

Borax

Borax is a salt (ionic compound), a hydrated borate of sodium, with chemical formula $\text{Na}_2\text{H}_{20}\text{B}_4\text{O}_{17}$ often written $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$.^[1] It is a colorless crystalline solid, that dissolves in water to make a basic solution. It is commonly available in powder or granular form, and has many industrial and household uses, including as a pesticide, as a metal soldering flux, as a component of glass, enamel, and pottery glazes, for tanning of skins and hides, for artificial aging of wood, as a preservative against wood fungus, and as a pharmaceutical alkalizer. In chemical laboratories, it is used as a buffering agent.^{[1][8]}

The compound is often called **sodium tetraborate decahydrate**, but that name is not consistent with its structure. The anion is not tetraborate $[\text{B}_4\text{O}_7]^{2-}$ but tetrahydroxy tetraborate $[\text{B}_4\text{O}_5(\text{OH})_4]^{2-}$,^[9] so the more correct formula should be $\text{Na}_2\text{B}_4\text{O}_5(\text{OH})_4 \cdot 8\text{H}_2\text{O}$. Informally, the product is often called **sodium borate decahydrate** or just **sodium borate**.

The terms **tincal** /ˈtɪŋkəl/ "tinkle" and **tincar** /ˈtɪŋkər/ "tinker" refer to native borax, historically mined from dry lake beds in various parts of Asia.^[10]

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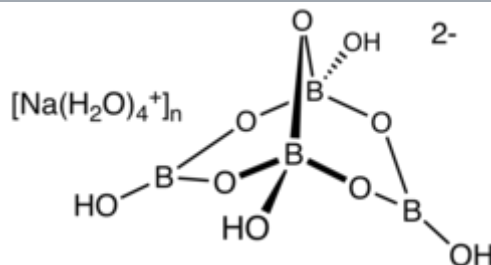
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Names

IUPAC name

disodium;3,7-dioxido-2,4,6,8,9-pentaoxa-1,3,5,7-tetraborabicyclo[3.3.1]nonane;decahydrate^[1]

Other names

borax decahydrate
sodium borate decahydrate
sodium tetraborate decahydrate
sodium tetrahydroxy tetraborate
hexahydrate

Identifiers

CAS Number

1303-96-4 (<https://commonchemistry.cas.org/detail?casrn=1303-96-4>)[✓]

3D model (JSmol)

Interactive image (<https://chemapps.stolaf.edu/jmol/jmol.php?model=%5BNa%2B%5D.O0B%28O%29O%5BB-%5D1%28O%29OB%28O%29O%5BB->

Uses

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History

Borax was first discovered in dry lake beds in [Tibet](#). Native tincal from Tibet, [Persia](#), and other parts of Asia was traded via the [Silk Road](#) to the [Arabian Peninsula](#) in the 8th century AD.^[10]

Borax first came into common use in the late 19th century when [Francis Marion Smith's Pacific Coast Borax Company](#) began to market and popularize a large variety of applications under the [20 Mule Team Borax trademark](#), named for the [method](#) by which borax was originally hauled out of the [California and Nevada deserts](#).^{[11][12]}

Etymology

The English word *borax* is Latinized: the [Middle English](#) form was *boras*, from [Old French](#) *boras*, *bourras*. That may have been from [Medieval Latin](#) *baurach* (another English spelling), *borac*(-um/em), *borax*, along with [Spanish](#) *borrax* (> *borraj*) and [Italian](#) *borrace*, in the 9th century.

