiscible liquid droplets). Also called "eletrophoretic potential" or "Dorn potential." Electroosmosis is the movement of a liquid through a capillary tubing or porous solid driven by an electrical potential difference. Also called "electroendosmosis." Electrophoresis is the movement of small suspended particles in a liquid driven by an electrical potential difference. This can occur in "dispersions" (suspended solid particles) or "emulsions" (suspended immiscible liquid droplets). Also called "cataphoresis." Electrokinetics should not be confused with electrode kinetics.

- Electrokinetic potential: Alternative name for "zeta potential." See electrokinetic effects.
- Electrokinetic remediation: See electroremediation.
- Electroless plating: Process to produce thin metallic coatings on objects without the application of external current. The plating bath contains a dissolved salt of the metal and a reducing agent. However, the reduction of the metal cation to metal occurs only on the surface of the object to be coated due to the catalytic nature of the surface. The advantages of this process over electroplating are the possibility to produce coatings on insulator materials, and to produce uniform thickness coatings on geometrically complex surfaces.
- Electrolysis: A process that decomposes a chemical compound into its elements or produces a new compound by the action of an electrical current. The electrical current is passed trough an electrolytic cell and oxidation/reduction reactions occur at the electrodes. E.g., water can be decomposed into hydrogen and oxygen, or a metal can be electroplated by electrolysis.
- Electrolyte: A chemical compound (salt, acid, or base) that dissociates into electrically charged ions when dissolved in a solvent. The resulting electrolyte (or electrolytic) solution is an ionic conductor of electricity. Very often, the so formed solution itself is simply called an "electrolyte." Also, molten salts and molten salt solutions are often called "electrolyte" when used in electrochemical cells, see ionic liquid.
- Electrolyte solution: See electrolyte.

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- Electrolytic capacitor: A storage device similar to any other type of electrical capacitor. However, only one of its conducting phases is a metallic plate, the other conducting phase is an electrolyte solution. The dielectric is a very thin (passive) oxide film on the surface of the metal (typically aluminum or tantalum) that constitutes one conducting phase of the capacitor. There is also another metal electrode immersed in the solution, which serves only as the electrical contact to the solution. Electrolytic capacitors typically have much larger capacitance than classical capacitors because the dielectric is very thin (on the order of millionth of centimeter). There are no economical ways to produce dielectric films that thin in any other way. The electrolytic capacitor is not to be confused with the electrochemical capacitor. The overall capacitance of this device is the sum of two series coupled capacitances because the metal electrical contact in the solution will have an electrical double layer. The capacitance of the double layer is even larger than that of the oxide covered electrode because the "dielectric" in the double layer is only a few molecular layers of the solvent. Consequently, the overall capacitance is dominated by the lower value of the oxide-covered electrode. An electrochemical capacitor, depending completely on double-layer capacitance, will have much larger capacitance than an electrolytic capacitor, however it can be operated only in a few volts potential range because of the limitation of the double-layer range. An electrolytic capacitor can be operated to tens or hundreds of volts, depending on the thickness of the dielectric oxide film.
- Electrolytic cell: An electrochemical cell that converts electrical energy into chemical energy. The chemical reactions do not occur "spontaneously" at the electrodes when they are connected through an external circuit. The reaction must be forced by applying an external electrical current. It is used to store electrical energy in chemical form, see rechargeable battery. It is also used to decompose or produce (synthesize) new chemicals by application of electrical power. This process is called electrolysis, e.g., water can be decomposed into hydrogen gas and oxygen gas. The free energy change of the

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overall cell reaction is positive.

- Electrolytic cleaning: See electrolytic degreasing.
- Electrolytic degreasing: Process for removal of grease, oil, etc from metal surfaces in preparation for electroplating. The metal is made the cathode in an electrolytic cell containing strongly basic (sometimes hot) solution that dissolves these coatings. The strong hydrogen evolution occurring on the cathode may reduce some of the coatings, and the strong bubble evolution removes the coatings mechanically, while the agitation of the solution helps the chemical dissolution of the coatings by the base. Also called: "electrolytic cleaning," "electrochemical cleaning," "electrocleaning," and "electrochemical degreasing." See also degreasing.
- Electrolytic grinding: See electrochemical grinding.
- Electrolytic hydrogen: See water electrolysis.
- Electrolytic oxygen: See water electrolysis.
- Electrolytic machining: See electrochemical machining.
- Electrolytic pickling: Process for removal of oxide scales from metal surfaces in preparation for electroplating. The metal is made the cathode in an electrolytic cell containing strongly acidic (sometimes hot) solution that dissolves the oxide scales. The strong hydrogen evolution occurring on the cathode may reduce some of the oxides, and the strong bubble evolution removes the scales mechanically, while the agitation of the solution helps the chemical dissolution of the scales by the acid. See also pickling.
- Electrolytic polishing: See electropolishing.
- Electrolytic refining: See electrorefining.
- Electrolytic solution: See electrolyte.
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- Electromachining: See electrochemical machining.
- Electrometallurgy: Branch of metallurgy (science dealing with the production of metals) using electrochemical processes, that is electrowinning.
- Electrometer: A voltmeter with very large input resistance. A typical modern voltmeter has an input resistance of around ten million ohms, an electrometer can have ten million times more. Electrometers are used to measure the electromotive force of electrochemical cells that can be easily polarized by

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current. The voltmeter always draws a small current, the magnitude depends on the ratio of the resistance of the cell and the voltmeter. High resistance cells (e.g., one containing a glass electrode, must be measured with an electrometer.

- Electromigration: The movement of ions under the influence of electrical potential difference.
- Electromotive force: The cell voltage of a galvanic cell measured when there is no current flowing through the cell. In other words, the equilibrium electrode potential difference between the two electrodes of the cell. Abbreviated as "emf."
- Electromotive series: A tabulation on which various substances, such as metals or elements, are listed according to their chemical reactivity or standard electrode potential. It is usually ordered with increasing standard electrode potentials (most negative on top). For metals, the order indicates the tendency to spontaneously reduce the ions of any other metal below it in the series (see cementation). During electrolytic reduction of cations (e.g., electroplating) an element lower in the series (more positive) will deposit first, and an element higher in the series (more negative) will deposit only when the solution is practically depleted of the ions of the first element. Also called "electrochemical series" and "galvanic series."
- Electron: See atomic structure.
- Electronation: Alternative name of a reduction process.
- Electroneutrality condition: The expression of nature's tendency to keep any system electrically neutral, that is, if it contains electrically charged particles the total sum of negative charges will be equal to the total sum of positive charges. Applying this condition to a solution of electrolytes implies the equality of the total positive ionic charges to the total negative ionic charges. This equality should hold even as we subdivide the solution into smaller and smaller volume elements. This condition results from the statistical distribution of the ions around each other considering the attractive tendency of oppositely charged particles and the repulsive tendency of similarly charged particles. Consequently, there is a statistical limit of the size of the volume element to which it applies. At the extreme, a volume small enough to contain only a single ion obviously cannot be

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electrically neutral.

- Electronic conductor: A material that conducts electricity with electrons as charge carriers.
- Electronic nose: See electrochemical nose.
- Electron-transfer reaction: See charge-transfer reaction.
- Electroorganic: Relating to organic electrochemistry.
- Electroosmosis: The movement of a liquid through a capillary tubing or porous solid driven by an electrical potential difference. See electrokinetic effects. Also called "electroendosmosis."
- Electroosmotic dewatering: Compaction of slurries by electroosmosis.
- Electroosmotic remediation: See electroremediation.
- Electrooxidation: Oxidation carried out with an electrochemical reaction.
- Electropainting: Alternative name for electrophoretic painting.
- Electrophoresis: As a phenomenon: the movement of small suspended particles or very large molecules in a liquid driven by an electrical potential difference. Also called "cataphoresis." See electrokinetic effects. As an electroanalytical technique: a separation method for very large organic molecules (usually of biological origin) based on their different electrophoretic velocities through an "immobilized" liquid phase. The liquid can be immobilized by a variety of "supports", e.g.: paper, gelatinous material, capillary tubing.
- Electrophoretic deposition (painting): Deposition of particles carried to a surface by electrophoresis. The loosely formed deposit layer typically needs compacting that can partially occur by electroosmotic removal of the liquid, or by other means. Electrode reactions occurring on the substrate surface can take part in "binding" the coating. Practical applications are surface coating and paint deposition (practiced on large scale in the automotive industry) and fabrication of ceramic products. Also called "electrocoating."
- Electrophoretic potential: Alternative name for "sedimentation potential." See electrokinetic effects.
- Electrophysiology: The study of the electrical properties of

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living tissue.

- Electroplating: The process that produces a thin, metallic coating on the surface on another metal (or any other conductor, e.g., graphite). The metal substrate to be coated is made the cathode in an electrolytic cell where the cations of the electrolyte are the positive ions of the metal to be coated on the surface. When a current is applied, the electrode reaction occurring on the cathode is the reduction of the metal ions to metal. E.g., gold ions can be discharged form a gold solution to form a thin gold coating on a less expensive metal to produce "custome" jewelry. Similarly, chromium coating is often applied to steel surfaces to make them more "rust resistant." Electroplating is also used in the production of integrated circuits on computer chips and for other modern electronic instrumentation. The anode material can either be the metal to be deposited (in this case the electrode reaction is electrodissolution that continuously supplies the metal ions) or the anode can be of nonreactive material and the anodic reaction is oxygen evolution (in this case the plating solution is eventually depleted of metal ions). Also called "electrodeposition." See also an Encyclopedia Article.
- Electroporation: The application of very brief, carefully controlled, pulsed, rotating electrical fields to human cells, a process that causes pores to open in the cell membrane and allows pharmaceuticals or genes to gain access to the cell's interior.
- Electropolishing: A process that produces a bright, shiny surface on a metal. The metal is anodically dissolved in an electrolytic cell under conditions that projections in the surface are dissolved faster than the smoother areas.
- Electroreduction: Reduction carried out with an electrochemical reaction.
- Electrorefining: An electrochemical process that produces a purified metal from a less pure metal. The metal to be purified is made the anode in an electrolytic cell and it is dissolved by the application of a current into a usually acidic aqueous electrolyte or a molten salt. At the same time, the pure metal is deposited on the cathode. The process is carried out under conditions that most impurities will either

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precipitate as "sludge" or remain dissolved in the electrolyte. Copper is one metal that is often electrorefined in aqueous solutions, and aluminum is electrorefined using a molten salt electrolyte. Also called "electrolytic refining" and "metal refining."

- Electroremediation: An electroosmotic process for removing soluble contaminants from soil. Electrosmosis is carried out in the wet soil with strategically placed electrodes, resulting in a movement of the contaminants toward the electrodes thereby cleansing the soil and concentrating the contaminants in a small volume of soil around the electrodes from where they can be easily removed. Also called "electrokinetic remediation" "electroosmotic remediation" and "soil remediation."
- Electrorheology: See electroviscosity.
- Electroseparation: A process that uses electrolysis to selectively remove a constituent from solution.
- Electrosorption: Adsorption at electrode surfaces. Generally, adsorption at electrically charged interfaces.
- Electrosynthesis: Production of chemicals in an electrolytic cell. See also Encyclopedia Articles on electrosynthesis of inorganic and organic compounds.
- Electrotype: See electroforming.
- Electroviscosity: The phenomenon of a change in viscosity due to the presence of charge on particles suspended in a solvent.
- Electrowinning: An electrochemical process that produces metals from their ores. Most metals occur in nature in oxidized form in their ores. While numerous ways exist to reduce the ores, for many metals electrochemical reduction is the most practical. The ore is dissolved (often following some chemical purification or preprocessing) in an acidic aqueous solution or in a molten salt and the resulting electrolyte solution is electrolyzed. The metal is deposited on the cathode (either in solid or in liquid form), while the anodic reaction is usually oxygen evolution. Copper and zinc are two metals that are often produced by aqueous electrolysis. Aluminum, magnesium, and sodium are some metals that can be produced by molten salt electrolysis. For aluminum, this is the only practically used production process (see an Encyclopedia Article). Also called "electroextraction."

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- Element, chemical: A substance that cannot be decomposed into simpler substances by chemical means.
- Elementary reaction step: Chemical reactions usually take place in a number of simple ("elementary") reaction steps proceeding in series. The overall reaction is the sum of the elementary reactions. E.g., the electroplating of copper on some metal involves three elementary steps: (1) a redox reaction in which the double positively charged copper cation reacts with an electron from the metal electrode to form a single charged copper ion, followed by (2) a metal deposition reaction in which the single charged copper ion reacts with a second electron to form a copper atom on the surface of the metal, and finally (3) an electrocrystallization step in which the copper atom becomes incorporated into the crystalline structure of the underlying metal. The rate-determining step in copper deposition is usually the first of these steps. Some complicated reactions can also involve parallel paths, each proceeding through a different series of elementary steps (different reaction mechanisms). The sum of the series elementary steps in each parallel path must add up to the same overall reaction.
- emf: Stands for electromotive force.
- Energy: The energy of a system expresses the ability of that system to do some useful work or generate heat. Energy can be in many forms; e.g., mechanical energy, chemical energy, heat energy, electrical energy, etc. The different forms of energy can be converted into each other. It is a fundamental law of nature that energy can never be converted from one form to another 100%, some of the energy is always converted into heat energy during the conversion. Also, heat can never be converted 100% into any other form of energy.
- Energy conversion: A process in which energy is converted from one of its many forms to another. The fuel cell is an electrochemical energy conversion device.
- Energy density: Characteristic parameter of a battery indicating the amount of electrical energy stored per unit weight or volume. The terminology is not strictly defined. Weight based energy density is often called "specific energy" or "gravimetric energy density." Volume based energy density is

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often called "energy density" or "volumetric energy density." The energy density is typically expressed as watt-hour/kilogram or watt-hour/liter.

