The **Beer–Lambert law**, also known as **Beer's law**, the **Lambert–Beer law**, or the **Beer–Lambert–Bouguer law** relates the [attenuation](https://en.wikipedia.org/wiki/Absorption_%28electromagnetic_radiation%29) of [light](https://en.wikipedia.org/wiki/Light) to the properties of the material through which the light is traveling. The law is commonly applied to [chemical analysis](https://en.wikipedia.org/wiki/Chemical_analysis) measurements and used in understanding attenuation in [physical optics](https://en.wikipedia.org/wiki/Physical_optics), for [photons](https://en.wikipedia.org/wiki/Photons), [neutrons](https://en.wikipedia.org/wiki/Neutrons) or rarefied gases. In [mathematical physics](https://en.wikipedia.org/wiki/Mathematical_physics), this law arises as a solution of the [BGK equation](https://en.wikipedia.org/wiki/Bhatnagar-Gross-Krook).

The law was discovered by [Pierre Bouguer](https://en.wikipedia.org/wiki/Pierre_Bouguer) before 1729.[[1]](https://en.wikipedia.org/wiki/Beer%E2%80%93Lambert_law#cite_note-1) It is often attributed to [Johann Heinrich Lambert](https://en.wikipedia.org/wiki/Johann_Heinrich_Lambert), who cited Bouguer's *Essai d'optique sur la gradation de la lumière* (Claude Jombert, Paris, 1729)—and even quoted from it—in his [*Photometria*](https://en.wikipedia.org/wiki/Photometria) in 1760.[[2]](https://en.wikipedia.org/wiki/Beer%E2%80%93Lambert_law#cite_note-2) Lambert's law stated that absorbance of a material sample is directly proportional to its thickness (path length). Much later, [August Beer](https://en.wikipedia.org/wiki/August_Beer) discovered another attenuation relation in 1852. Beer's law stated that absorbance is proportional to the concentrations of the attenuating species in the material sample. [[3]](https://en.wikipedia.org/wiki/Beer%E2%80%93Lambert_law#cite_note-3) The modern derivation of the Beer–Lambert law combines the two laws and correlates the absorbance to both the concentrations of the attenuating species as well as the thickness of the material sample.[[4]](https://en.wikipedia.org/wiki/Beer%E2%80%93Lambert_law#cite_note-4)

**Beer–Lambert law**

By definition, the [transmittance](https://en.wikipedia.org/wiki/Transmittance) of material sample is related to its [optical depth](https://en.wikipedia.org/wiki/Optical_depth) *τ* and to its [absorbance](https://en.wikipedia.org/wiki/Absorbance) *A* as

T = Φ e t Φ e i = e − τ = 10 − A , where

* Φet is the [radiant flux](https://en.wikipedia.org/wiki/Radiant_flux) *transmitted* by that material sample;
* Φei is the radiant flux received by that material sample.

The **Beer–Lambert law** states that, for *N* attenuating species in the material sample,

T = e − ∑ i = 1 N σ i ∫ 0 ℓ n i ( z ) d z = 10 − ∑ i = 1 N ε i ∫ 0 ℓ c i ( z ) d z ,

or equivalently that

τ = ∑ i = 1 N τ i = ∑ i = 1 N σ i ∫ 0 ℓ n i ( z ) d z ,

A = ∑ i = 1 N A i = ∑ i = 1 N ε i ∫ 0 ℓ c i ( z ) d z ,

where

* *σi* is the [attenuation cross section](https://en.wikipedia.org/wiki/Cross_section_%28physics%29) of the attenuating species *i* in the material sample;
* *ni* is the [number density](https://en.wikipedia.org/wiki/Number_density) of the attenuating species *i* in the material sample;
* *εi* is the [molar attenuation coefficient](https://en.wikipedia.org/wiki/Molar_attenuation_coefficient) of the attenuating species *i* in the material sample;
* *ci* is the [amount concentration](https://en.wikipedia.org/wiki/Amount_concentration) of the attenuating species *i* in the material sample;
* *ℓ* is the path length of the beam of light through the material sample.

