

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 $\text{Br}(\text{l})$
- Mercury $\text{Hg}(\text{l})$

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 crystal
- 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)
- Magnesium Mg(s)
- Sodium Na(s)
- Calcium Ca(s)
- Potassium K(s)
- Aluminum Al(s)
- Iron Fe(s)
- Nickel Ni(s)
- Copper Cu(s)
- Zinc Zn(s)
- Silver Ag(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^+
• Sodium ion	Na^+
• Potassium ion	K^+
• Silver ion	Ag^+
• Copper(I) ion	Cu^+
• Hydronium ion	H_3O^+
• Ammonium ion	NH_4^+
• Zinc ion	Zn^{2+}
• Cadmium ion	Cd^{2+}
• Magnesium ion	Mg^{2+}
• Calcium ion	Ca^{2+}
• Barium ion	Ba^{2+}
• Mercury(II) ion	Hg^{2+}
• Nickel(II) ion	Ni^{2+}
• Copper(II) ion	Cu^{2+}
• Lead(II) ion	Pb^{2+}
• Aluminum ion	Al^{3+}
• Chromium(II) ion	Cr^{2+}
• Chromium(III) ion	Cr^{3+}
• Iron(II) ion	Fe^{2+}
• Iron(III) ion	Fe^{3+}
• Cobalt(II) ion	Co^{2+}
• Cobalt(III) ion	Co^{3+}
• Tin(II) ion	Sn^{2+}
• Tin(IV) ion	Sn^{4+}
• Manganese ion	Mn^{2+}
• Manganese(IV) ion	Mn^{4+}

Anions (negatively charged ions)

• Fluoride ion	F^-
• Bromide ion	Br^-
• Iodide ion	I^-
• Oxide	O^{2-}
• Hydroxide	OH^-
• Nitride	N^{3-}
• Nitrite	NO_2^-

• Nitrate	NO_3^-
• Cyanide	CN^-
• Chloride ion	Cl^-
• Hypochlorite	ClO^-
• Chlorite	ClO_2^-
• Chlorate	ClO_3^-
• Perchlorate	ClO_4^-
• Sulfide	S^{2-}
• Sulfite	SO_3^{2-}
• Sulfate	SO_4^{2-}
• Hydrogen sulfate	HSO_4^- (also called bisulfate)
• Phosphate	PO_4^{3-}
• Hydrogen phosphate	HPO_4^{2-}
• Dihydrogen phosphate	H_2PO_4^-
• Carbonate	CO_3^{2-}
• Hydrogen carbonate	HCO_3^- (also called bicarbonate)
• Acetate	CH_3CO_2^-
• Permanganate	MnO_4^-
• Molybdate	MoO_4^{2-}