- Energy efficiency: For a rechargeable battery: the fraction, usually expressed as a percentage, of the electrical energy stored in a battery by charging that is recoverable during discharging. For an electrolytic cell: the fraction, usually expressed as a percentage, calculated as the theoretically required energy divided by the energy actually consumed in the process (production of a chemical, electroplating, etc). Inefficiencies arise from current inefficiencies and the inevitable heat losses due to polarization. See also coulometric efficiency.
- Energy source (supply): See electrical source (supply).
- Energy storage: A process in which energy is stored in some form, ready for future use on demand. The time scale of storage can extend to many years if needed. The battery is an electrochemical energy storage device.
- E-nose: See electrochemical nose.
- Equalization: The process by which all cells of a multi-cell rechargeable battery are brought to the same state of charge.
- Equalizing charge: Passage of an amount of charge by which the undercharged cells of a battery are brought up to a fully charged condition without damaging those already fully charged.

- Equilibrium: An electrode or an electrochemical cell is said to be in "equilibrium" when there is no net current flowing and there are no net electrode reactions taking place in the system. (See, however, exchange current density.) In equilibrium, the potential of the electrodes is the equilibrium potential and the cell voltage is the electromotive force.
- Equilibrium cell voltage: See electromotive force.
- Equilibrium electrode potential: The electrical potential of an electrode measured against a reference electrode when there is no current flowing trough the electrode. In other words, the electromotive force of an electrochemical cell consisting of the electrode in question and a reference electrode. Also called: "open circuit potential (ocp)." See also

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equilibrium and standard electrode potential. The concept of equilibrium potential is probably easiest to demonstrate with a simple metal/metal-ion electrode system. When a metal (e.g., silver) is immersed in a solution containing its ion (e.g., silver nitrate solution) metal ions will cross the metal/solution interface. They will pass from the phase where the "chemical energy" of the ion is large to the phase where the "chemical energy" of the ion is smaller. Depending on the system, this can occur in either direction. However only the positively charged (e.g., silver) cations can pass through the interface. The negatively charged electrons cannot pass into the solution, and the anions (e.g., nitrate) cannot pass into the metal. Consequently, charge accumulation occurs at the interface forming an electrical double layer. Consider an example when the metal ions move preferentially from the metal into the solution: the metal surface becomes negatively charged because of the accumulation of the electrons left behind, while the solution layer near the metal surface becomes positively charged because of the accumulation of silver ions. This process produces a potential difference between the two phases that will slow and eventually stop the passage of the metal ions. At "equilibrium" the chemical driving force and the opposing electrical force are equal. The potential difference between the metal and the solution phases under these conditions is the "equilibrium potential difference." This potential difference cannot be measured because there is no way to make an electrical connection to the solution phase without setting up another electrode potential. Consequently, electrode potentials are always measured against a reference electrode whose potential is known on an arbitrary scale. See standard hydrogen electrode.

- Equilibrium potential: See equilibrium electrode potential.
- Equilibrium voltage: See electromotive force.
- Equivalent circuit: An electrical circuit (usually comprised of series and parallel coupled resistors and capacitors) that models the fundamental properties and behavior of electrodes or electrochemical cells.
- Equivalent weight: A characteristic weight of a substance relating to a specific reaction the substance participates. In

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electrochemical reactions, the molecular weight or atomic weight divided by the number of electrons transferred during the reaction. Consequently, the equivalent weight of a substance can be different for different reactions. E.g. the equivalent weight of the cuprous ion (singly charged copper ion) is equal to its atomic weight, independently whether it is oxidized to cupric ion (doubly charged copper ion) or it is reduced to (electrically neutral) copper metal. On the other hand, the equivalent weight of the cupric ion is one half of its atomic weight if it is reduced to copper metal, but it is the atomic weight if it is reduced only to cuprous ion. In a wider sense, the molecular weight or the atomic weight divided by the valence change occurring during the reaction. For acid/base reactions, the molecular weight divided by the number of hydrogen ions produced or consumed during the reaction.

- Exchange current density: At the equilibrium potential there is no net current flowing through the electrode. However, the equilibrium is a dynamic one, that is, the electrode reaction proceeds at "equal rates" both in the forward and in the reverse direction, resulting in a zero "net" reaction rate and a zero "net" current. The rate of the electrode reaction can be expressed as an equivalent current density and the "exchange current density" of a reaction is the current density flowing "equally" in both directions in equilibrium. A large exchange current density indicates a fast reaction (see also non-polarizable electrode), while a small exchange current density indicates a slow reaction (see also polarizable electrode)
- Expander: A substance added in small amount to the active materials of a lead-acid battery to improve the service life and capacity of the electrodes. In particular, an expander prevents the increase in crystal grain size of lead in the negative electrode.

- External electrolyte: The electrolyte solution in the electrochemical cell into which the reference electrode is immersed. Contrast with the internal electrolyte of the reference electrode.

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Electrochemistry Dictionary - F

- F: Symbol and abbreviation of farad, and symbol and abbreviation of the Faraday number. (Often a "bold-face" letter is used for the latter, but this is not a general practice.) It is usually obvious from the context which meaning is appropriate.
- Failure: The state in which the performance of a cell or battery does not meet the normal specifications.

- farad: Measurement unit of capacitance. Symbol: "F," which is the same as the symbol of the Faraday Number. It is usually obvious from the context which meaning is appropriate. A capacitor has a capacitance of one farad when one coulomb charges it to one volt.
- Faraday shield (cage): a network of parallel wires connected to a common conductor at one end to provide electrostatic shielding without affecting electromagnetic waves. The common conductor is usually grounded.
- Faraday's Laws: Some of the most fundamental laws of electrochemistry discovered by Faraday in the 1830's. They are usually stated as: (1) In any electrolytic process the amount of chemical change produced is proportional of the total amount of electrical charge passed through the cell. (2) The mass of the chemicals changed is proportional to the chemicals' equivalent weight. The proportionality constant being the Faraday Number.
- Faraday Number (Faraday constant): The Faraday Number (or constant) gives the amount of electrical charge needed to change one gram-equivalent of substance by electrochemical reaction. Its value is 96,485.34 coulombs or 26.80 ampere-hours. This charge is often simply called one "Faraday." Symbol: "F," which is the same as the symbol of the farad. It is usually obvious from the context which meaning is appropriate. The Faraday number is the product of Avogadro's number and the electrical charge of a single electron.
- Faradic current (density): The current (or current density) that is flowing through an electrochemical cell and is causing

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(or is caused by) chemical reactions (charge transfer) occurring at the electrode surfaces. Contrast with capacitive current.

- Faradaic reaction: See heterogeneous charge-transfer reaction.
- Filling solution: See internal electrolyte.
- First kind electrode: See electrode of the first kind.
- Fixed ion: The permanently attached charged fragment in an ion-exchange resin. Contrast with counterion.
- Flade potential: Alternative name for the passivation potential.

- Flat-plate array: A photovoltaic array in which the incident solar radiation strikes a flat surface and no concentration of sunlight is involved.
- Float charging: A method of maintaining a rechargeable battery in a fully charged condition by continuous, long-term, constant-voltage charging, at a level sufficient to balance self-discharge. See also trickle charging.
- Float voltage: The voltage required for retaining a rechargeable battery in fully charged condition. See float charging.
- Flow-through electrode: An electrode that permits the electrolyte to flow through it, e.g., a porous electrode or a packed-bed electrode. This type of electrode is especially useful for removing small traces of impurities from the solution by electrolysis (e.g., waste treatment) because the solution contacts a large surface of the electrode material.
- Fluidized bed electrode: See packed bed electrode.
- Formal electrode potential: Similar to a standard electrode potential except that both the oxidized and the reduced species are present in unit concentration instead of unit activity. It is not as well defined as the standard potential but it is useful in cases when the activities are unknown.
- Forming: Electrochemical processing of a rechargeable battery by repeated charging/discharging that converts the electrode materials into usable form. This treatment is needed for some batteries during manufacturing, or when first put into use (and sometime when returned to service after a long storage). Also called "conditioning."

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- Formula weight: Essentially the same as the molecular weight, but it can be used more generally, e.g., also for ions.

- Fresnel lens: A concentrating lens, positioned above and concave to a PV material to concentrate light on the material.
- Fuel cell: A device that converts chemical energy into electrical energy. It is different from a battery in that the energy conversion continues till fuel and oxidizing agent are fed to the fuel cell; that is, in principle indefinitely. (A battery is manufactured with a limited amount of chemicals, and it is exhausted when all the chemicals have reacted.) It is a galvanic cell, where spontaneous chemical reactions occur at the electrodes. The fuel is oxidized at the anode, and the oxidizing agent (almost always oxygen or air) is reduced at the cathode. Presently, the most commonly used fuel is hydrogen. More conventional fuels (e.g., gasoline or natural gas) must be converted ("reformed") into hydrogen before they can be utilized in a fuel cell. Fuel cells that can burn hydrocarbon fuels directly are in the development stage. Some fuel cells employ an aqueous solution as electrolyte, that can be either acidic or basic (alkaline), or an ion-exchange membrane soaked in aqueous solution can act as the electrolyte (see PEM) these fuel cells operate at relatively low temperatures (from room temperature to not much above the boiling point of water). Some fuel cells employ molten salts (especially carbonates) as electrolytes and have to operate at many hundreds of ^{o}C temperature. Others employ ionically conductive solids as electrolyte and must operate close to 1000 ^{o}C. A single fuel cell has a rather small (typically less then one volt) cell voltage. For practical applications a large number of them are assembled, series coupled, in what is called a "fuel cell stack." (A term essentially analogous to the original meaning of the battery.)
- Fugacity: The expression of "activity" for a component in a mixture of gases. It has the same physical meaning as the activity for a component in a solution.

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Electrochemistry Dictionary - G

- Galvanic cell: An electrochemical cell that converts chemical energy into electrical energy. A cell in which chemical reactions occur spontaneously at the electrodes when they are connected through an external circuit, producing an electrical current. E.g., in a fuel cell hydrogen is oxidized at the anode by transferring electrons to the anode and the oxygen is reduced at the cathode by accepting electrons from the cathode. During this process the electrons are carried from the anode to the cathode through an outside electrical circuit where the electrical current can drive a motor, light a light bulb, etc. In contrast, in an electrolytic cell electrical power must be supplied to force the non-spontaneous reverse reaction, the electrolysis of water. See also electrochemical reaction, battery, and fuel cell. Also called "voltaic" cell. The free energy change of the overall cell reaction is negative.
- Galvanic series: See electromotive series.
- Galvanizing: Process for coating iron or steel with a thin layer of zinc for corrosion protection. It can be carried out electrochemically by electroplating (called "electrogalvanizing") or by "hot-dip" galvanizing consisting of immersing the substrate into molten zinc.
- Galvanometer: A very sensitive ammeter that can be used to measure currents in the range of one millionth to one billionth of an ampere.
- Galvanoplasty: A somewhat archaic, today very seldom used, term for electroforming.
- Galvanostat: An electronic instrument that controls the current through an electrochemical cell at a preset value, as long as the needed cell voltage and current do not exceed the compliance limits of the galvanostat. Also called "amperostat."
- Galvanostatic technique: An electrochemical measuring technique for electrochemical analysis or for the determination of the kinetics and mechanism of electrode reactions based on the control of the current flowing through the system.
- Gas electrode: Any electrode with one of the reactants or

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products in the gaseous phase. The solution surrounding the electrode is typically saturated with the gas. Essentially a redox electrode with the "dissolved" gas as one of the potential determining species. E.g., the oxidized species for the "chlorine electrode" is the dissolved chlorine gas, while the reduced species is the chloride ion in solution. Under equilibrium conditions, the chemical potential of the gaseous chlorine is the same as that of the dissolved chlorine. This may not be the case when current is flowing through the electrode: during the electrolytic production of chlorine, the solution may become supersaturated in chlorine if the nucleation of the gas bubbles requires considerable activation energy.

- Gassing: Gas evolution which takes place towards the end of the charging of a battery.

- Geometric(al) current density: Current density calculated with the geometric electrode area.
- Geometric(al) electrode area: The surface area of an electrode calculated from its geometrical dimensions. Contrast with true electrode area.
- Glass electrode: A membrane electrode with a thin glass membrane (usually in the form of a bulb at the end of a glass tubing) sensing element. It is most often used as a pH electrode, but some glass compositions can also be sensitive to the concentration of other cations (e.g., sodium).
- Grain boundary: The surface separating two regions of a solid having different crystal orientations.

- Gram-equivalent: An amount of a substance equal in grams to its equivalent weight.
- Gram-atom: A concept similar to gram-mole except it relates to atoms rather than molecules.
- Gram-mole: An amount of a compound equal in grams to its molecular weight. E.g., the molecular weight of water is 18, so 18 grams of water is called a gram-mole of water. This provides an atomistically fundamental unit because one gram-mole of any material will contain the same number of molecules (this is a very large number, called "Avogadro's" number). One gram-mole of hydrogen gas contains the exactly

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same number of molecules as one gram-mole of table salt (sodium chloride), even though the latter is much heavier. The simplified expression of "mole" is often used in place of "gram-mole" and also in place of gram-atom. It is usually obvious from the context which meaning is appropriate. The measurement unit and symbol of the "gram-mole" or "mole" is the "mol".

