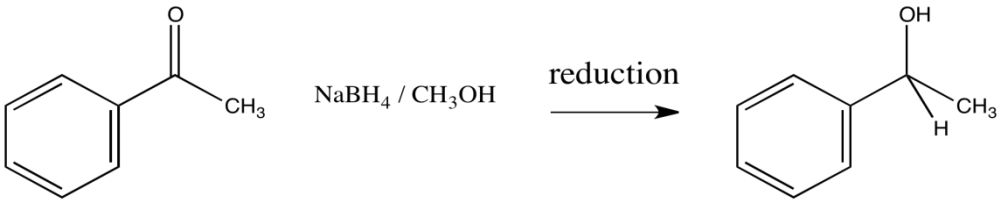
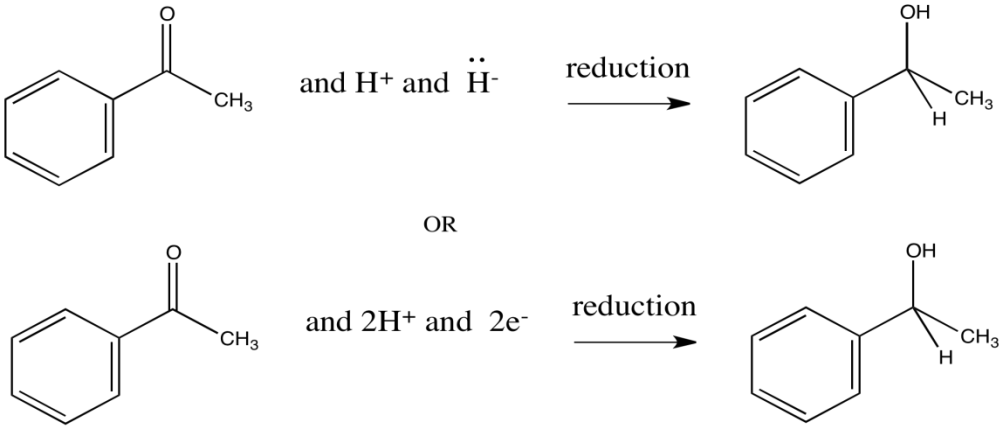
ORGANIC OXIDATION

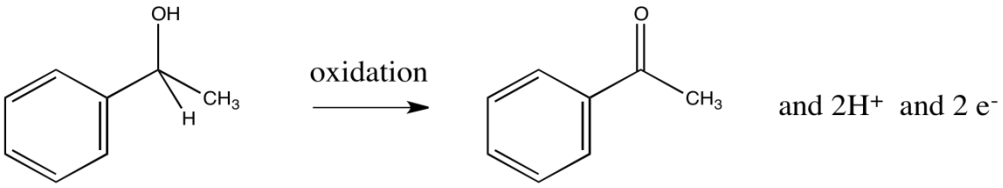
You may recall that conversion of an aldehyde or ketone to an alcohol is referred to as a reduction. The hydride from an NADH molecule or a BH_4^- anion acts as a nucleophile, adding H^- to the carbonyl carbon. A proton source can then protonate the oxygen of the resulting alkoxide ion, forming an alcohol.



In this reduction, two electrons and two protons are donated to the carbonyl compound to produce an alcohol.

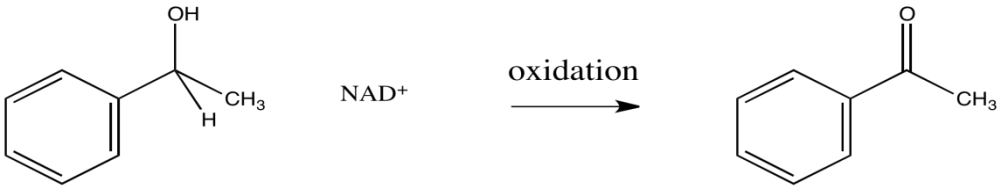


The opposite process, the loss of two protons and two electrons from an alcohol to form a ketone or aldehyde, is an oxidation.



In biological pathways, oxidation is often the microscopic reverse of reduction. That means that the products of a reduction, NAD^+ and an alcohol, could react together under the right circumstances to form NADH and a carbonyl. The reduction of NAD+ by a hydride donor is possible because, although the NAD^+ loses the aromaticity of its nicotinamide ring upon becoming NADH, it also loses its

positive charge. Charge stabilization is frequently an energetic problem for molecules.



Notice that this same argument has been used to look at biological oxidation and reduction in both directions. That's because each side of the equation has some energetic advantage. The NAD^+ is aromatic. The NADH is neutral. This is a well-balanced system energetically, and the balance of the reaction can be tipped in either direction. The direction of the reaction is influenced by the surroundings.

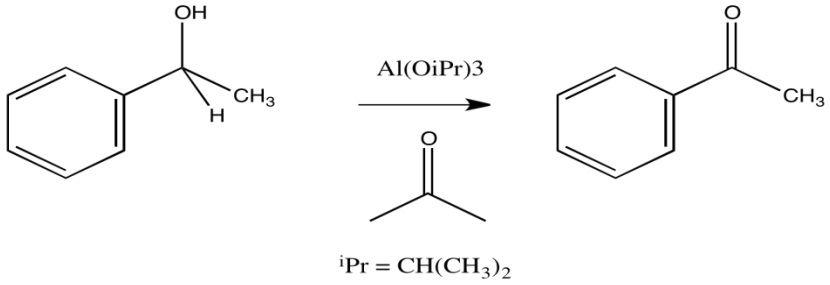
In biology, NADH and NAD^+ are just cofactors in a reaction. A reduction would take place in an enzyme that specifically carries out reductions, and an oxidation would occur in an enzyme specific for the oxidation. The enzyme is just a large protein that holds the substrate (such as the alcohol) and cofactor (such as NAD^+) together in close proximity. Acidic and basic sites are provided by nearby amino acid residues, and other amino acid side chains may push the reactants into optimum position for one reaction or another.

In the laboratory, enzymes and cofactors can sometimes be added to reaction flasks in order to oxidize or reduce substrates. Sometimes these reactions are not convenient, however. In addition, there are a number of other ways to carry out oxidations and reductions. For example, addition of a hydride could be accomplished via addition of sodium borohydride. That would result in reduction of a carbonyl to an alcohol.

By analogy to the NADH / NAD^+ approach in nature, the easiest way to oxidize an alcohol to a carbonyl would be to remove a hydride and a proton. Nature uses enzymes to bring reactants together for transformations like this. In the laboratory, metals are often used to bring two reactants together. This is sometimes true in enzymes, too: a metal at the enzyme active site may tether two molecules together, or even activate one so that it is ready to react. Metals can "hold onto" reactants because molecules with lone pairs will often coordinate to metals; a lone pair is shared with the electrophilic metal.

In a process known as an Oppenauer oxidation, a Lewis acidic metal such as aluminum is used for this tethering role. Aluminum tris(isopropoxide), $Al(OCH(CH_3)_2)_3$ carries out the oxidation of an alcohol when dissolved in acetone or

propanone, $(CH_3)_2C=O$. In this reaction, the acetone is a sacrificial oxidant. When both the alcohol and a molecule of acetone are coordinated to the aluminum, a hydride is transferred from the alcohol carbon to the carbonyl carbon of the coordinated acetone. The alcohol is converted to an aldehyde or ketone and the acetone is converted to isopropanol.



Source : http://employees.csbsju.edu/cschaller/Reactivity/carbonyl/COoxdn.htm