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<div>ChEBI</div>	<div>CHEBI:86222 (https://www.ebi.ac.uk/chebi/searchId.do?chebiId=86222)</div>
<div>ChEMBL</div>	<div>ChEMBL3833375 (https://www.ebi.ac.uk/chembl/db/index.php/compound/inspect/ChEMBL3833375)</div>
<div>ChemSpider</div>	<div>17339255 (https://www.chemspider.com/Chemical-Structure.17339255.html)</div>
<div>EC Number</div>	<div>603-411-9 (https://echa.europa.eu/substance-information/-/substanceinfo/100.129.152)^[1]</div>
<div>E number</div>	<div>E285 (preservatives)</div>
<div>KEGG</div>	<div>D03243 (https://www.kegg.jp/entry/D03243)</div>
<div>PubChem CID</div>	<div>16211214 (https://pubchem.ncbi.nlm.nih.gov/compound/16211214)</div>
<div>RTECS number</div>	<div>VZ2275000</div>
<div>UNII</div>	<div>91MBZ8H3QO (https://fdas.s.nlm.nih.gov/srs/srsdirect.js?p?regno=91MBZ8H3QO)</div>
<div>InChI</div>	<div><div>InChI=1S/B4O7.2Na.10H2O/c5-1-7-3-9-2(6)10-4(8-1)11-3;;;;;;;;;;/h;;;10*1H2/q-2;2*+1;;;;;;;;;;Key: CDMADVZSLOHIFP-UHFFFAOYSA-N</div><div>InChI=1/B4O7.2Na.10H2O/c5-1-7-3-9-2(6)10-4(8-1)11-3;;;;;;;;;;/h;;;10*1H2/q-2;2*+1;;;;;;;;;;Key: CDMADVZSLOHIFP-UHFFFAOYAP</div></div>
<div>SMILES</div>	<div>[Na+].[Na+].O0B(O)O[B-]1(O)OB(O)O[B-]0(O)O1.O.O.O.O.O.O.O.O</div>
<div>Properties</div>	
<div>Chemical formula</div>	<div>B₄O₇Na₂·10H₂O Na₂B₄O₇·10H₂O B₄H₂₀Na₂O₁₇</div>
<div>Molar mass</div>	<div>381.37 (decahydrate)</div>
<div>Appearance</div>	<div>white, crystalline solid</div>

The words *tincal* and *tincar* were adopted into English in the 17th century from Malay *tingkal* and from Urdu/Persian Arabic *تینکار tinkār/tankār*; thus the two forms in English. These all appear to be related to the Sanskrit टंकण *tāṅkaṇa*.^{[13][14]}

Hydrates

The term *borax* properly refers to the so called decahydrate $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$, more correctly written $\text{Na}_2\text{B}_4\text{O}_5(\text{OH})_4 \cdot 8\text{H}_2\text{O}$. However, the term may be applied also to the related compounds

Borax pentahydrate

Borax pentahydrate has the formula $\text{Na}_2\text{B}_4\text{O}_7 \cdot 5\text{H}_2\text{O}$, more properly $\text{Na}_2\text{B}_4\text{O}_5(\text{OH})_4 \cdot 3\text{H}_2\text{O}$. It is a colorless solid with density is 1.880 kg/m^3 that crystallizes from water solutions above 60.8°C in the rhombohedral crystal system. It occurs naturally as the mineral tinkhanite.^[15] It can be obtained by heating the decahydrate above 61°C .^[16]

Borax dihydrate

Borax dihydrate has the formula $\text{Na}_2\text{B}_4\text{O}_7 \cdot 2\text{H}_2\text{O}$, more properly $\text{Na}_2\text{B}_4\text{O}_5(\text{OH})_4$. It can be obtained by heating the decahydrate or pentahydrate to above $116\text{--}120^\circ\text{C}$.^[16]

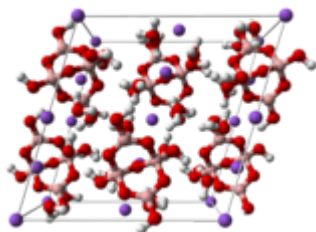
Anhydrous borax

Anhydrous borax is sodium tetraborate proper, with formula $\text{Na}_2\text{B}_4\text{O}_7$. It can be obtained by heating any hydrate to 300°C .^[16] It has one amorphous (glassy) form and three crystalline forms -- α , β , and γ , with melting points of 1015, 993 and 936 K respectively. $\alpha\text{-Na}_2\text{B}_4\text{O}_7$ is the stable form.^[16]

