

The Standard States of Elements

The standard states of elements are the forms that they adopt at a temperature of 25°C and pressure of 1 atmosphere (1 atm).

These forms of the elements are the reactants in the formation equations of multi-element substances.

The heat of formation (ΔH_f°) of an element in its standard state is zero.

Below is the list of the elements whose standard states you need to know for this course. Please note that some elements have multiple possible forms at the standard state such as carbon, which can be either graphite or diamond. However only one of these forms is the true standard state; in those cases the proper state will be listed next to the formula for the element.

Gases

- Hydrogen $\text{H}_2(\text{g})$
- Nitrogen $\text{N}_2(\text{g})$
- Oxygen $\text{O}_2(\text{g})$
- Fluorine $\text{F}_2(\text{g})$
- Chlorine $\text{Cl}_2(\text{g})$

Liquids

- Bromine $\text{Br}_2(\ell)$
- Mercury $\text{Hg}(\ell)$

Solids

There are two distinct classes of elemental solids. Molecular solids, unlike other elemental solids, have specific molecular structures (arrangements of bonded atoms) that are packed close to each other (held by van der Waals forces) to form the solid. The atoms of a molecular solid are only bonded to the other atoms in their specific molecule, unlike the elements in the other elemental solids, which are bound to all their nearest neighboring elements.

Molecular Solids

- Phosphorus P_4 - white
- Sulfur $\text{S}_8(\text{s})$ - rhombic
- Iodine $\text{I}_2(\text{s})$

Solids (Non-Metal)

- Silicon $\text{Si}(\text{s})$
- Carbon $\text{C}(\text{s})$ - graphite

Solids (Metal)

Lithium	Li(s)	Iron	Fe(s)
Magnesium	Mg(s)	Nickel	Ni(s)
Sodium	Na(s)	Copper	Cu(s)
Calcium	Ca(s)	Zinc	Zn(s)
Potassium	K(s)	Silver	Ag(s)
Aluminum	Al(s)	Gold	Au(s)

Common Ionic Species in Aqueous Solution

Below is the list of common aqueous ions that you are expected to know for this course. You need to know the name, formula, and charge of each ion as the names and formulas will be used interchangeably in homework and exam questions.

Cations (positively charged ions)

Lithium ion	Li ⁺	Nickel(II) ion	Ni ²⁺
Sodium ion	Na ⁺	Copper(II) ion	Cu ²⁺
Potassium ion	K ⁺	Lead(II) ion	Pb ²⁺
Silver ion	Ag ⁺	Aluminum ion	Al ³⁺
Copper(I) ion	Cu ⁺	Chromium(II) ion	Cr ²⁺
Hydronium ion	H ₃ O ⁺	Chromium(III) ion	Cr ³⁺
Ammonium ion	NH ₄ ⁺	Iron(II) ion	Fe ²⁺
Zinc ion	Zn ²⁺	Iron(III) ion	Fe ³⁺
Cadmium ion	Cd ²⁺	Cobalt(II) ion	Co ²⁺
Magnesium ion	Mg ²⁺	Cobalt(III) ion	Co ³⁺
Calcium ion	Ca ²⁺	Tin(II) ion	Sn ²⁺
Barium ion	Ba ²⁺	Tin(IV) ion	Sn ⁴⁺
Mercury (I) ion	Hg ₂ ²⁺	Manganese ion	Mn ²⁺
Mercury(II) ion	Hg ²⁺	Manganese(IV) ion	Mn ⁴⁺

Anions (negatively charged ions)

Fluoride ion	F^-	Perchlorate	ClO_4^-
Bromide ion	Br^-	Sulfide	S^{2-}
Iodide ion	I^-	Sulfite	SO_3^{2-}
Oxide	O^{2-}	Sulfate	SO_4^{2-}
Hydroxide	OH^-	Hydrogen sulfate	HSO_4^-
Nitride	N^{3-}	Phosphate	PO_4^{3-}
Nitrite	NO_2^-	Hydrogen phosphate	HPO_4^{2-}
Nitrate	NO_3^-	Dihydrogen phosphate	$H_2PO_4^-$
Cyanide	CN^-	Carbonate	CO_3^{2-}
Chloride ion	Cl^-	Hydrogen carbonate	HCO_3^-
Hypochlorite	ClO^-	Acetate	$CH_3CO_2^-$
Chlorite	ClO_2^-	Permanganate	MnO_4^-
Chlorate	ClO_3^-	Molybdate	MoO_4^{2-}