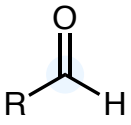
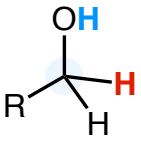
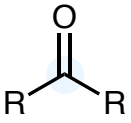
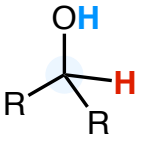
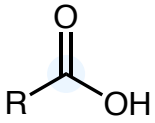
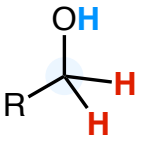
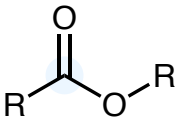
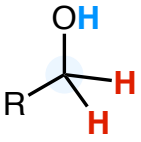
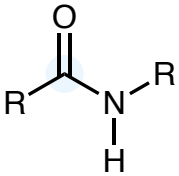
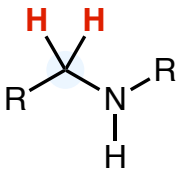
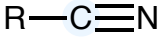
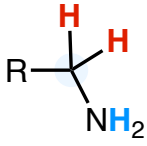
Reduction and Oxidation

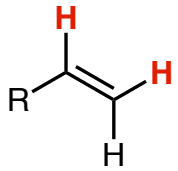
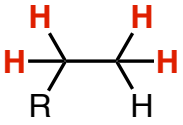
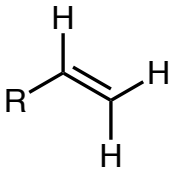
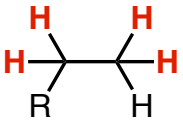
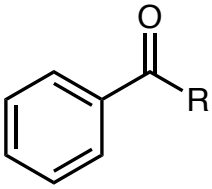
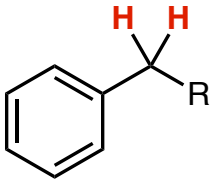
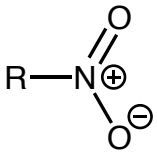
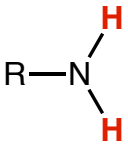
This Core Concept Sheet covers common reduction and oxidation reactions in organic chemistry.

Reduction is commonly described as a decrease in oxidation state for carbon atom(s). Often, this results in an **increase in the number of C—H bonds and/or** a **decrease in the number of C—O bonds**.

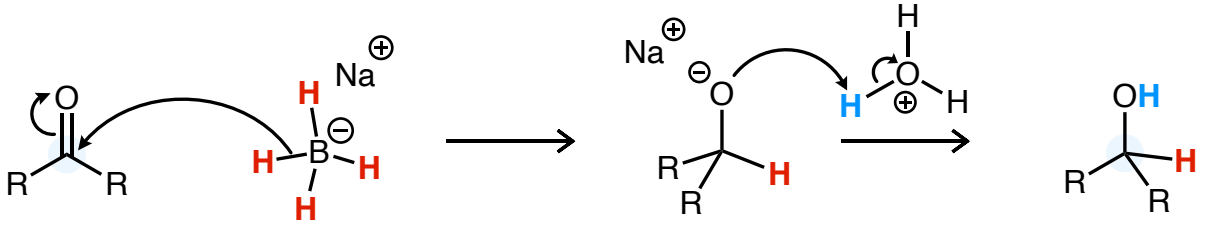
The table below shows the most common reductions you will see. It is important to recognize that **$NaBH_4$ is a weaker reducing agent than $LiAlH_4$** and, as shown below, $NaBH_4$ does not reduce carboxylic acids, esters, amides, or nitriles.