- Gouy-Chapman model of the double layer: A model of the electrical double layer. According to this model, the excess ions are non-uniformly distributed in the vicinity of the electrode, their concentration is the largest at the surface of the electrode, decreasing non-linearly till they reach bulk concentration. The "thickness" of this so called "diffuse layer" is variable, but it is typically around the order of magnitude of a millionth of a centimeter.
- Gouy-Chapman-Stern model of the double layer: A model of the electrical double layer. The Gouy-Chapman model predicts an unrealistically large surface concentration, because it assumes that the ions are infinitely small and can get infinitely close to the surface of the electrode. The "Stern modification" is essentially a combination of the Helmholtz and Gouy-Chapman models. It assumes a "plane of closest approach" where a portion of the excess ions reside and attaches to this a Gouy-Chapman type "diffuse layer."
- Grid: The lead framework of a lead-acid battery plate which holds the active material in place.
- Grid-connected: An energy producing system connected to the utility transmission grid. (Also called utility interactive.)
- Group: A set of electrodes within a cell which are connected in parallel.

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Electrochemistry Dictionary - H

- **Haber-Luggin capillary:** See Luggin capillary.
- **Half cell:** A somewhat archaic term, indicating a structure that contains an electrode and the surrounding electrolyte. Electrochemical cells are often divided, containing two separate electrolytes (one surrounding each electrode, e.g., the Daniell cell). In these cases the electrode and its electrolyte can be considered "half" of the cell. Commercially available reference electrodes can be considered "half cells."
- **Half-cell reaction:** A not incorrect, but somewhat archaic term for electrode reaction.
- **Half reaction:** See electrode reaction.
- **Hanging-mercury-drop electrode:** A variation of the dropping-mercury electrode, where the mercury is not flowing continuously. A "hanging drop" is formed at the end of the capillary and is used as a working electrode. The advantage of this electrode arrangement is that the droplet can easily be renewed by feeding some mercury if the electrode surface becomes contaminated. Also called "static-mercury-drop electrode." Abbreviated as "hmde."
- **Helmholtz layer:** See the Helmholtz model of the double layer.
- **Helmholtz model of the double layer:** The simplest model of the electrical double layer. The excess ions in the solution side of the double layer line up in one plane ("Helmholtz plane") very close to the electrode surface. In a somewhat more complex model there are two planes of closest approach of the ions. Ions in the "outer Helmholtz plane" are about two solvent-molecule diameters away from the electrode surface because both the ions and the electrode surface are solvated. Ions in the "inner Helmholtz plane" have shed their solvation layer (these are usually the weekly solvated, large anions) and penetrated the solvent layer on the electrode; these, so called contact adsorbed, ions are sitting directly on the electrode surface. The ionic portion of the Helmholtz model is often called the "Helmholtz layer" or "compact layer."
- **Helmholtz plane:** See the Helmholtz model of the double

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layer.

- Henderson equation: An equation that predicts the value of the liquid junction potential for simple cases.
- HER: Stands for hydrogen evolution reaction.
- Heterogeneous charge-transfer reaction: A charge-transfer reaction with the charge transferred across a phase boundary, typically between a solid and a liquid phase. Contrast with homogeneous charge-transfer reaction.
- Hittorf method: An experimental method for the determination of transport numbers. Electrolysis is carried out in a three-compartment cell and the concentration changes occurring in the anode and cathode compartments can be used to calculate the transport numbers. The concentration in the center compartment should remain unchanged.
- HMDE: Stands for hanging-mercury-drop electrode.
- Homogeneous charge-transfer reaction: A charge-transfer reaction with both reactants present in the same phase. Typically both reactants are dissolved species in a solution while the charge is transferred from one to the other. Contrast with heterogeneous charge-transfer reaction.
- Hybrid cell: Electrochemical cell in which one of the two active reagents is in the gas phase and may be supplied from an external source. A hybrid cell occupies an intermediate position between closed cells and fuel cells.
- Hybrid electric vehicle: A vehicle that has more than one type of power supply to support the drive: e.g. Battery/motor plus fossil fuel/internal combustion engine.
- Hybrid system: A power system consisting of two or more power generating subsystems (e.g., the combination of a wind turbine and a photovoltaic system).
- Hydration: Solvation occurring in an aqueous solution.
- Hydration number: The number of water molecules associated with an ion in the process of solvation in aqueous solutions.
- Hydrodynamic boundary layer: A thin immobile layer of fluid that always exists at a solid/moving-fluid interface. Whether the movement of the fluid is due to "forced" or "natural" convection, a thin layer of fluid will always remain completely

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immobile at the surface of the solid due to the solid-liquid interactive forces.

- Hydrodynamic voltammetry: Voltammetry under conditions of convective mass transport to/from the surface of the working electrode.
- Hydrogen economy: A proposed, new energy distribution system based on hydrogen gas as the energy carrier and hopefully on a renewable energy supply. Hydrogen could be generated (using e.g., solar energy) in a variety of ways, one of them being water electrolysis. Hydrogen would be distributed to the end users through a system similar to today's gas pipelines. The hydrogen could be used either by burning to generate heat or by fuel cells to generate electricity.
- Hydrogen electrode: A redox electrode with dissolved hydrogen gas being the reduced species and hydrogen ions the oxidized species. Hydrogen gas (or a gas mixture containing hydrogen) is bubbled through the electrolyte to keep a desired dissolved hydrogen content. The inert metallic electrode is usually platinized platinum. The equilibrium potential of this electrode depends on the concentration (strictly speaking, activity) of both the hydrogen ions and the dissolved hydrogen gas (controlled by the hydrogen gas pressure), see Nernst equation. The electrode can be used as a measuring electrode in a sensor to determine the hydrogen ion concentration (pH), or it can be used as a reference electrode if all the concentrations are known and constant. It is used equally often for both purposes. It is also the most fundamental reference electrode as the standard hydrogen electrode. See also the dynamic hydrogen electrode and the reversible hydrogen electrode.
- Hydrogen evolution reaction: An electrode reaction in which hydrogen gas is produced at the cathode of an electrolytic cell by the reduction of hydrogen ions or the reduction of the water molecules of an aqueous solution. Abbreviated as "her." See also water electrolysis.
- Hydrogen production: See water electrolysis.
- Hydrogen scale of electrode potentials: See standard hydrogen electrode.
- Hydrolysis: A chemical reaction in which water reacts with

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another substance and gives decomposition or other products, often a reaction of water with a salt to create an acid or a base.

- Hydrous: A substance that contains water. The opposite of anhydrous.
- Hypochlorite production: See brine electrolysis.

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Electrochemistry Dictionary - I

- Ideal non-polarizable electrode: An electrode that is practically not polarizable. That is, the potential of the electrode will not change from its equilibrium potential with the application of even a large current density. The reason for this behavior is that the electrode reaction is extremely fast (has an almost infinite exchange current density). Also called "ideal depolarized electrode." Contrast with ideal polarizable electrode.
- Ideal polarized (polarizable) electrode: An electrode is called "ideal polarizable" if no electrode reactions can occur within a fairly wide electrode potential range. Consequently, the electrode behaves like a capacitor and only capacitive current (no faradaic current) is flowing upon a change of potential. Many electrodes can behave as an ideal polarized electrode but only within an electrode potential range called the "double-layer range." Also called "completely-polarizable electrode" and "totally-polarized electrode." Contrast with ideal non-polarizable electrode.
- IHP: Stands for "inner Helmholtz plane." See the Helmholtz model of the double layer.
- Ilkovic equation: A relation between diffusion limited current density and time in a polarograhic experiment. The diffusion current density is proportional to the growth-time of the mercury drop on the one-sixth power, and to the mass-flowrate of the mercury on the two-third power. The proportionality constant contains the product of the concentration of the reactant and the square root of the diffusion coefficient of the reactant.
- Immobilized electrolyte: See dry cell.

- Impedance: Impedance is the analogue of the resistance or resistivity when applied to alternating current. That is, it is a measure of a material's inability to carry the electrical current. In many materials, the impedance varies as the frequency of the applied electrical potential changes, due to the properties of the liquid or solid. In electrochemistry, the

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impedance of the electrode reaction is also frequency dependent.

- Indicator electrode: See working electrode.
- Indifferent electrolyte: See supporting electrolyte.
- Indirect electrolysis: The production of chemicals in an electrolytic cell through intermediate electrolysis products. It is often used in the oxidation/reduction of organic compounds that would otherwise react very slowly at the electrode surface. An intermediate oxidizing/reducing agent is produced at the electrode surface and the agent reacts with the organic in the bulk solution. The agent is continuously regenerated by the electrolysis. A typical oxidizing agent is the ferric (trivalent iron) ion, and an example of the reducing agent is the cerous (trivalent cerium) ion. The reactive intermediate is often called a "mediator," and the overall reaction a "mediated reaction."
- Indirect electrosynthesis: See indirect electrolysis.
- Inert electrode: An electrode that serves only as a source or sink for electrons without playing a chemical role in the electrode reaction. Noble metals, mercury, and carbon are typically used as inert electrodes. See for example the redox electrode. The "inert" nature of the electrode can sometimes be questioned. While the electrode may not take part in the reaction as a reactant or product, it still can act as an electrocatalyst.
- Inert electrolyte: See supporting electrolyte.
- Inhibitor: A substance added to the electrolyte which prevents an electrochemical process, generally by modifying the surface state of an electrode. A well known example is that of corrosion inhibitors which prevent metal corrosion.

- Initial drain: Current that a cell or battery supplies when first placed on a fixed load.

- Inner Helmholtz plane: See the Helmholtz model of the double layer. Abbreviated as "IHP."
- Inner-sphere charge-transfer reaction: A charge-transfer reaction with the reactants in direct contact with each other, without any intervening solvent molecules. Note that a

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"reactant" can also be an electrode. Contrast with outer-sphere charge-transfer reaction.

- Insulator (electrical): A material that will not carry any electrical current. It has zero conductivity and infinite resistivity.
- Interconnect: An electrically conductive structural part that connects series-connected cells in a fuel cell stack.
- Intermediate: A molecular or ionic species that is formed (directly or indirectly) from the reactants and reacts further (directly or indirectly) to form the products of the reaction. It does not accumulate during the course of the reaction.
- Internal electrolyte: The electrolyte solution inside a reference electrode assembly such as the silver/silver-chloride electrode. (Also called "filling solution.") Internal electrolytes are used also in membrane electrodes. Contrast with external electrolyte.
- Internal reference electrode: A reference electrode used inside a membrane electrode assembly as an electrical contact, with stable potential, to the internal electrolyte.
- Internal resistance: Resistance to the flow of direct current within a cell, causing a drop in closed circuit voltage proportional to the current drain from the cell.

- Ion: An electrically charged chemical particle (atom, molecule, or molecule fragment). "Anions" are negatively charged, and "cations" are positively charged.
- Ion-exchange membrane: A plastic sheet formed from ion-exchange resin. The utility of such membranes is based on their property that they are permeable preferentially only to either positive ions (cation-exchange membrane) or to negative ions (anion-exchange membrane).
- Ion-exchange resin: A polymeric resin that contains electrically charged fragments ("fixed ions") permanently attached to the polymer backbone, electrical neutrality is achieved by attached mobile "counterions" in the solution phase the resin is immersed into. A practical use of such resin is the removal of unwanted ions from a solution by replacing them with other ions. E.g., a cation exchange resin containing fixed negative charges with attached mobile sodium ions can

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be used to remove "hardness" from water if the calcium and magnesium ions are more strongly attracted to the resin and therefore will replace the sodium ions. Eventually all the sodium ions will go into solution and the ion-exchange process terminates. The resin can be regenerated by soaking in a high concentration sodium salt solution. Such process can also be used to remove unwanted ions from polluted water streams.

- Ionic conductor: A material that conducts electricity with ions as charge carriers. See also electrolyte.
- Ionic liquid: A liquid containing mostly ions, a molten salt in which the molecules are fully (or almost fully) dissociated. Contrast with electrolyte solution in which the dissociated salt is dissolved in a solvent, with the solvent not (or only slightly) dissociated. Corresponding examples are molten sodium chloride (table salt) and aqueous solution of sodium chloride.
- Ionic mobility: A quantitative measure of an ion's ability to move under the influence of a potential difference in solution. (See also electromigration.) It is the speed of movement under the influence of unit potential difference. While the mobility is defined in terms electromigration, it also affects the speed of diffusion.
- Ionics: Part (sub-discipline) of electrochemistry that deals with the behavior of ions in liquid solutions, ionic liquids, and solids ("solid-state ionics"). See also electrodics.
- Ion-selective membrane: See ion-exchange membrane.
- Ion-selective electrode: An electrode or electrode assembly with a potential that is dependent on the concentration of an ionic species in the test solution and is used for electroanalysis. Ion-selective electrodes are often membrane type electrodes. Abbreviated as "ISE."
- Ion-sensing electrode: See ion-selective electrode.
- ir (drop) compensation: Some potentiostats are equipped with an optional ir compensation. The potentiostat electronically corrects for the solution ir drop and the potential of the working electrode is controlled (at least in principle) at the correct value. Unfortunately, most potentiostats become unstable at full compensation, so one can only make a partial compensation, resulting in an uncompensated ir drop and an error in the potential control. The user must provide the

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solution resistance value, though some potentiostat setups will measure it automatically. Contrast with ir (drop) correction.

- ir (drop) correction: A numerical correction of measured potential of the working electrode for the solution ir drop. (One must know the value of the current and the value of the resistance of the electrolyte between the working and the reference electrodes.) It cannot be simply stated whether this correction is positive or negative because of the contradictory conventions used for the anodic and cathodic currents. In either case, the absolute value of the corrected potential must be smaller than that of the uncorrected potential. Contrast with ir (drop) compensation.
- ir drop: The electrical potential difference between the two ends of a conducting phase during a current flow. It is the product of the current (i) and the resistance (r) of the conductor. In electrochemistry, it refers to the solution ir drop, or to the ohmic loss in an electrochemical cell. See also Ohm's law.
- ir loss, ir drop: Decrease in the voltage of a cell during the passage of current due to the internal resistance of the bulk phases within the cell mainly that of the electrolyte and the separators. Also known as 'ohmic loss'.