Chemistry

Structure

Density	1.73 g/cm^3 (decahydrate, solid) ^[2]
Melting point	743°C ($1,369^\circ\text{F}$; $1,016 \text{ K}$) (anhydrous) ^[2] 75°C (decahydrate, decomposes) ^[2]
Boiling point	$1,575^\circ\text{C}$ ($2,867^\circ\text{F}$; $1,848 \text{ K}$) (anhydrous) ^[2]
Solubility in water	31.7 g/L ^[2]
Magnetic susceptibility (χ)	$-85.0 \cdot 10^{-6} \text{ cm}^3/\text{mol}$ (anhydrous) ^[2] :p.4.135
Refractive index (n_D)	$n_1=1.447$, $n_2=1.469$, $n_3=1.472$ (decahydrate) ^[2] :p.4.139
Structure ^[3]	
Crystal structure	Monoclinic, mS92, No. 15
Space group	C2/c
Point group	2/m
Lattice constant	$a = 1.1885 \text{ nm}$, $b = 1.0654 \text{ nm}$, $c = 1.2206 \text{ nm}$ $\alpha = 90^\circ$, $\beta = 106.623^\circ$, $\gamma = 90^\circ$
Lattice volume (V)	1.4810 nm^3
Formula units (Z)	4
Pharmacology	
ATC code	S01AX07 (WHO (https://www.whooc.no/atc_ddd_index/?code=S01AX07))
Hazards	
GHS labelling:	
Pictograms	
Hazard statements	H360
Precautionary statements	P201, P308+P313
NFPA 704 (fire diamond)	^[7]
NIOSH (US health exposure limits):	



The structure of borax according to X-ray crystallography.

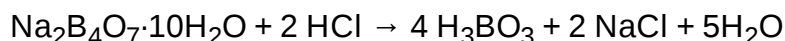
From the chemical perspective, borax contains the $[\text{B}_4\text{O}_5(\text{OH})_4]^{2-}$ ion. In this structure, there are two four-coordinate boron centers and two three-coordinate boron centers.

Physical properties

The crystalline decahydrate is a proton conductor at temperatures above 21 °C. Conductivity is maximum along the *b* axis.^[9]

Reactions

Borax is also easily converted to boric acid and other borates, which have many applications. Its reaction with hydrochloric acid to form boric acid is:



The "decahydrate" is sufficiently stable to find use as a primary standard for acid base titrimetry.^[17]:p.316

Molten borax dissolves many metal oxides to form glasses. This property is important for its uses in metallurgy and for the borax bead test of qualitative chemical analysis.

Solubility

Borax is soluble in a variety of solvents; however, it is notably insoluble in ethanol.^[1]

<u>PEL</u> (Permissible)	none ^[4]
<u>REL</u> (Recommended)	TWA 1 mg/m ³ (anhydrous and pentahydrate) ^{[4][5]} TWA 5 mg/m ³ (decahydrate) ^[6]
<u>IDLH</u> (Immediate danger)	N.D. ^[4]
Related compounds	
Other <u>anions</u>	<u>Sodium aluminate</u>
Other <u>cations</u>	<u>Lithium tetraborate</u>
Related compounds	<u>Boric acid</u> , <u>sodium perborate</u>
Except where otherwise noted, data are given for materials in their <u>standard state</u> (at 25 °C [77 °F], 100 kPa).	
<u>Infobox references</u>	

Solubility of borax decahydrate in some solvents^[18]

Organic solvent	Temperature °C (°F)	Borax decahydrate % by weight in saturated solution
Glycerol 98.5%	20 (68)	52.60
Glycerol 86.5%	20 (68)	47.19
Ethylene glycol	25 (77)	41.60
Diethylene glycol	25 (77)	18.60
Methanol	25 (77)	19.90
Aqueous ethanol 46.5%	15.5 (60)	2.48
Acetone	25 (77)	0.60
Ethyl acetate	25 (77)	0.14

Solubility of borax decahydrate in water^[18]

Temperature °C (°F)	Borax decahydrate % by weight in saturated solution
0 (32)	1.99
5 (41)	2.46
10 (50)	3.09
15 (59)	3.79
20 (68)	4.70
25 (77)	5.80
30 (86)	7.20
35 (95)	9.02
40 (104)	11.22
45 (113)	14.21
50 (122)	17.91
55 (131)	23.22
60 (140)	30.32
65 (149)	33.89
70 (158)	36.94
75 (167)	40.18
80 (176)	44.31
85 (185)	48.52
90 (194)	53.18
95 (203)	58.94
100 (212)	65.63

Natural sources

Borax occurs naturally in evaporite deposits produced by the repeated evaporation of seasonal lakes. The most commercially important deposits are found in: Turkey; Boron, California; and Searles Lake, California. Also, borax has been found at many other locations in the Southwestern United States, the Atacama desert in Chile, newly discovered deposits in Bolivia, and in Tibet and Romania. Borax can also be produced synthetically from other boron compounds.