ACID

An **acid** is a [molecule](https://en.wikipedia.org/wiki/Molecule) or [ion](https://en.wikipedia.org/wiki/Ion) capable of donating a [hydron](https://en.wikipedia.org/wiki/Hydron_(chemistry)" \o "Hydron (chemistry)) (proton or hydrogen ion H+), or, alternatively, capable of forming a [covalent bond](https://en.wikipedia.org/wiki/Covalent_bond) with an [electron pair](https://en.wikipedia.org/wiki/Electron_pair) (a Lewis acid).[[1]](https://en.wikipedia.org/wiki/Acid#cite_note-IUPAC_acid-1)

The first category of acids is the proton donors or [Brønsted acids](https://en.wikipedia.org/wiki/Br%C3%B8nsted%E2%80%93Lowry_acid%E2%80%93base_theory" \o "Brønsted–Lowry acid–base theory). In the special case of aqueous solutions, proton donors form the[hydronium ion](https://en.wikipedia.org/wiki/Hydronium_ion) H3O+ and are known as [Arrhenius acids](https://en.wikipedia.org/wiki/Acid-base_reaction#Arrhenius_theory). [Brønsted](https://en.wikipedia.org/wiki/Johannes_Nicolaus_Br%C3%B8nsted" \o "Johannes Nicolaus Brønsted) and [Lowry](https://en.wikipedia.org/wiki/Thomas_Martin_Lowry) generalized the Arrhenius theory to include non-aqueous solvents. A Brønsted or Arrhenius acid usually contains a hydrogen atom bonded to a chemical structure that is still energetically favorable after loss of H+.

Aqueous Arrhenius acids have characteristic properties which provide a practical description of an acid.[[2]](https://en.wikipedia.org/wiki/Acid#cite_note-2) Acids form [aqueous solutions](https://en.wikipedia.org/wiki/Aqueous_solution)with a sour taste, can turn blue [litmus](https://en.wikipedia.org/wiki/Litmus) red, and react with [bases](https://en.wikipedia.org/wiki/Base_(chemistry)) and certain metals (like [calcium](https://en.wikipedia.org/wiki/Calcium)) to form [salts](https://en.wikipedia.org/wiki/Salt_(chemistry)). The word *acid* is derived from the [Latin](https://en.wikipedia.org/wiki/Latin) *acidus/acēre* meaning *sour*.[[3]](https://en.wikipedia.org/wiki/Acid#cite_note-3) An aqueous solution of an acid has a [pH](https://en.wikipedia.org/wiki/PH) less than 7 and is colloquially also referred to as 'acid' (as in 'dissolved in acid'), while the strict definition[[1]](https://en.wikipedia.org/wiki/Acid" \l "cite_note-IUPAC_acid-1) refers only to the [solute](https://en.wikipedia.org/wiki/Solution). A lower pH means a higher acidity, and thus a higher concentration of [positive hydrogen ions](https://en.wikipedia.org/wiki/Hydron_(chemistry)) in the [solution](https://en.wikipedia.org/wiki/Solution). Chemicals or substances having the property of an acid are said to be **acidic**.

Common aqueous acids include [hydrochloric acid](https://en.wikipedia.org/wiki/Hydrochloric_acid) (a solution of [hydrogen chloride](https://en.wikipedia.org/wiki/Hydrogen_chloride) which is found in [gastric acid](https://en.wikipedia.org/wiki/Gastric_acid) in the stomach and activates [digestive enzymes](https://en.wikipedia.org/wiki/Digestive_enzymes)), [acetic acid](https://en.wikipedia.org/wiki/Acetic_acid) (vinegar is a dilute aqueous solution of this liquid), [sulfuric acid](https://en.wikipedia.org/wiki/Sulfuric_acid) (used in [car batteries](https://en.wikipedia.org/wiki/Car_battery)), and[citric acid](https://en.wikipedia.org/wiki/Citric_acid) (found in citrus fruits). As these examples show, acids (in the colloquial sense) can be solutions or pure substances, and can be derived from acids (in the strict[[1]](https://en.wikipedia.org/wiki/Acid" \l "cite_note-IUPAC_acid-1) sense) that are solids, liquids, or gases. [Strong acids](https://en.wikipedia.org/wiki/Acid_strength) and some concentrated weak acids are [corrosive](https://en.wikipedia.org/wiki/Corrosive_substance), but there are exceptions such as [carboranes](https://en.wikipedia.org/wiki/Carborane" \o "Carborane) and [boric acid](https://en.wikipedia.org/wiki/Boric_acid).