- Irreversible electrode: An electrode with an irreversible electrode reaction.
- Irreversible electrode reaction: A qualitative term for a slow electrode reaction. An electrode reaction having a small exchange current density. Opposite: reversible electrode reaction. See also quasi-reversible electrode reaction.
- ISE: Stands for ion-selective electrode.
- Isoelectric focusing: A variation of the electrophoretic separation technique. The separation of molecules occurs in a combination of potential an pH gradients resulting in sharper separations compared to simple electrophoresis.

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Electrochemistry Dictionary - J

- **Junk batteries:** This term usually refers to spent automotive lead-acid batteries, which are purchased by secondary lead smelters. The standard form of shipment is in the whole and undrained state to meet environmental regulations. Lead metal constitutes around half the weight of a junk battery. Other parts, including the plastic case, also are recycled.

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Electrochemistry Dictionary - K

- k: The letter "k" when used as a prefix before a unit symbol indicates a multiplier of 10^3. Symbol of "kilo". E.g., kΩ = 10^3 ohm, one kiloohm, one thousand ohms. (The symbol is the letter "k" followed by the "Greek capital omega" letter, some browsers unfortunately do not support this.)
- kilo: When used as a prefix before a unit name it indicates a multiplier of 10^3. E.g., kiloohm = 10^3 ohm, one thousand ohms. Symbol: "k".
- kiloohm: 10^3 ohm, symbol: "kΩ" (one thousand ohms). (The symbol is the letter "k" followed by the "Greek capital omega" letter, some browsers unfortunately do not support this.)
- Kilowatt-hour (kWh): energy unit defined as 1,000 watts of electricity for one hour (equivalent to 3,413 Btu).
- Kinetics: Chemical kinetics is a scientific discipline dedicated to the study of the rates of chemical reactions. How fast is a reaction proceeding in time, and what is affecting the rate.
- kΩ: Symbol and abbreviation of kiloohm (= 10^3 ohm, one thousand ohms). (The symbol is the letter "k" followed by the "Greek capital omega" letter, some browsers unfortunately do not support this.)

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Electrochemistry Dictionary - L

- **Lead-acid battery:** A rechargeable battery. During discharging, the reaction on the positive electrode is the conversion of lead dioxide to lead sulfate, while on the negative electrode it is the conversion of metallic lead to lead sulfate. The reactions are reversed during charging. The current collector can be lead in both electrodes. The electrolyte is sulfuric acid. While it is one of the earliest practical storage batteries (1866), it is still very widely used today, e.g. as automobile starter battery.
- **Leakage current:** See current leakage.
- **Leclanche cell (battery):** One of the earliest practical non-rechargeable batteries (Georges-Lionel Leclanche). It uses a zinc anode (negative electrode) and a manganese dioxide cathode (positive electrode) with ammonium chloride solution as electrolyte. The initially liquid electrolyte was later "immobilized," and this system became the first dry cell. It is still widely used.
- **Leveling agent, leveler:** Small amounts of (usually organic) compounds added to an electroplating solution that changes the mechanism of the plating to produce a metal deposit smoother than the original substrate.
- **Limiting current density:** The maximum current density that can be achieved for an electrode reaction at a given concentration of the reactant in the presence of a large excess of supporting electrolyte. The mass transport occurs exclusively through diffusion in the diffusion layer, driven by the concentration difference of the reactant between the edge of the diffusion layer and the electrode surface. As the current density is increased (usually by changing the electrode potential), the surface concentration of the reactant must decrease so that the concentration difference driving the diffusion can increase and provide the required flux of the reactant. However, the surface concentration obviously cannot decrease below zero, thereby a situation is reached when further change of the electrode potential cannot increase the reactant flux, and correspondingly the current density. The

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concept of "limiting current density" is valid even in the absence of supporting electrolyte. However, the situation is more complex in this case because electromigrational effects must also be taken into consideration.

- Linear-sweep voltammetry: See voltammetry.
- Liquid-junction potential: A potential difference between two solutions of different compositions separated by a membrane type separator. The simplest example is the case of two solutions containing the same salt in different concentrations. The salt will diffuse from the higher concentration side to the lower concentration side. However, the diffusion rate of the cation and the anion of the salt will very seldom be exactly the same (see mobility). Let us assume for this example that the cations move faster; consequently, an excess positive charge will accumulate on the low concentration side, while an excess negative charge will accumulate on the high concentration side of the junction due to the slow moving anions. This sets up a potential difference that will start an electromigration of the ions that will increase the net flux of the anions and decrease the net flux of the cations. In steady-sate conditions, the two ions will move at the same speed and a potential difference will be created between the two solutions. This "steady-sate" potential difference seems constant, but this is misleading because it slowly changes as the concentrations between the two solutions equalize. The diffusion process will "eventually" result in equal concentrations of the salt in the two solutions separated by the membrane, and the liquid-junction potential will vanish. For a simple case, the value of the liquid junction potential can be calculated by the so called "Henderson" equation.
- Load: A device that consumes electrical power, e.g. a motor or a light bulb.
- Local cell: See corrosion.
- LSV: Stands for "linear-sweep voltammetry," see voltammetry.
- Luggin probe or Luggin-Haber capillary: a device used in measuring the potential of an electrode with a significant current density imposed on its surface. (The probe minimizes the IR drop that would otherwise be included in the measurement and without significantly disturbing the current

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distribution on the specimen. A salt bridge with a thin, capillary tip at one end. This can be useful for minimizing the solution ir drop by placing the fine capillary tip very close to the surface of the working electrode, when the salt bridge is used to connect the working and reference electrode compartments of a three-electrode cell. The solution distance causing the ir drop can be easily limited to a few millimeters; and, in specially designed cells, often to a much smaller distance.

- LV: Stands for "linear-sweep voltammetry," see voltammetry

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Electrochemistry Dictionary - M

- m: The letter "m" when used as a prefix before a unit symbol indicates a multiplier of 10^{-3}. Symbol of "milli". E.g., mV = 10^{-3} volt, one millivolt, one thousandth of a volt.
- M: The letter "M" when used as a prefix before a unit symbol indicates a multiplier of 10^{6}. Abbreviation of "meg" or "mega". E.g., MΩ = 10^{6} ohm, one megohm, one million ohms. (The symbol is the letter "M" followed by the "Greek capital omega" letter, some browsers unfortunately do not support this.)
- μ: The letter "μ" when used as a prefix before a unit symbol indicates a multiplier of 10^{-6}. Abbreviation of "micro". E.g., μV = 10^{-6} volt, one microvolt, one millionth of a volt.
- mA: Symbol and abbreviation of milliampere (= 10^{-3} ampere, one thousandth of an ampere).
- μA: Symbol and abbreviation of microampere (= 10^{-6} ampere, one millionth of an ampere).
- Magnetoelectrochemistry: Electrochemical phenomena occurring under the influence of magnetic field.
- Maintenance: The procedures which are required in order to keep a battery in proper operating conditions. They may include trickle-charging to compensate for self-discharge, addition of water to the electrolyte, etc.

- Maintenance-free battery: A rechargeable battery which does not require periodic "topping up" (addition of water) to maintain electrolyte volume. See also sealed battery.
- Mass transport: The phenomenon of movement (transportation) of mass (e.g., chemical compounds, ions) from one part of the system to another. Most of the time this occurs through diffusion and convection. Under special circumstances it can also occur through electromigration since the movement of the electrically charged ions also carries mass with them (e.g., ionic current through an ion-exchange membrane. The mass transport and the charge transport are typically "decoupled" in electrochemistry; that is, the reacting species

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and the charge carrying species are not necessarily identical. E.g., one would intuitively assume that during electroplating of copper from a solution of copper sulfate all the mass and charge required for the electrode reaction at the cathode would be carried by the copper cations in the solution. That is not the case at all. In the presence of a large excess of supporting electrolyte, all the current is carried by electromigration of the ions of the supporting electrolyte (both in the bulk solution and in the diffusion layer) while all the mass is carried by the copper ions by convection in the bulk solution and by diffusion in the diffusion layer. In the absence of any supporting electrolyte, all the mass is still carried by the copper ions, while the current is divided between the copper cations and the sulfate anions according to the ratio of their transport numbers (both in the bulk electrolyte and in the diffusion layer). The situation is maybe more self-explanatory in the case of an electrically neutral molecule reactant that cannot carry any current.

- Mass-transport overpotential (polarization): See concentration overpotential.
- Measuring electrode: See working electrode.
- Mediated reaction: See indirect electrolysis.
- Mediator: See indirect electrolysis.
- Meg or mega: When used as a prefix before a unit name it indicates a multiplier of 10^6. E.g., megohm = 10^6 ohm, one million ohms. Symbol: "M".
- Megohm: 10^6 ohm, symbol: "MΩ" (one million ohms). (The symbol is the letter "M" followed by the "Greek capital omega" letter, some browsers unfortunately do not support this.)
- Membrane: See separator.
- Membrane electrode: An ion-selective electrode assembly terminating in an ion permeable (e.g., ion-exchange) membrane sensing element. The membrane separates the internal filling solution (that contains a fixed concentration of the ion to be detected) and the test solution. The potential across the membrane depends on the concentration ratio of the ion in the two solutions. The assembly also contains an internal reference electrode immersed in the filling solution,

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serving as an electrical contact with a stable potential. The potential of this assembly is then measured against an external reference electrode immersed in the test solution. See also Donnan potential.

- Membrane potential: See Donnan potential.
- Metal deposition/dissolution: A class of electrode reactions involving oxidation/reduction of a solid metal and its dissolved ion, e.g., if a copper metal rod is immersed in a copper sulfate solution, the copper cations can be cathodically reduced to copper metal, or the copper metal can be anodically oxidized to copper ions. Compare with a redox reaction where both the oxidized and the reduced species are in solution. The terms "electrodeposition" and "electrodissolution" are often used to describe these reactions. These reactions are used in many technologies, such as electroplating, electrowinning, and electrorefining. And also in electrogravimetry.
- Metal displacement reaction: See cementation.
- Metal plating: See electroplating.
- Metal refining: See electrorefining.
- mho: Alternative name of siemens.
- micro: When used as a prefix before a unit name it indicates a multiplier of 10^{-6}. E.g., microvolt = 10^{-6} volt, one millionth of a volt. Symbol: "μ".
- microampere: 10^{-6} ampere, symbol: "μA" (one millionth of an ampere).
- microelectrode: A small electrode, with dimensions not larger than a few millimeters, and typically with dimensions of a small fraction of a millimeter.
- microvolt: 10^{-6} volt, symbol: "μV" (one millionth of a volt).
- Migration: See electromigration.
- milli: When used as a prefix before a unit name it indicates a multiplier of 10^{-3}. E.g., millivolt = 10^{-3} volt, one thousandth of a volt. Symbol: "m".
- milliampere: 10^{-3} ampere, symbol: "mA" (one thousandth of an ampere).
- millivolt: 10^{-3} volt, symbol: "mV" (one thousandth of a volt).
- Mixed potential: The electrode potential when two electrode

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reactions occur on the same electrode surface. The mixed potential has a value in between the equilibrium potentials of the two electrode reactions. The mixed potential is a steady-state phenomena, with the corrosion potential being a good example.

- **MΩ:** Symbol and abbreviation of megohm (= 106 ohm, one million ohms). (The symbol is the letter "M" followed by the "Greek capital omega" letter, some browsers unfortunately do not support this.)
- **Mobility, ionic:** See ionic mobility.
- **mol:** The measurement unit and symbol of mole.
- **mole:** See gram-mole.
- **Molar concentration:** See concentration.
- **Molarity:** See concentration.
- **Molecular weight:** The weight of a molecule of a compound that may be calculated as the sum of the atomic weights of its constituent atoms.
- **Molecule:** The smallest physical unit of a substance that retains all the physical and chemical properties of that substance. It may consist of a single atom or of a group of atoms bonded together chemically.
- **Molten-carbonate fuel cell:** A fuel cell that employs a molten, ionically conductive salt (carbonate) as electrolyte. Due to the high melting point of these salts, these fuel cells must operate at high temperatures.
- **Multimeter:** Instrument that can be used for the measurement of more than one parameter. Typically, it can be used to measure current, potential, and resistance.
- **mV:** Symbol and abbreviation of millivolt (= 10-3 volt, one thousandth of a volt).
- **μV:** Symbol and abbreviation of microvolt (= 10-6 volt, one millionth of a volt).

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Electrochemistry Dictionary - N

- n: The letter "n" when used as a prefix before a unit symbol indicates a multiplier of 10-9. Abbreviation of "nano". E.g., nV = 10-9 volt, one nanovolt, one billionth of a volt.
- nA: Symbol and abbreviation of nanoampere (= 10-9 ampere, one billionth of an ampere).
- nano: When used as a prefix before a unit name it indicates a multiplier of 10-9. E.g., nanovolt = 10-9 volt, one billionth of a volt. Symbol: "n".
- nanoampere: 10^{-9} ampere, symbol: "nA" (one billionth of an ampere).
- Nanometer: abbreviated "nm", a unit of length equal to one thousandth of a micrometer.
- nanovolt: 10^{-9} volt, symbol: "nV" (one billionth of a volt).
- Negative: Negatively charged electrode, usually of a secondary cell; acts as anode during discharge and cathode during charge.