Borax "cottonball"

Naturally occurring borax (known by the trade name Rasorite-46 in the United States and many other countries) is refined by a process of recrystallization.^[19]

Uses



Borax-based laundry detergent

Ant control

Borax is used in control solutions because it is toxic to ants. Because it is slow-acting, worker ants will carry the borax to their nests and poison the rest of the colony.^[20]



Traction steam engine hauling borax, Death Valley National Park, California, 1904

Household products

Borax is used in various household laundry and cleaning products,^{[21][22]} including the 20 Mule Team Borax laundry booster, Boraxo powdered hand soap, and some tooth bleaching formulas.^{[23][24]}

pH buffer

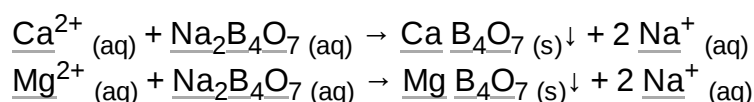
Borate ions (commonly supplied as boric acid) are used in biochemical and chemical laboratories to make buffers, e.g. for polyacrylamide gel electrophoresis of DNA and RNA, such as TBE buffer (borate buffered tris-hydroxymethylaminomethonium)^{[25][26]} or the newer SB buffer or BBS buffer (borate buffered saline) in coating procedures. Borate buffers (usually at pH 8) are also used as preferential equilibration solution in dimethyl pimelimidate (DMP) based crosslinking reactions.

Co-complexing agent

Borax as a source of borate has been used to take advantage of the co-complexing ability of borate with other agents in water to form complex ions with various substances. Borate and a suitable polymer bed are used to chromatograph non-glycated hemoglobin differentially from glycated hemoglobin (chiefly HbA1c), which is an indicator of long-term hyperglycemia in diabetes mellitus.

Water-softening agent

Borax alone does not have a high affinity for the hardness cations, although it has been used for water-softening. Its chemical equation for water-softening is given below:



The sodium ions introduced do not make water 'hard'. This method is suitable for removing both temporary and permanent types of hardness.

Flux

A mixture of borax and ammonium chloride is used as a flux when welding iron and steel. It lowers the melting point of the unwanted iron oxide (scale), allowing it to run off. Borax is also used mixed with water as a flux when soldering jewelry metals such as gold or silver, where it allows the molten solder to wet the metal and flow evenly into the joint. Borax is also a good flux for "pre-tinning" tungsten with zinc — making the tungsten soft-solderable.^[27] Borax is often used as a flux for forge welding.^[28]

Small-scale gold mining

In artisanal gold mining, borax is sometimes used as part of a process known as the borax method (as a flux) meant to eliminate the need for toxic mercury in the gold extraction process, although it cannot directly replace mercury. Borax was reportedly used by gold miners in parts of the Philippines in the 1900s.^{[29][30]} There is evidence that, in addition to reducing the environmental impact, this method achieves better gold recovery for suitable ores and is less expensive. This borax method is used in northern Luzon in the Philippines, but miners have been reluctant to adopt it elsewhere for reasons that are not well understood.^[31] The method has also been promoted in Bolivia^[32] and Tanzania.^[33]



Old steam tractor and borax wagons, Death Valley National Park

Flubber

A rubbery polymer sometimes called Slime, Flubber, 'gluep' or 'glurch' (or erroneously called Silly Putty, which is based on silicone polymers), can be made by cross-linking polyvinyl alcohol with borax. Making flubber from polyvinyl acetate-based glues, such as Elmer's Glue, and borax is a common elementary-science demonstration.^{[34][35]}