The second category of acids are [Lewis acids](https://en.wikipedia.org/wiki/Lewis_acids_and_bases), which form a covalent bond with an electron pair. An example is [boron trifluoride](https://en.wikipedia.org/wiki/Boron_trifluoride) (BF3), whose boron atom has a vacant [orbital](https://en.wikipedia.org/wiki/Atomic_orbital) which can form a covalent bond by sharing a lone pair of electrons on an atom in a base, for example the nitrogen atom in [ammonia](https://en.wikipedia.org/wiki/Ammonia) (NH3). [Lewis](https://en.wikipedia.org/wiki/Gilbert_N._Lewis) considered this as a generalization of the Brønsted definition, so that an acid is a chemical species that accepts electron pairs either directly *or* by releasing protons (H+) into the solution, which then accept electron pairs. However, hydrogen chloride, acetic acid, and most other Brønsted-Lowry acids cannot form a covalent bond with an electron pair and are therefore not Lewis acids.[[4]](https://en.wikipedia.org/wiki/Acid#cite_note-Oxtoby8th-4) Conversely, many Lewis acids are not Arrhenius or Brønsted-Lowry acids. In modern terminology, an *acid* is implicitly a Brønsted acid and not a Lewis acid, since chemists almost always refer to a Lewis acid explicitly as*a Lewis acid*

BASE

n [chemistry](https://en.wikipedia.org/wiki/Chemistry), **bases** are substances that, in [aqueous solution](https://en.wikipedia.org/wiki/Aqueous_solution), are slippery to the touch, taste [astringent](https://en.wikipedia.org/wiki/Taste#Astringency), change the color of indicators (e.g., turn red [litmus paper](https://en.wikipedia.org/wiki/Litmus_paper) blue), react with [acids](https://en.wikipedia.org/wiki/Acid) to form [salts](https://en.wikipedia.org/wiki/Salts), promote certain chemical reactions ([base catalysis](https://en.wikipedia.org/wiki/Base_catalysis)), accept [protons](https://en.wikipedia.org/wiki/Proton) from any proton donor, and/or contain completely or partially displaceable OH− [ions](https://en.wikipedia.org/wiki/Ions). Examples of bases are the hydroxides of the [alkali metals](https://en.wikipedia.org/wiki/Alkali_metal) and [alkaline earth metals](https://en.wikipedia.org/wiki/Alkaline_earth_metal) ([NaOH](https://en.wikipedia.org/wiki/Sodium_hydroxide" \o "Sodium hydroxide), [Ca(OH)](https://en.wikipedia.org/wiki/Calcium_hydroxide" \o "Calcium hydroxide)[2](https://en.wikipedia.org/wiki/Calcium_hydroxide" \o "Calcium hydroxide), etc.).