- Nernst equation: An equation defining the equilibrium potential of an electrode. The potential is the sum of the standard electrode potential and a correction term for the deviation from unit concentrations of the reactant and the product of the electrode reaction in the solution; if the "reduced" form is a metal, a pure metal (not alloyed with other metals) is considered to be at unit concentration. The correction term is the product of the "Nernst slope" and the logarithm of the ratio of the concentrations (strictly speaking, activities) of the oxidized species and the reduced species. At room temperature, the Nernst slope is 0.05916 volt divided by the number of electrons transferred during the reaction. E.g., for a simple metal deposition/dissolution reaction the slope is 0.05916 for a single charged metal cation, 0.00296 volt for a double charged ion, etc.
- Nernst slope: See Nernst equation. It is equal to the change of equilibrium electrode potential when the concentration (strictly speaking, activity) of a species involved in the electrode reaction changes by ten fold.

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- Nernstian behavior: An electrode is said to behave "nernstially" if the equilibrium electrode potential obeys the Nernst equation when the concentration (strictly speaking, activity) of a species involved in the electrode reaction changes. Opposite: non-nernstian behavior.
- Nernstian (or Nernst's) hypothesis: See diffusion layer.
- Nernstian reaction: See reversible electrode reaction.
- Neutralization: (1) The reaction of an acid and a base to form a "neutral" (pH = 7) solution. (2) The removal of electrical charge to produce a "neutral" (electrically uncharged) particle or object.
- Neutron: See atomic structure.
- NHE: Stands for "normal hydrogen electrode," which is an alternative name for the standard hydrogen electrode.
- Noble metal: A metal that resists oxidation (corrosion) in air, and therefore retains its metallic luster. Examples are platinum and gold. These metals have high positive standard electrode potentials and are the lowest ones on the electromotive series. Contrast with active metal.
- Non-aqueous solution: A solution with the solvent anything but water (e.g., organic or inorganic liquid, molten salt).
- Non-faradaic current (density): See capacitive current (density).
- Non-nernstian behavior: An electrode is said to behave "non-nernstially" if the equilibrium electrode potential does not obey the Nernst equation when the concentration (strictly speaking, activity) of a species involved in the electrode reaction changes. Opposite: nernstian behavior.
- Non-ohmic resistance (behavior): A system or system element is behaving "non-ohmically" if it does not follow Ohm's law. That is, the value of the resistance depends on the current or the potential. Opposite: ohmic behavior. The resistance can be formally defined as the differential of the potential with respect of the current. In the case of Ohm's law, this is the constant value of the resistance. In electrochemistry, a typical "non-ohmic" element is the charge-transfer resistance. The charge-transfer reaction can be considered a circuit element because it requires a certain amount of overpotential to force through a current. However, the pertinent relation here is the

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Tafel law (at least at relatively large overpotentials), and the differential of the current (that is the resistance) is a function of the current itself.

- Non-polarizable electrode: An electrode that is not easily polarizable. That is, the potential of the electrode will not change significantly from its equilibrium potential with the application of even a large current density. The reason for this behavior is that the electrode reaction is inherently fast (has a large exchange current density). See also overpotential. Opposite: polarizable electrode.
- Non-rechargeable battery: A battery in which the chemical reaction system providing the electrical current is not easily "chemically" reversible. It provides current until all the chemicals placed in it during manufacture are used up. It is discarded after a single discharge. Also called "primary" battery or cell. Contrast with rechargeable battery. This battery always operates as a galvanic cell. Consequently, the anode is the negative electrode, while the cathode is the positive electrode.
- Normal electrode potential: Alternative name for standard electrode potential.
- Normal hydrogen electrode: Alternative name for standard hydrogen electrode. Abbreviated as "NHE."
- Nucleus: See atomic structure.
- nV: Symbol and abbreviation of nanovolt (= 10-9 volt, one billionth of a volt).

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Electrochemistry Dictionary - O

- **Ω**: Symbol and abbreviation of ohm. (The symbol is the "Greek capital omega" letter, some browsers unfortunately do not support this.)
- OCP: Stands for open-circuit potential. See equilibrium potential.
- OCV: Stands for open circuit voltage.
- OER: Stands for oxygen evolution reaction.
- Ohm: Measurement unit of the electrical resistance. Symbol: "Ω". (The symbol is the "Greek capital omega" letter, some browsers unfortunately do not support this.)
- Ohmic loss: See ir loss.

- Ohmic resistance (behavior): A system or system element is behaving "ohmically" if it follows Ohm's law. That is, the value of the resistance is independent of the current and the potential. Typically, metals and electrolyte solutions are "ohmic." Opposite: non-ohmic behavior.
- Ohm's Law: The relation amongst the current flowing through a resistor and the potential difference between the two ends of the resistor. The potential difference is equal to the product of the current and the resistance (volt = ampere times ohm).
- Ohmic drop: See ir drop.
- Ohmic loss: The total ir drop in an electrochemical cell, including the ir drop in the solution between the electrodes and in any separator.
- Ohmic overpotential (polarization): See solution ir drop and ohmic loss.
- Ohmmeter: Instrument used for the measurement of electrical resistance.
- OHP: Stands for "outer Helmholtz plane." See the Helmholtz model of the double layer.
- One-shot battery: See reserve battery.
- Open-circuit potential: See equilibrium potential. Abbreviated as "ocp."
- Open circuit voltage (OCV): The voltage of a cell or battery

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under no-load condition, measured with a high impedance voltmeter or potentiometer. If the battery has recently been delivering or receiving current, then the voltage will probably be in the process of settling to its eventual equilibrium. This settling process can take hours for some batteries.

- ORP electrode: Stands for oxidation/reduction potential electrode.
- ORR: Stands for oxygen reduction reaction.
- Outer Helmholtz plane: See the Helmholtz model of the double layer. Abbreviated as "OHP."
- Outer-sphere charge-transfer reaction: A charge-transfer reaction with the reactants separated from each other by some solvent molecules due to the solvation of the reactants. Note that a "reactant" can also be an electrode. Contrast with inner-sphere charge-transfer reaction.
- Overall reaction: See cell reaction.
- Overcharge: The continued application of charging current to a cell or battery after it has reached its maximum state of charge.

- Overcharging: During the charging of a rechargeable battery, eventually enough electrical charge is supplied to convert all the active material stored in the electrodes. If charging continues, the battery is said to be "overcharged." It very much depends on the battery system whether overcharging is detrimental to the battery or not.
- Over discharge: Forced discharge of a cell or a battery past 100% of the available capacity. In the case of a multicell battery, the over discharge may cause cell reversal.

- Overpotential: The difference in the electrode potential of an electrode between its equilibrium potential and its operating potential when a current is flowing. The overpotential represents the extra energy needed (an energy loss that appears as heat) to force the electrode reaction to proceed at a required rate (or its equivalent current density). Consequently, the operating potential of an anode is always more positive than its equilibrium potential, while the operating potential of a cathode is always more negative than

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its equilibrium potential. The overpotential increases with increasing current density, see Tafel equation. The value of the overpotential also depends on the "inherent speed" of the electrode reaction: a slow reaction (with small exchange current density) will require a larger overpotential for a given current density than a fast reaction (with large exchange current density). Also referred to as "polarization" of the electrode. See also overvoltage. An electrode reaction always occurs in more than one elementary step, and there is an overpotential associated with each step. Even for the simplest case, the overpotential is the sum of the concentration overpotential and the activation overpotential.

- Overvoltage: The difference between the cell voltage (with a current flowing) and the open-circuit voltage (ocv). The overvoltage represents the extra energy needed (an energy loss that appears as heat) to force the cell reaction to proceed at a required rate. Consequently, the cell voltage of a galvanic cell (e.g., a rechargeable battery during discharging) is always less than its ocv, while the cell voltage of an electrolytic cell (e.g., a rechargeable battery during charging) is always more than its ocv. Occasionally also referred to as "polarization" of the cell. The overvoltage is the sum of the overpotentials of the two electrodes of the cell and the ohmic loss of the cell. Unfortunately, the terms "overvoltage" and "overpotential" are sometimes used interchangeably.
- Oxidant: Alternative expression for oxidizing agent.
- Oxidation: The loss of electrons by a chemical species.

- Oxidation/reduction: In a narrow sense, oxidation means the reaction of a substance with oxygen. Hydrogen can react with oxygen to be oxidized to water. Hydrocarbon fuels (gasoline, natural gas, etc) can react with oxygen to be oxidized to carbon dioxide and water. Iron can react with oxygen to be oxidized to "rust." During oxidation, the oxygen itself is being reduced. Oxidation and reduction always occur simultaneously. During these reactions, electrons are transferred from the substance that is oxidized to the oxygen. In a wider sense, all electron-transfer reactions are considered oxidation/reduction. The substance gaining electrons

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("oxidizing agent" or "oxidant") is oxidizing the substance that is losing electrons ("reducing agent" or "reductant"). In the process, the "oxidizing agent" is itself reduced by the "reducing agent." Consequently, the reduction process is sometimes called "electronation," and the oxidation process is called "de-electronation."

- Oxidation/reduction potential: A measure of the oxidation/reduction capability of a solution. It is a redox potential measured with an inert electrode. An oxidizing solution (e.g., one saturated with oxygen) has a more positive potential than a reducing solution (e.g., one saturated with hydrogen).
- Oxidation/reduction potential electrode: A measuring electrode used for the determination of the oxidation/reduction potential of a solution. Abbreviated as "ORP."
- Oxidizing agent: A substance that is affecting oxidation by accepting electrons from another substance. See oxidation/reduction. Also called "oxidant."
- Oxygen evolution reaction: An electrode reaction in which oxygen gas is produced at the anode of an electrolytic cell by the oxidation of hydroxyl (OH-) ions or the oxidation of the water molecules of an aqueous solution. Abbreviated as "oer." See also water electrolysis. It is the reverse reaction of oxygen reduction.
- Oxygen production: See water electrolysis.
- Oxygen reduction reaction: An electrode reaction in which oxygen gas is reduced at the cathode of an electrochemical cell. The product of the reduction can be hydroxyl (OH-) ions or water molecules (or occasionally hydrogen peroxide molecules). Abbreviated as "orr." It is the reverse reaction of oxygen evolution. It is a very important and much studied electrode reaction because it occurs at the cathode of practically all fuel cells and it occurs at the cathode of many (though not all) corrosion cells.

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Electrochemistry Dictionary - P

- **Packed-bed electrode:** An electrode assembly consisting of loosely packed small particles of the electrode material (e.g., some metal or carbon) with the electrolyte flowing through the bed. This type of electrode is especially useful for removing small traces of impurities from the solution by electrolysis (e.g., waste treatment) because the solution is well stirred and it contacts a large surface of the electrode material.
- **Paint electrodeposition:** See electrophoretic deposition.
- **Parallel connected:** A method of connection in which positive terminals are connected together and negative terminals are connected together. Current output adds and voltage remains the same. (See also series connected.)
- **Parallel-coupled cells:** Individual electrochemical cells can be combined in assemblies by parallel or series coupling (or a combination of the two). In case of "parallel" coupling, the positive electrode of every cell is connected together and the negative electrode of every cell is connected together, resulting in two external terminals. The voltage of every cell must be identical in parallel coupled assemblies. The overall current passing through the assembly is the sum of the individual cell currents, while the assembly voltage is identical to the individual cell voltage. Parallel coupling is often used in batteries. Cell lines and stacks can also be parallel coupled. Contrast with series coupling.
- **Partial current (density):** The two current densities at which the electrode reaction is proceeding in the anodic and cathodic directions at an electrode potential. The actual (net) current density is the algebraic sum of the two partial current densities (one is considered positive the other negative). Electrode reactions are typically "chemically" reversible, that is, they can proceed both in forward and reverse direction. At equilibrium, the reaction is proceeding at equal rate in both directions (see exchange current density): the "anodic partial current density" and the "cathodic partial current density" are equal and the net current density is zero. When the electrode

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is polarized, the partial current densities are unequal and the net current density is not zero. If the electrode is negatively polarized, the cathodic reaction speeds up (compared with its rate at equilibrium), while the anodic reaction slows down and a net cathodic current density results (and vice versa for anodic polarization).

- Partial reaction: See electrode reaction.
- Passivation: The formation of a thin adherent film or layer on the surface of a metal or mineral that acts as a protective coating to protect the underlying surface from further chemical reaction, such as corrosion, electrodissolution, or dissolution. The passive film is very often, though not always, an oxide. A passivated surface is often said to be in a "passive state." The surface oxidation can result from chemical or electrochemical (anodic) oxidation. During anodic passivation, in the current-potential plots, the current, instead of increasing with potential, falls to a very small value. See passivation potential.
- Passivation potential: The most negative electrode potential at which a passivating film is formed electrochemically. It is equal to or more positive than the equilibrium potential of formation of the compound (usually oxide) constituting the passive film. Usually the current goes through a maximum at the passivation potential. Also called the "Flade" potential.
- Passivity: The condition of a metallic material corresponding to an immeasurably small rate of corrosion.

- PEM: Stands for either polymer-electrolyte membrane or proton-exchange membrane.
- Permselectivity: The permeation of certain ions in preference to other ions through an ion-exchange membrane.
- pH: A measure of the acidity/alkalinity (basicity) of a solution. The pH scale extends from 0 to 14 (in aqueous solutions at room temperature). A pH value of 7 indicates a neutral (neither acidic nor basic) solution. A pH value of less than 7 indicates an acidic solution, the acidity increases with decreasing pH value. A pH value of more than 7 indicates a basic solution, the basicity or alkalinity increases with increasing pH value. The pH of a solution is equal to the

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negative, ten-based logarithm of the activity of the hydrogen ions in the solution. Neutral water dissociates into equal amounts of hydrogen (H^+) cations and hydroxyl (OH^-) anions. As the product of the concentrations (activities) of the two ions is always a constant 10-14, water has a pH of 7. In acidic solutions the hydrogen ions are in excess, while in basic solutions the hydroxyl ions are in excess.