Food additive

Borax, given the E number E285, is used as a food additive, but is banned in some countries, such as Australia, China, Thailand and the United States.^[36] As a consequence, certain foods, such as caviar, produced for sale in the United States contain higher levels of salt to assist preservation.^[37]

In addition to its use as a preservative, borax imparts a firm, rubbery texture to food. In China, borax (Chinese: 硼砂; pinyin: péng shā or Chinese: 月石; pinyin: yuè shí) has been found in foods including wheat and rice noodles named lamian (Chinese: 拉面; pinyin: lāmiàn), shahe fen (Chinese: 沙河粉; pinyin: shāhéfěn), char kway teow (Chinese: 粿條; pinyin: guǒ tiáo), and chee cheong fun (Chinese: 腸粉; pinyin: chángfěn)^[38] In Indonesia, it is a common, but forbidden,^[39] additive to such foods as noodles, bakso (meatballs), and steamed rice.

When consumed with boric acid, numerous studies have demonstrated an inverse correlation between borax and various types of cancers.^[40] Boric acid and borax are low in toxicity for acute oral exposures, at approximately the same acute toxicity as salt. The average dose for asymptomatic ingestion cases, which accounts for 88% of all ingestions, is around 0.9 grams. However, the range of reported asymptomatic doses is wide, from 0.01 to 88.8 g.^[41]

Other uses

- Ingredient in enamel glazes^[42]
- Component of glass, pottery, and ceramics^[43]
- Used as an additive in ceramic slips and glazes to improve fit on wet, greenware, and bisque
- Fire retardant^[44]
- Anti-fungal compound for cellulose insulation^[45]
- Moth proofing 10% solution for wool^[45]
- Pulverized for the prevention of stubborn pests (e.g. German cockroaches) in closets, pipe and cable inlets, wall panelling gaps, and inaccessible locations where ordinary pesticides are undesirable^[46]
- Precursor for sodium perborate monohydrate that is used in detergents, as well as for boric acid and other borates
- Tackifier ingredient in casein, starch and dextrin based adhesives^[47]
- Precursor for boric acid, a tackifier ingredient in polyvinyl acetate, polyvinyl alcohol based adhesives
- To make indelible ink for dip pens by dissolving shellac into heated borax
- Curing agent for snake skins
- Curing agent for salmon eggs, for use in sport fishing for salmon^[48]
- Swimming pool buffering agent to control pH^[49]
- Neutron absorber, used in nuclear reactors and spent fuel pools to control reactivity and to shut down a nuclear chain reaction^[50]
- As a micronutrient fertilizer to correct boron-deficient soils.^{[51][52]}
- Preservative in taxidermy^[53]
- To color fires with a green tint^[54]
- Was traditionally used to coat dry-cured meats such as hams to improve the appearance and discourage flies.^{[55][56][57]}
- Used by blacksmiths in forge welding^[28]
- Used as a flux for melting metals and alloys in casting to draw out impurities and prevent oxidation.
- Used as a woodworm treatment (diluted in water)
- In Particle Physics as an additive to Nuclear emulsion, to extend the latent image lifetime of charged particle tracks. The first observation of the pion, which was awarded the 1950 Nobel Prize, used this type of emulsion.^{[58][59]}



Rio Tinto borax mine pit, Boron, California

Toxicity

Borax, sodium tetraborate decahydrate, according to one study, is not acutely toxic. Its LD₅₀ (median lethal dose) score is tested at 2.66 g/kg in rats, meaning that a significant dose of the chemical is needed to cause severe symptoms or death. The lethal dose is not necessarily the same for humans. On pesticide information websites it is listed as a non-lethal compound and of no hazardous concerns.

Borax has been in use as an insecticide in the United States with various restrictions since 1946. All restrictions were removed in February 1986 due to the low toxicity of borax, as reported in two EPA documents relating to boric acid and borax.^{[60][61]}

EPA has determined that, because they are of low toxicity and occur naturally, boric acid and its sodium salts should be exempted from the requirement of a tolerance (maximum residue limit) for all raw agricultural commodities.^[60]

Although it cited inconclusive data, a re-evaluation in 2006 by the EPA still found that "There were no signs of toxicity observed during the study and no evidence of cytotoxicity to the target organ."^[62] In the reevaluation, a study of toxicity due to overexposure was checked and the findings were that "The residential handler inhalation risks due to boric acid and its sodium salts as active ingredients are not a risk concern and do not exceed the level of concern..." but that there could be some risk of irritation to children inhaling it if used as a powder for cleaning rugs.