These particular substances produce [hydroxide](https://en.wikipedia.org/wiki/Hydroxide) ions (OH−) in aqueous solutions, and are thus classified as [Arrhenius bases](https://en.wikipedia.org/wiki/Arrhenius_base). For a substance to be classified as an Arrhenius base, it must produce hydroxide ions in an aqueous solution. In order to do so, Arrhenius believed the base must contain hydroxide in the formula. This makes the Arrhenius model limited, as it cannot explain the basic properties of aqueous solutions of [ammonia](https://en.wikipedia.org/wiki/Ammonia) (NH3) or its organic derivatives ([amines](https://en.wikipedia.org/wiki/Amine)).[[1]](https://en.wikipedia.org/wiki/Base_(chemistry)#cite_note-Chemistry_9E-1) There are also bases that do not contain a hydroxide ion but nevertheless react with water, resulting in an increase in the concentration of the hydroxide ion.[[2]](https://en.wikipedia.org/wiki/Base_(chemistry)#cite_note-Chemical_Principles-2) An example of this is the reaction between ammonia and water to produce ammonium and hydroxide.[[2]](https://en.wikipedia.org/wiki/Base_(chemistry)#cite_note-Chemical_Principles-2) In this reaction ammonia is the base because it accepts a proton from the water molecule.[[2]](https://en.wikipedia.org/wiki/Base_(chemistry)#cite_note-Chemical_Principles-2) Ammonia and other bases similar to it usually have the ability to form a bond with a proton due to the unshared pair of electrons that they possess.[[2]](https://en.wikipedia.org/wiki/Base_(chemistry)#cite_note-Chemical_Principles-2) In the more general [Brønsted–Lowry acid–base theory](https://en.wikipedia.org/wiki/Br%C3%B8nsted%E2%80%93Lowry_acid%E2%80%93base_theory" \o "Brønsted–Lowry acid–base theory), a base is a substance that can accept [hydrogen cations](https://en.wikipedia.org/wiki/Hydron_(chemistry)) (H+)—otherwise known as [protons](https://en.wikipedia.org/wiki/Proton). In the [Lewis model](https://en.wikipedia.org/wiki/Lewis_acids_and_bases), a base is an [electron pair](https://en.wikipedia.org/wiki/Electron_pair) donor.[[3]](https://en.wikipedia.org/wiki/Base_(chemistry)#cite_note-3)

In water, by altering the [autoionization](https://en.wikipedia.org/wiki/Self-ionization_of_water" \o "Self-ionization of water) [equilibrium](https://en.wikipedia.org/wiki/Chemical_equilibrium), bases yield solutions in which the hydrogen ion [activity](https://en.wikipedia.org/wiki/Activity_(chemistry)) is lower than it is in pure water, i.e., the water has a [pH](https://en.wikipedia.org/wiki/PH) higher than 7.0 at standard conditions. A soluble base is called an [**alkali**](https://en.wikipedia.org/wiki/Alkali) if it contains and releases OH− ions [quantitatively](https://en.wikipedia.org/wiki/Stoichiometry). However, it is important to realize that basicity is not the same as [alkalinity](https://en.wikipedia.org/wiki/Alkalinity). Metal [oxides](https://en.wikipedia.org/wiki/Oxide), hydroxides, and especially [alkoxides](https://en.wikipedia.org/wiki/Alkoxide" \o "Alkoxide) are basic, and counteranions of [weak acids](https://en.wikipedia.org/wiki/Acid_strength) are weak bases.

Bases can be thought of as the chemical opposite of [acids](https://en.wikipedia.org/wiki/Acid). However, some strong acids are able to act as bases.[[4]](https://en.wikipedia.org/wiki/Base_(chemistry)#cite_note-Gilbert-4) Bases and acids are seen as opposites because the effect of an acid is to increase the [hydronium](https://en.wikipedia.org/wiki/Hydronium) (H3O+) concentration in water, whereas bases reduce this concentration. A reaction between an acid and base is called [neutralization](https://en.wikipedia.org/wiki/Neutralization_(chemistry)). In a neutralization reaction, an aqueous solution of a base reacts with an aqueous solution of an acid to produce a solution of [water](https://en.wikipedia.org/wiki/Water) and [salt](https://en.wikipedia.org/wiki/Salt_(chemistry)) in which the salt separates into its component ions. If the aqueous solution is [saturated](https://en.wikipedia.org/wiki/Saturated_solution) with a given salt [solute](https://en.wikipedia.org/wiki/Solvent), any additional such salt [precipitates](https://en.wikipedia.org/wiki/Precipitate) out of the solution.

The notion of a base as a concept in chemistry was first introduced by the French chemist [Guillaume François Rouelle](https://en.wikipedia.org/wiki/Guillaume_Fran%C3%A7ois_Rouelle) in 1754. He noted that acids, which at that time were mostly volatile liquids (like [acetic acid](https://en.wikipedia.org/wiki/Acetic_acid)), turned into solid salts only when combined with specific substances. Rouelle considered that such a substance serves as a "base" for the salt, giving the salt a "concrete or solid form"