- pH buffer: See buffer solution.
- pH electrode: An electrode assembly with a pH dependent potential. A variety of different electrodes can be used for this purpose, the most common one is the glass electrode.
- pH meter: Volt meter that measures the electrical potential difference between a pH electrode and a reference electrode and displays the result in terms of pH value of the sample solution in which they are immersed.
- Photoelectrochemical cell: A galvanic cell in which usable current and voltage are simultaneously produced upon absorption of light by at least one of the electrodes. Also called "photogalvanic cell."
- Photoelectrochemistry: Chemistry resulting from the interaction of light with electrochemical systems. See also photoelectrochemical cell and photoelectrolytic cell.
- Photoelectrolytic cell: An electrolytic cell in which the production of chemicals is caused by or speeded up by the absorption of light by at least one of the electrodes. The process occurring in such cell is called "photoelectrosynthesis."
- Photoelectrosynthesis: Production of chemicals in a photoelectrolytic cell, where the production is caused by or speeded up by the absorption of light by at least one of the electrodes.
- Photogalvanic cell: See photoelectrochemical cell.
- Photovoltaic cell: The semiconductor device that converts light into dc electricity. The building block of photovoltaic modules.
- pH standard: See buffer solution.
- Pickling: Process for removal of oxide scales from metal surfaces in preparation for electroplating. Typically, the metal is immersed in hot, strongly acidic solution that dissolves the oxide scales. The solution usually also contains some corrosion

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inhibitor to avoid dissolution of the metal itself. See also electrolytic pickling.

- Pile: An archaic name for a battery or other series-coupled electrochemical cells. See, e.g. the voltaic pile.
- Plate: In the terminology of secondary batteries, this has the same meaning as 'electrode'.

- Plating: See electroplating.
- Platinized platinum electrode: A platinum metal electrode that is covered with a rough, large surface area platinum coating. The purpose is to produce an electrode with a large true area that will be relatively non polarizable. See also platinum black.
- Platinum black: A rough, large surface area platinum coating usually deposited on a platinum metal electrode. See also platinized platinum electrode.
- Polarizable electrode: An electrode that is easily polarizable. That is, the potential of the electrode will change significantly from its equilibrium potential with the application of even a small current density. The reason for this behavior is that the electrode reaction is inherently slow (has a small exchange current density). See also overpotential and ideal polarized electrode. Opposite: non-polarizable electrode.
- Polarization: The change of potential of an electrode from its equilibrium potential upon the application of a current. See overpotential for a more detailed description. Somewhat confusingly, the term "polarization" is often also used in place of overvoltage. Deviation from equilibrium conditions in an electrode or galvanic cell caused by the passage of current. It is related to the irreversible phenomena at the electrodes (electrode polarization) or in the electrolytic phase (concentration polarization).
- Polarization loss: Reduction in the voltage of a cell delivering current from its equilibrium value. : positive: Positively charged electrode, usually of a secondary cell; acts as cathode during discharge and anode during charge.

- Polarization curve: Alternative name for current-potential plot.

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- Polarogram: The graphical representation of the result of polarography.
- Polarograph: An instrument used in carrying out polarographic analysis.
- Polarography: A classical electroanalytical technique discovered in 1922 by J. Heyrovsky, for which he was awarded the Nobel Prize for Chemistry in 1959. Essentially, it is linear-sweep voltammetry using a dropping-mercury electrode for working electrode and a large mercury pool as counter electrode. See also Ilkovic equation.
- Pole: Alternative name of a terminal.
- Polymer-electrolyte membrane: An ion-exchange membrane that is used both as a "separator" and as the electrolyte in some fuel cells. Abbreviated as "PEM."
- Porous electrode: An electrode consisting of a highly porous solid. This is often used in fuel cells with gaseous reactants. In this case, the charge-transfer reaction proceeds mainly at the triple interface formed by the electrode material, the electrolyte, and the gaseous reactant. The pores of the structure are partly filled by the electrolyte and partly by the gas. A porous electrode provides a much larger area for reaction than a solid electrode with the gas bubbled around it. A porous electrode can also be used as a flow-through electrode.
- Post: See terminal.

- Pot: An alternative name of an industrial electrolytic cell used in aluminum production.
- Potential: See electrical potential.
- Potential of zero charge: The electrode potential where the charge in the electrical double layer is zero. Abbreviated as "pzc."
- Potential-pH diagram: A diagram often used in the field of corrosion to indicate the corrosion tendency and stability of a metal in aqueous solutions. The equilibrium potential of the metal is plotted against the pH of the solution, usually for a series of concentrations of the metal ion. The curves demarcate potential-pH domains where a species of the metal is predominant in equilibrium, this can be the metal, its ion,

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oxide, or hydroxide. In simplified version, the diagram can indicate the potential-pH domains where the metal is immune to corrosion, corrodes, or passivates. The diagrams must be used with some caution because they represent equilibrium conditions and the corrosion tendency is also influenced by kinetic effects. Also called "Pourbaix diagram." See also an Encyclopedia Article.

- Potential-ramp technique: Alternative name for voltammetry.
- Potential-step voltammetry: Alternative name for chronoamperometry.
- Potential-sweep technique: Alternative name for voltammetry.
- Potentiodynamic technique: Alternative name for linear-sweep voltammetry. This expression is primarily used in the field of corrosion.
- Potentiokinetic technique: Alternative name for linear-sweep voltammetry. This expression is primarily used in the field of corrosion.
- Potentiometer: Can be used in more than one meaning: 1. A continuously variable resistor. More precisely, a resistor with continuously variable tap. This can provide three resistance values, a fixed resistance between the two end connectors, and two variable resistances, one between either end connector and the variable tap connector. The sum of the two variable resistances is the fixed resistance. 2. A somewhat archaic measurement system, based on a resistor with a continuously variable tap, that can be used to measure the electromotive force of electrochemical cells that can be easily polarized by current. It uses a comparison technique to compare a "standard" voltage source to the unknown, under conditions of practically zero current. It is seldom used today because high input resistance voltmeters and electrometers are readily available.
- Potentiometry: An electroanalytical technique based on the measurement of the electromotive force of an electrochemical cell comprised of a measuring and a reference electrode. The simplest example of a measuring electrode is a metal electrode whose potential depends on the concentration of the cation of the electrode metal (see Nernst equation).

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- Potentiostat: An electronic instrument that controls the electrical potential between the working and reference electrodes of a three-electrode cell at a preset value. It forces whatever current is necessary to flow between the working and counter electrodes to keep the desired potential, as long as the needed cell voltage and current do not exceed the compliance limits of the potentiostat.
- Potentiostatic technique: An electrochemical measuring technique for electrochemical analysis or for the determination of the kinetics and mechanism of electrode reactions based on the control of the electrode potential.
- Pourbaix diagram: See potential-pH diagram.
- Power: See electrical power.
- Power density: Characteristic parameter of a battery indicating its electrical power per unit weight or volume. The terminology is not strictly defined. Weight based power density is often called "specific power" or "gravimetric power density." Volume based power density is often called "power density" or "volumetric power density. The power density is typically expressed as watt/kilogram or watt/liter.
- Power source (supply): See electrical source (supply).
- Preparative electrochemistry: See electrosynthesis.
- Primary battery: A cell or battery whose useful life is over once its reactants have been consumed; i.e. One not ed to be recharged.

- Primary current distribution: A current distribution that is completely controlled by the resistivity of the electrolyte solution between the working and counter electrodes. The current always follows the least resistive path; consequently, a non-uniform current distribution will result if the geometry of the electrodes is such that the resistivity of the current path is not the same to every point on the working electrode. Every other effect that may influence the current distribution is ignored in this case, or assumed to be negligible. See also secondary and tertiary current distribution.
- Proton: See atomic structure.
- Proton-exchange membrane: An ion-exchange membrane that is used both as a "separator" and as the electrolyte in some

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fuel cells. Abbreviated as "PEM."

- PZC: Stands for potential of zero charge.

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Electrochemistry Dictionary - Q

- Quad: a measure of energy equivalent to a quadrillion (a million times a million times one thousand, or 1015) British thermal units (Btu).
- Quasi-reversible electrode: An electrode with a quasi-reversible electrode reaction.
- Quasi-reversible electrode reaction: A qualitative term for an intermediate speed electrode reaction. An electrode reaction having an intermediate exchange current density, between that of an irreversible and a reversible electrode reaction.

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Electrochemistry Dictionary - R

- Radical: A molecule or atom possessing an unpaired electron.
- Rate: See C-rate.

- Rate constant: The rate of a chemical reaction is proportional to the product of the concentrations of all the reactants taking part in the reaction, with the "rate constant" the proportionality factor. In other words, the rate constant is the rate of the reaction when all reactants are present in unit concentration. The rate constant of a chemical reaction is a function of temperature and pressure. For an electrode reaction the rate constant is also a function of the electrode potential.
- Rated capacity: The total charge a battery is able to deliver on discharge under some specified conditions. Usually expressed in ampere-hours.
- Rate-determining step: The slowest elementary reaction step in the series of steps comprising the overall reaction. The slowest step will control the rate of the overall reaction. This is analogous to a traffic situation, the time required to drive from the suburbs to downtown may completely depend on the time spent in one traffic jam on the road. Abbreviated as "rds."
- Rational potential: The potential of an electrode expressed against the potential of zero charge (pzc) of the same electrode in the same solution. This provides a potential scale specific for each electrode, with the origin (zero potential) always at the respective pzc. Consequently, two electrodes having the same "rational potential" are typically not at the same "potential" (as measured against any reference electrode). However, the potential of these two electrodes is displaced by the same amount from their respective pzc; therefore, the charge density in the double layer of the two electrodes will be approximately equal. Consequently, the comparison of electrode behavior at the same "rational potential" is more meaningful for some purposes than a comparison at the same "potential on some arbitrary scale." The charge densities of two electrodes at the same rational

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potential are only approximately equal because the double-layer capacitance and its potential dependence varies from electrode to electrode.

- RDE: Stands for rotating-disk electrode.
- rds: Stands for rate-determining step.
- Reactant: A chemical species that is taking part in a chemical reaction by reacting (sometimes by itself, but usually with other reactants) to form the products of the reaction. (electrode) reaction mechanism: The totality of all the elementary reaction steps occurring in series or parallel that fully defines the overall electrode reaction.
- Reaction overpotential (polarization): The overpotential (alternatively called polarization) associated with a chemical reaction (without charge transfer) step that is an elementary step in the overall electrode reaction.
- Rechargeable battery: A battery in which the chemical reaction system providing the electrical current is easily "chemically" reversible. After discharging, it can be recharged by applying an electrical current to its terminals. Some batteries can be recharged hundreds to thousands times. See, e.g. the lead-acid battery. Also called "secondary" battery, and "accumulator." Contrast with non-rechargeable battery. It operates as a galvanic cell during discharge and as an electrolytic cell during charge. As a consequence, the anode is the negative electrode during discharge, while it is the positive electrode during charge; at the same time, the cathode is the positive electrode during discharge, while it is the negative electrode during charge. This can create a confusing situation, and it is preferable to refer to the electrodes of a rechargeable battery as "positive" and "negative," because this designation is independent of the operational mode. Unfortunately, this nomenclature is not always followed. Often the "negative" electrode is designated as anode and the "positive" electrode is designated as cathode. This naming convention is a carry-over from the convention of the non-rechargeable battery.
- Recombining cell: A secondary cell in which provision has been made for the products of overcharge reactions to recombine so that no net change occurs to the composition of

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the cell system as a result of overcharging.

- Rectifier: An electrical equipment that converts alternating current into direct current.
- Redox battery: A rechargeable battery with two redox electrodes contained in compartments typically separated by an ion-exchange membrane E.g., a battery with iron and chromium redox couples in the two compartments. During discharge, "ferric" (trivalent iron) cations are reduced to "ferrous" (divalent iron) ions at one of the redox electrodes, while "chromous" (divalent chromium) ions are oxidized to "chromic" (trivalent chromium) ions at the other electrode. The reverse reactions occur during charging. An advantage of this system is that the polarization losses are relatively small because the redox reactions are typically fast and no solid phases are being formed during the reaction. Also, the solutions containing the iron and chromium salts can be stored in separate large tanks and circulated to a small "battery," permitting the storage of large amounts of energy.
- Redox couple: See redox reaction.
- Redox electrode: An inert electrode (e.g., platinum, gold, carbon) the potential of which is controlled by a redox reaction in solution. This is somewhat of a misnomer since all electrodes involve oxidation/reduction. The distinction is that in the case of a redox electrode both oxidized and reduced species are dissolved in the solution surrounding the electrode.
- Redox potential: The potential of a redox electrode.
- Redox reaction: A class of electrode reactions involving oxidation/reduction of two dissolved species. E.g., iron metal can exist in solution as a doubly positively charged ("ferrous") ion or a triply positively charged ("ferric") ion. Such a system is often called a "redox couple," such as the "ferrous/ferric" couple. The ferric ions can be cathodically reduced to ferrous ions, or the ferrous ions can be anodically oxidized to ferric ions. With these reactions, an inert electrode is used that does not take part in any reactions under the conditions of the oxidation/reduction of the ions. This electrode then acts only as a source or sink of electrons; examples are: carbon, graphite, platinum, gold. Compare with a metal

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deposition/dissolution reaction where one of the reacting species is a solid metal and the other species is in solution.