Functional Group	Structure	Conditions for Reduction →			Reduction Product	
aldehyde		1. $NaBH_4$ 2. H_3O^+	*or*	1. $LiAlH_4$ 2. H_3O^+		1° alcohol
ketone		1. $NaBH_4$ 2. H_3O^+	*or*	1. $LiAlH_4$ 2. H_3O^+		2° alcohol
carboxylic acid		—		1. $LiAlH_4$ 2. H_3O^+		1° alcohol
ester		—		1. $LiAlH_4$ 2. H_3O^+		1° alcohol
amide		—		1. $LiAlH_4$ 2. H_3O^+		amine
nitrile		—		1. $LiAlH_4$ 2. H_3O^+		1° amine

The table below shows the reduction of unsaturated carbon systems, such as alkynes, alkenes, and acylbenzenes. Note that H_2/Pt are strongly reducing conditions capable of reducing all the the functional groups below.

Functional Group	Structure	Conditions for Reduction →	Reduction Product	
alkyne		H_2, Lindlar's catalyst		alkene
alkyne		H_2, Pt		alkane
alkene		H_2, Pt		alkane
acylketone		H_2, Pt (or Clemmensen reduction, or Wolff-Kishner reduction)		alkane
nitro group		H_2, Pt		amine

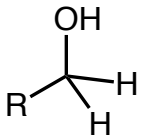
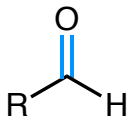
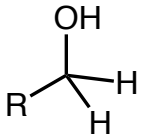
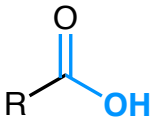
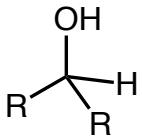
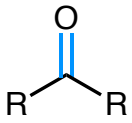
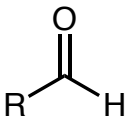
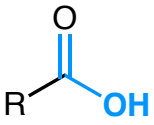
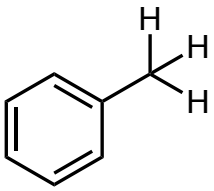
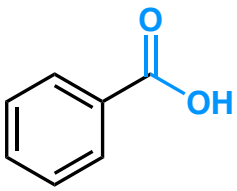
Example Mechanism for Reduction of a Carbonyl



ketone $NaBH_4$ tetrahedral intermediate **2º alcohol**

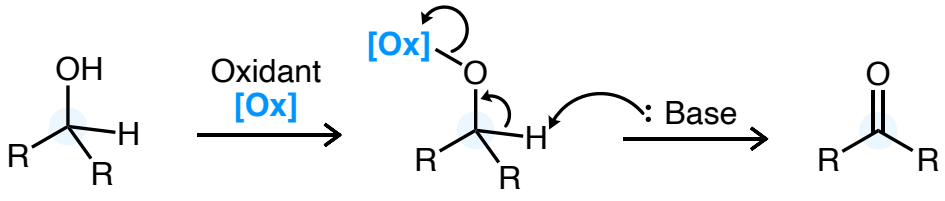
Oxidation is commonly described as an increase in oxidation state for carbon atom(s). Often, this results in a **decrease in the number of C—H bonds and/or** an **increase in the number of C—O bonds**.

The table below shows the most common oxidations you will see. Similar to the reduction conditions, we must recognize that **$KMnO_4$ is a stronger oxidant than Swern or PCC oxidation**. In some cases, only the stronger oxidant is suitable (see the benzylic C—H oxidation). In others (see the 1° alcohol oxidations), different oxidation conditions result in different products.

Functional Group	Structure	Conditions for Oxidation →	Oxidation Product	
1° alcohol		**PCC**, **DMP**, or **Swern**		aldehyde
1° alcohol		1. **KMnO$_4$**, NaOH 2. H_3O^+		carboxylic acid
2° alcohol		**PCC**, **DMP**, or **Swern** (or can use $KMnO_4$ conditions)		ketone
aldehyde		1. **KMnO$_4$**, NaOH 2. H_3O^+		carboxylic acid
benzylic C-H		1. **KMnO$_4$**, NaOH 2. H_3O^+		aryl carboxylic acid

Example Mechanism for Oxidation of an Alcohol

Note: Although the initial steps and specific structures will depend on the oxidizing agent used (PCC, DMP, etc.), **the general flow of electrons to produce a new C=O π bond will remain similar.**



2° alcohol **ketone**