Sodium tetraborate decahydrate has no known hazard issues.^[63]

Overexposure to borax dust can cause respiratory irritation, while no skin irritation is known to exist due to external borax exposure. Ingestion may cause gastrointestinal distress including nausea, persistent vomiting, abdominal pain, and diarrhea. Effects on the vascular system and human brain include headaches and lethargy, but are less frequent. In severe cases, a "beefy" red rash affecting the palms, soles, buttocks and scrotum has occurred.^[64]

Possible carcinogen

The Indonesian Directorate of Consumer Protection warns of the risk of liver cancer with high consumption of borax over a period of 5–10 years.^[57]

Risk to fertility and pregnancy

Borax was added to the Substance of Very High Concern (SVHC) candidate list on December 16, 2010. The SVHC candidate list is part of the EU Regulations on the Registration, Evaluation, Authorisation and Restriction of Chemicals 2006 (REACH), and the addition was based on the revised classification of borax as *toxic for reproduction* category 1B under the CLP Regulations. Substances and mixtures imported into the EU which contain borax are now required to be labelled with the warnings "May damage fertility" and "May damage the unborn child".^[65] It was proposed for addition to REACH Annex XIV by the ECHA on July 1, 2015.^[66] If this recommendation is approved, all imports and uses of borax in the EU will have to be authorized by the ECHA.

Review of the boron toxicity (as boric acid and borates) published 2012 in *Journal of Toxicology and Environmental Health* concluded: "It clearly appears that human B [boron] exposures, even in the highest exposed cohorts, are too low to reach the blood (and target tissue) concentrations that would be required to exert adverse effects on reproductive functions."^[67]

A draft risk assessment released by Health Canada in July 2016 has found that overexposure to boric acid has the potential to cause developmental and reproductive health effects. Since people are already exposed to boric acid naturally through their diets and water, Health Canada advised that exposure from other sources should be reduced as much as possible, especially for children and pregnant women. The concern is not with any one product, but rather multiple exposures from a variety of sources. With this in mind, the department also announced that registrations for certain pesticides that contain boric acid, which are commonly used in homes, will have their registrations cancelled and be phased out of the marketplace. As well, new, more protective label directions are being introduced for other boric acid pesticides that continue to be registered in Canada (for example, enclosed bait stations and spot treatments using gel formulations).^[68]

See also

- Borax bead test
- John Veatch
- List of cleaning agents
- Sodium borohydride
- Ulexite

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External links

- [International Chemical Safety Card 0567 \(https://www.ilo.org/dyn/icsc/showcard.display?p_lang=en&p_card_id=0567&p_version=2\)](https://www.ilo.org/dyn/icsc/showcard.display?p_lang=en&p_card_id=0567&p_version=2)
 - [International Chemical Safety Card 1229 \(https://www.ilo.org/dyn/icsc/showcard.display?p_lang=en&p_card_id=1229&p_version=2\)](https://www.ilo.org/dyn/icsc/showcard.display?p_lang=en&p_card_id=1229&p_version=2) (fused borax)
 - [National Pollutant Inventory – Boron and compounds \(https://web.archive.org/web/20060209040519/http://www.npi.gov.au/database/substance-info/profiles/15.html\)](https://web.archive.org/web/20060209040519/http://www.npi.gov.au/database/substance-info/profiles/15.html)
 - [NIOSH Pocket Guide to Chemical Hazards \(https://www.cdc.gov/niosh/npg/npgd0058.html\)](https://www.cdc.gov/niosh/npg/npgd0058.html)
 - [Sodium Borate in sefsc.noaa.gov \(https://web.archive.org/web/20020821230321/http://www.sefsc.noaa.gov/HTMLdocs/SodiumBorate.htm\)](https://web.archive.org/web/20020821230321/http://www.sefsc.noaa.gov/HTMLdocs/SodiumBorate.htm)
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