- Reducing agent: A substance that is affecting reduction by donating electrons to another substance. See oxidation/reduction. Also called "reductant."
- Reductant: Alternative expression for reducing agent.
- Reduction: The gain of electrons by a chemical species. See oxidation/reduction

- Reference electrode: An electrode that has a well known and stable equilibrium electrode potential or a nonpolarizable electrode with a known and highly reproducible potential. It is used as a reference point against which the potential of other electrodes (typically that of the working electrode or measuring electrode) can be measured in an electrochemical cell. In principle it can be any electrode fulfilling the above requirements. In practice, there are a few commonly-used (and usually commercially-available) electrode assemblies that have an electrode potential independent of the electrolyte used in the cell. For some common reference electrodes see e.g., the silver/silver-chloride electrode, calomel electrode, and hydrogen electrode. Strictly speaking, there can be a small change in the potential of these electrodes depending on the electrolyte because the presence of a liquid-junction potential. This is very often (justifiably or not) ignored. The liquid-junction potential is also minimized by the use of high concentration potassium chloride as the filling solution of the reference electrodes, because the diffusion rate of both ions is very closely the same in these solutions.
- Reserve battery: A non-rechargeable battery that is stored in an "inactive" form until its intended, immediate use. E.g., the battery is stored "dry," and it can be activated by injection of the electrolyte. Or, a battery operating with molten salt electrolyte is stored at a temperature below the electrolyte melting point, and it is activated by the sudden application of heat to melt the electrolyte. The advantages of such arrangements are an extremely long shelf life without practically any loss of stored energy, and the possibility to produce a very powerful battery with very reactive chemicals

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that would otherwise cause a very fast self discharge. Most reserve batteries are made for military applications.

- Residual current (density): A small faradaic current density flowing through an electrode under conditions when zero faradaic current is expected (e.g., within the double-layer range). It is caused by traces of impurities in the electrolyte. Also called "background current (density)."
- Resistance: See resistivity.
- Resistance overpotential (polarization): See solution ir drop.
- Resistivity (electrical): The measure of a material's inability to carry electrical current. The measurement unit of the resistivity (resistance) is the ohm. See also impedance. The reciprocal of conductivity.
- Resistor: An electrical circuit element with a fixed resistivity.
- Rest potential: See equilibrium potential.
- Reversal: See cell reversal.

- Reversible electrode: An electrode with a reversible electrode reaction.
- Reversible electrode reaction: A qualitative term for a fast electrode reaction. There are, unfortunately, several meanings attributed to the term "reversibility," resulting in possibly confusing situation. An electrode reaction is considered reversible in the "electrochemical sense" if the reaction is fast, that is, if the exchange current density of the electrode reaction is large. In contrast, in the "chemical sense," reversibility indicates that the reaction can proceed both in forward and backward (reverse) direction. Also called nernstian reaction. Opposite: irreversible electrode reaction. See also quasi-reversible electrode reaction. Both of the above described meanings of reversibility are different from the meaning in the "thermodynamic sense."
- Reversible hydrogen electrode: A commonly used reference electrode. A hydrogen electrode immersed directly into the electrolyte of the electrochemical cell and usually (unless otherwise sated) operated with one atmosphere pressure hydrogen gas. The equilibrium potential depends on the hydrogen ion concentration (strictly speaking, activity) of the cell electrolyte.

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- Rotating-disk electrode: A specialized hydrodynamic electrode used in the study of the kinetics and mechanism of electrode reactions and in electroanalysis for ensuring a known and controllable flow of solution over the electrode. The flow control is achieved by using a flat disc electrode that is rotated in the solution resulting in a defined hydrodynamic boundary layer. Abbreviated as "RDE."
- Rotating-ring-disk electrode: A variant of the rotating-disk electrode which includes a second electrode - a concentric ring electrode - that is placed outside the disk and used to analyze the species generated on the disk. The ring is electrically insulated from the disk so that their potentials can be controlled independently. Abbreviated as "RRDE."
- Rotating-wire electrode: An electrode made of metal wire (often platinum) rotated about its axis at a known and constant velocity. It is used in the study of the kinetics and mechanism of electrode reactions and in electroanalysis.
- Roughness factor: The ratio between the true electrode area and the geometric electrode area.
- RRDE: Stands for rotating-ring-disk electrode.

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Electrochemistry Dictionary - S

- Salt bridge: An ionically conducting path between separate compartments of an electrochemical cell. Often the working and reference (and occasionally even the counter) electrodes are in completely separate compartments and the required conducting path between them is provided by a tubing filled with highly conducting electrolyte solution. A common arrangement for a "salt bridge" is an inverted "U" shaped glass tubing with its ends dipped into the solutions of the two cell compartments; however, other materials and shapes are also used. The salt bridge may contain any conducting solution, but very often a highly concentrated potassium chloride solution (often immobilized by some gelling agent) is used.
- Sand equation: An equation relating current density, transition time, and concentration of the reactant in a chronopotentiometric experiment, assuming that the current is sufficiently large to immediately result in diffusion limiting conditions. The equation is valid only for planar electrodes in unstirred solution. The product of the current density and the square root of the transition time divided by the concentration is a constant. The constant is proportional to the square root of the diffusion coefficient of the reactant. Because the equation was derived for an unstirred solution, it ceases to be valid once natural convection starts.
- Saturated solution: See solubility.
- SCE: Stands for "saturated calomel electrode." See calomel electrode.
- Sealed battery: See maintenance-free battery. A battery which can be operated without regard to position.
- Second kind electrode: See electrode of the second kind.
- Secondary battery, storage battery: Cell or battery which can be recharged after discharge, under specified conditions.

- Secondary current distribution: A current distribution that is controlled by the resistivity of the solution (see primary current distribution) and the charge-transfer resistance of the electrode reaction occurring on the working electrode. That is,

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a current distribution taking into effect the activation overpotential. A large charge-transfer resistance (that is, a slow reaction), compared to the solution resistance, tends to make the current distribution more uniform. This still ignores the effect of the concentration overpotential, see tertiary current distribution.

- Sedimentation potential: An electrical potential difference that arises when small suspended particles move through a liquid (e.g., forced by gravity). Also called "Dorn potential. See electrokinetic effects.
- Self discharge: Capacity loss of a cell or battery under open circuit conditions due to chemical reactions within the cell. A slow discharging of a battery without being connected to an external load. This is caused partly by impurities and side reactions (reactions other than the cell reaction) and partly by the imperfect separation of the active chemicals in the battery causing a slow "direct" reaction between them. The rate of the self discharge determines the shelf life of a non-rechargeable battery.
- Self discharge rate: The rate at which a cell or battery loses service capacity when standing idle.

- Semipermeable membrane: A separator through which certain molecules can pass but others cannot.
- Sensing electrode: See working electrode.
- Separator: Electrically insulating layer of material which physically separates electrodes of opposite polarity. Separators must be permeable to the ions of the electrolyte and may also have the function of storing or immobilizing the electrolyte. Often a thin structural material (usually a sheet) used to separate the electrolyte of a divided electrochemical cell into two or more compartments. A separator is typically either a membrane or a diaphragm. The distinction between these two separators is somewhat blurred. A membrane typically has very small pores that permit only diffusional or conductive motion of the solvent or the electrolyte from one compartment to another. A diaphragm has larger pores so that it permits the flow (see convection) of the electrolyte solution from one compartment to another but still restricts the complete

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intermixing the two solutions.

- Series connected: A method of connection in which the positive terminal of one device is connected to the negative terminal of another. The voltages add and the current is limited to the least of any device in the string. (See also parallel connected.)
- Series-coupled cells: Individual electrochemical cells can be combined in assemblies by series or parallel coupling (or a combination of the two). In case of "series" coupling, the positive electrode of one cell is connected to the negative electrode of the next cell, and so on. The assembly has only two external terminals. The overall voltage of the assembly is the sum of the individual cell voltages, while the current passing through every cell (and the assembly) is the same. Series coupling can be used in a number of assemblies, such as battery, cell line, and stack. Contrast with parallel coupling.
- Service life: Timescale of satisfactory performance of a battery under a specified operating schedule, expressed in units of time or number of charge/ discharge cycles.

- SHE: Stands for standard hydrogen electrode.
- Shedding: The process whereby poorly adhering active mass (generally in the positive plate of a lead-acid cell) falls from the grid to form a sludge (mud) on the floor of the cell.

- Shelf life: Period of time a cell can be kept idle after manufacture without significant deterioration. The time period a non-rechargeable battery can be stored after manufacturing so that it still can provide a required amount of electricity when connected to a load. The shelf life of modern batteries is many years.
- Short-circuit: The condition when the terminals of a cell or battery are connected directly.

- Siemens: The measurement unit of electrical conductance. Symbol: "S". The reciprocal of ohm, and sometimes called "mho."
- Silver/silver-chloride electrode: A commonly used reference electrode. The electrode assembly consists of a silver metal

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electrode in contact with solid silver chloride (usually as a coating on the silver metal) immersed in an aqueous chloride salt solution saturated with silver chloride. All these are contained in a small vessel, typically made of glass tubing. The internal electrolyte of the reference electrode assembly and the external electrolyte into which the whole assembly is immersed are in ionic contact through a separator. A typical separator is a small porous ceramic plug sealed into the end of the glass tubing. The operating principle of this electrode is that of an electrode of the second kind. The equilibrium electrode potential is a function of the chloride concentration of the internal electrolyte ("filling solution"). The most commonly used electrolyte is 4 molar potassium chloride, producing a potential of 0.222 volt against the standard hydrogen electrode at 25 oC. Occasionally, other concentrations of potassium chloride or other chloride salts are used.

- SLI battery: A battery of usually 12 V or 24 V used for Starting, Lighting and Ignition in vehicles with internal combustion engines.

- Solar constant: The rate at which energy is received from the sun just outside the earth's atmosphere on a surface perpendicular to the sun's rays. Approximately equal to 1.36 kW/m2.
- SMDE: Stands for static-mercury-drop electrode.
- Sodium chlorate production: See brine electrolysis.
- Sodium chloride solution, electrolysis: See brine electrolysis.
- Sodium hydroxide production: See brine electrolysis.
- Sodium hypochlorite production: See brine electrolysis.
- Soil remediation: See electroremediation.
- Solid-oxide fuel cell: A fuel cell that employs a solid, ionically conductive material as electrolyte. Due to the typically low ionic conductivity of solid oxides, these fuel cells must operate at very high temperatures.
- Solubility: The maximum amount of a species that can be dissolved in a given solvent. It is usually expressed as the maximum achievable concentration. A solution is called "saturated" if it contains the maximum dissolvable amount.

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- Solubility product: The solubility of slightly soluble salts is often expressed as the product of the solubility concentrations of its ions. E.g., the solubility product of silver chloride is the product of the concentrations of the silver and chloride ions in the saturated solution of this salt. The significance of the solubility product is that its value cannot be exceeded even in the presence of other dissolved salts. Consequently, the solubility of silver chloride is less in a solution containing potassium chloride than in pure water. This is because in the calculation of the solubility product one must use the "total" chloride concentration in the solution, therefore a silver concentration lower than in water is needed to satisfy a constant solubility product. The solubility (the saturated solution concentration) of the salt, in the absence of any other dissolved species in the solution, is the square root of the solubility product for a salt like the silver chloride. Strictly speaking, activities should be used instead of concentrations.
- Solute: The dissolved species (e.g., a salt) in a solution.
- Solution ir drop: The ir drop in the electrolyte solution of a three-electrode cell between the working and the reference electrodes. This ir drop (which is expressed as a potential) is always included in the measured potential of the working electrode. Therefore, it is important to minimize this error, and to place the reference electrode as close as possible to the working electrode (see Luggin tip). It is also called "ohmic overpotential (or polarization)" or "resistance overpotential (or polarization)." One can correct for the ir drop to obtain the real electrode potential, or in some cases one can compensate for the ir drop during potential control. During the measurement of an electromotive force (potential measurement without any current flowing), the ir drop is always zero, and the position of the reference electrode is immaterial. See also ohmic loss.
- Solvation: Ions in solution are always surrounded by solvent molecules. A few of these molecules will be more or less strongly attached to the ion (mainly because of the attraction of the charged ion and the dipole of the solvent molecule) and this assembly may be considered as a single unit for some purposes. E.g., the solvent molecules will move together with

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the ion during diffusion and electromigration. The number of solvent molecules so attached to an ion is called the "solvation number." The surface of an electrode also can, and usually is, solvated. Since the electrodes usually have some excess charge (see electrical double layer,) they also attract the solvent dipoles, and the electrode surface is usually covered by a monolayer of strongly oriented solvent molecules. Under certain extreme conditions, a solution can contain free electrons that are stabilized by solvation. The solvation number is not very exactly defined since its value may depend on the measurement technique.

- Solvation number: See solvation.
- Sonoelectrochemistry: Electrochemical phenomena occurring under the influence of soundwaves (typically ultrasound).
- Source: See electrical source (supply).
- Specific conductance: The quantitative and characteristic measure of the conductivity of a given substance. This characteristic constant is the numerical value of the conductivity between two opposite sides of a unit cube (usually a cube of one centimeter) of the substance. Also called "specific conductivity."
- Specific energy: The energy output of a battery per unit weight, usually expressed as Wh kg^{-1}.
- Specific ion electrode: See ion-selective electrode.
- Specific power: The power output of a battery per unit weight, usually expressed as W kg^{-1}.
- Specific resistance: The quantitative and characteristic measure of the resistivity of a given substance. This characteristic constant is the numerical value of the resistivity between two opposite sides of a unit cube (usually a cube of one centimeter) of the substance. Also called "specific resistivity."
- Spectroelectrochemistry: The simultaneous application of electrochemical and optical spectroscopic techniques to investigate a phenomenon.
- Stack: A series-coupled assembly of cells, a term used primarily for fuel cells.

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- **Standard cell:** A non-rechargeable cell (battery) whose emf is accurately known and remains sufficiently constant. It is less and less used nowadays because the availability of electronic voltage standards.
- **Standard electrode potential:** The equilibrium potential of an electrode when both the oxidized and the reduced species are present in unit concentration (strictly speaking, activity) in the solution; if the "reduced" form is a metal, a pure metal (not alloyed with other metals) is considered to be at unit concentration. (See also the Nernst equation.) The standard potentials are always expressed against the standard hydrogen electrode the potential of which is zero "by definition." Standard potentials are a function of the temperature, they are usually tabulated for 25^{o}C. Also called "normal electrode potential." The standard potential is the electromotive force of an electrochemical cell comprised of the electrode in question and the standard hydrogen electrode. Strictly speaking, one must use unit activities rather than concentrations.
- **Standard hydrogen electrode:** The most fundamental reference electrode in electrochemistry. "By definition" its equilibrium potential is considered zero at any temperature, because this electrode was chosen as an arbitrary zero point for electrode potentials. A zero point is needed since the potential of a single electrode cannot be measured, only the difference of two electrode potentials is measurable. All electrode potentials are expressed on this "hydrogen scale." It is a hydrogen electrode with an electrolyte containing unit concentration of hydrogen ions and saturated with hydrogen gas at unit atmosphere pressure. This electrode can be somewhat inconvenient to use because of the need to supply hydrogen gas. Therefore, other reference electrodes (e.g., calomel or silver/silver chloride) are often used instead, but the measured electrode potentials can be converted to the "hydrogen scale." Abbreviated as "SHE." Also called "normal hydrogen electrode." Strictly speaking, one must use unit activity rather than concentration of hydrogen ions and unit fugacity rather than unit pressure of hydrogen gas.
- **Standard rate constant of electrode reaction:** The rate

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constant of an electrode reaction at the standard electrode potential.

- State of charge: For a rechargeable battery: the fraction, usually expressed as a percentage, of the total electrical energy stored in a battery by charging that is still available for discharging at a certain point of time. Contrast with depth of discharge.
- Static-mercury-drop electrode: Alternative name for hanging-mercury-drop electrode. Abbreviated as "smde."
- Stationary state: See steady state.
- Steady state: A state of a system in which the conditions do not change in time, or at least they do not seem to change with time. That is, the change occurs on a time scale longer than the time scale of the observations. A good example of the creation and slow vanishing of a steady-state condition is the liquid-junction potential.
- Stern modification of the double layer theory: See the Gouy-Chapman-Stern model of the double layer.
- Storage battery: See secondary battery.
- Streaming potential: An electrical potential difference that arises when liquid is flowing by a solid surface, e.g., when liquid is forced through a capillary tubing or porous solid by a pressure differential. See electrokinetic effects.
- Stripping analysis: A group of electroanalytical techniques for the determination of trace amounts of substances, consisting of two steps: preconcentration and analysis. The preconcentration involves the electrodeposition or adsorption of the substance to be determined on the surface of an electrode. This is followed by the "stripping" analysis of the substance by an electroanalytical technique. For example, traces of metal ions can be preconcentrated by cathodic electrodeposition followed by anodic dissolution (stripping). Or traces of halides (e.g., chloride) can be anodically preconcentrated at a mercury electrode as mercury salts, followed by cathodic stripping.
- Supercapacitor: See electrochemical capacitor.
- Supply: Alternative expression for source.
- Supporting electrolyte: An electrolyte added to the solution

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for the sole purpose to increase the solution conductivity, while the electrolyte does not take part in any reactions. Also called "inert," "indifferent," or "swamping" electrolyte.

- Surface active agent: A substance which modifies the behaviour of a phase by interacting with its surface. For example, in the case of lead-acid batteries, the morphology of the active materials deposited at the electrodes may be strongly affected by the addition of surface-active agents.

- Swamping electrolyte: Alternative expression for supporting electrolyte.

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Electrochemistry Dictionary - T

- **Tafel slope:** the slope of the straight line portion of a polarization curve, usually occurring at more than 50 mV from the open-circuit potential, when presented in a semi-logarithmic plot in terms of volts per logarithmic cycle of current density (commonly referred to as volts per decade).
- **Tafel line:** See Tafel equation.
- **Tafel plot:** See Tafel equation.
- **Tafel slope:** See Tafel equation.
- **Taper charging:** A charging regime delivering moderately high rate of current when the battery is at a low state of charge and tapering the charging current to lower rates as the battery is charged.
- **Terminal:** The external electrical connection posts of an electrochemical cell to which a power source or a load can be connected. For example, in case of a battery, to which either a load (e.g., motor, light bulb) can be connected to use the electrical energy of the battery, or to which a charger can be connected to charge the battery. Every battery has only two terminals (positive and negative) independent whether the battery contains one or more cells internally. This term is also used for cell stacks and for electrolytic cells. A terminal can also be called a "pole."
- **Tertiary current distribution:** A current distribution that is controlled by the resistivity of the solution (see primary current distribution), the activation overpotential (see secondary current distribution), and the concentration overpotential. The concentration changes occurring at the working electrode surface affect the rate of the electrode reaction and can therefore be considered as an additional surface resistivity.
- **Thermal battery:** A type of reserve cell which is activated by raising the temperature.

- **Thermal management:** The means whereby a battery system is maintained within a specified temperature range while undergoing charge or discharge.

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- Thermal runaway: A process in which a cell undergoes an uncontrolled rise in temperature due to the passage of increasing current (on, say, short-circuit discharge or constant voltage charging) as the temperature rises.

- Thermocell (thermogalvanic cell): A galvanic cell consisting of two identical half cells that are kept at different temperatures.
- Thick cells: Conventional cells, such as crystalline silicon cells, which are typically from 4 to 17 mils thick. In contrast, thin-film cells are several microns thick.
- Thin-film cells: Photovoltaic cells made from a number of layers of photo-sensitive materials. These layers are typically applied using a chemical vapor deposition process in the presence of an electric field.
- Third kind electrode: See electrode of the third kind.
- Three-electrode cell: An electrochemical cell containing a working electrode, a counter electrode, and a reference electrode. A current may flow between the working and counter electrodes, while the potential of the working electrode is measured against the reference electrode. This setup can be used in basic research to investigate the kinetics and mechanism of the electrode reaction occurring on the working electrode surface, or in electroanalytical applications.
- Throwing power: A qualitative term used in electroplating to describe the ability of the system to produce a uniformly thick deposit on the substrate surface. That is, the "throwing power" is considered "good" when the current distribution is uniform even on an irregularly shaped substrate. The throwing power is a function of both the geometrical arrangement in the electroplating cell and the composition of the plating solution.

- Totally-polarized electrode: Alternative expression for ideal polarized electrode.
- Transference number: See transport number.
- Transition time: Characteristic time in a chronopotentiometric experiment indicating the exhaustion of a reactant concentration at the electrode surface. The potential of the electrode changes sharply upon reaching the transition time.

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- Transport number: The fraction of the total current carried in a solution by a given ion. Ions may carry drastically different portions of the total current if their mobilities are different. E.g., in a solution of sodium chloride, less than half of the current is carried by the positively charged sodium cations and more than half is carried by the negatively charged chloride anions because the chloride ions are able to move faster (they have a larger ionic mobility). The transport numbers of the anion and the cation adds up to unity. As a matter of fact, the case when the ions move equally and the transport number of both ions is equal to 0.5 is a rarity. The Hittorf method is an experimental technique for the determination of the transport numbers. Also called "transference number." For the simplest case of a solution of a single salt of univalent ions, the transport numbers are defined as the mobility of the ion divided by the sum of mobilities of the two ions. If there are more than one solutes present (e.g., an acidified sodium chloride solution or a mixture of sodium chloride and potassium bromide), every ion will have its own transport number with the sum of them being unity. In these cases, the concentrations of the ions must also be taken into account in the calculation of the transport numbers, and in the case of polyvalent ions, the charges of the ions must also be accounted for.
- Trickle charging: A method of maintaining a rechargeable battery in a fully charged condition by continuous, long-term, slow-rate charging, at a level sufficient to balance self-discharge and occasional discharge. Also called "boost charging." See also float charging.
- True current density: See current density.
- True electrode area: The surface area of an electrode taking into consideration the surface roughness. For a perfectly smooth electrode, it is equal to the geometric electrode area, but it is larger than that for most electrodes. The ratio of the two defines the roughness factor.
- Tuberculation: Development or formation of small mounds of corrosion products on the inside of steel or iron pipes. These tubercles roughen the inside of the pipe, increasing its resistance to water flow and the possibility of erosion

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corrosion.

- Two-electrode cell: A classical electrochemical cell containing two electrodes.

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Electrochemistry Dictionary - U

- Ultracapacitor: See electrochemical capacitor.
- Ultramicroelectrode: A very small electrode, with dimensions not larger than few tens of a micrometer, and occasionally with dimensions of a fraction of a micrometer.
- Uncompensated IR drop: The part of the solution IR drop that is not automatically compensated for by the electronic control instrumentation.
- Uncompensated (solution) resistance: See uncompensated ir drop.
- Underpotential deposition: The electrodeposition of a metal on a foreign metal at potentials less negative than the equilibrium potential of the deposition reaction. Such a process is energetically unfavorable and it can occur only because of a strong interaction between the two metals, with their interaction energy changing the overall energetics to favorable. Consequently, only one (very seldom two) monolayer can be deposited this way, and this is a very convenient way to produce well-controlled monolayer deposits. Abbreviated as "UPD."
- Uninterruptible power supply (UPS): A power system which maintains current flow without even a momentary break, in the event of mains or generator failure.
- Unpolarizable electrode: See non-polarizable electrode.
- UPD: Stands for underpotential deposition.

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Electrochemistry Dictionary - V

- V: Symbol and abbreviation of volt.
- Viscosity: The resistance to flow exhibited by a liquid or gas subjected to deformation.
- Volt: Measurement unit of the electrical potential. Symbol: "V".
- Voltage: A term sometimes used interchangeably with electrical potential. See also cell voltage.
- Voltage compliance: See compliance limits.
- Voltage delay: Time interval at the start of a discharge during which the working voltage of a cell is below its steady value. The phenomenon is generally due to the presence of passivating films on the negative electrode.
- Voltage source (supply): See electrical source (supply).
- Voltaic cell: See galvanic cell.
- Voltaic pile (Volta pile): The first (1800) laboratory source of electricity, essentially what we would call today a non-rechargeable battery. Volta assembled (piled up) different metal disks (e.g., copper and zinc) separated by solution soaked pasteboards, repeating the pattern many tens of times. This was essentially a battery containing many series-coupled Daniell cells (a cell which was a later improvement) providing rather high cell voltage and current capabilities, but very short life time.
- Voltammetry: An electrochemical measuring technique used for electrochemical analysis or for the determination of the kinetics and mechanism of electrode reactions. "Voltammetry" is a family of techniques with the common characteristics that the potential of the working electrode is controlled (typically with a potentiostat) and the current flowing through the electrode is measured. In one of the most common applications of the technique, the potential is scanned linearly in time; this is called the "linear-sweep voltammetry," "LSV," or "LV." "Cyclic voltammetry (CV)" is a linear-sweep voltammetry with the scan continued in the reverse direction at the end of the first scan, this cycle can be repeated a number of times.
- Voltammogram: Graphical representation of the results of a

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voltammetric measurement.

- Voltmeter: Instrument used for the measurement of electrical potential differences.

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Electrochemistry Dictionary - W

- W: Symbol and abbreviation of watt.
- Wh: Symbol and abbreviation of watt-hour.
- Water electrolysis: Process for the electrochemical decomposition of water in a divided electrolytic cell by electrolysis. Typically, hydrogen gas is produced at the steel cathode (see hydrogen evolution) and oxygen gas is produced at the nickel anode (see oxygen evolution). The cell is divided to avoid mixing the hydrogen and oxygen gases. The electrolyte is typically an aqueous potassium hydroxide solution. Potassium hydroxide is used to provide a large ionic conductivity, even though the potassium is not reacting at any of the electrodes (see supporting electrolyte).
- Watt: Measurement unit of electrical power. Symbol: "W". Related units are that of power density: watt/kilogram (W/kg) and watt/liter (W/l).
- Watt-hour: Measurement unit of electrical energy. Symbol: "Wh". Related units are that of energy density: watt-hour/kilogram (Wh/kg) and watt-hour/liter (Wh/l).
- Wet cell: A cell in which the liquid electrolyte is free-flowing.

- Working electrode: The test or specimen electrode in an electrochemical cell. Or the electrode in a three-electrode cell where "the action is." The kinetics and mechanism of the electrode reaction may be under investigation, or the reaction occurring on the working electrode may be used to perform an electrochemical analysis of the electrolyte solution. It can serve either as an anode or a cathode, depending on the applied polarity. One of the electrodes in some "classical two-electrode" cells can also be considered a "working" ("measuring," "indicator," or "sensing") electrode, e.g., in a potentiometric electroanalytical setup where the potential of the measuring electrode (against a reference electrode) is a measure of the concentration of a species in the solution.

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Electrochemistry Dictionary - X

- X-rays: electromagnetic radiation (photon), of shorter wavelength than ultraviolet radiation. Produced by bombardment of atoms by high quantum energy particles. Radiation wavelength is from 10^{-11} to 10^{-9} m.

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Electrochemistry Dictionary - Y

- Yield: evidence of plastic deformation in structural materials. also called plastic flow or creep. see also flow.
- Yield point: the first stress in a material, usually less than the maximum attainable stress, at which an increase in strain occurs without an increase in stress.
- Yield strength: the stress at which a material exhibits a specified deviation from proportionality of stress and strain. An offset of 0.2% is used for many metals.
- Yield stress: the stress level in a material at or above the yield strength but below the ultimate strength, i.e. a stress in the plastic range.

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Electrochemistry Dictionary - Z

- Zeolite: A group of hydrated sodium aluminosilicates, either natural or synthetic, with ion exchange properties. (See gel zeolite, greensand.)
- Zeta potential: Alternative name for "electrokinetic potential." See electrokinetic effects.
- Zinc-carbon cell (battery): See Leclanche cell.

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