**CATALYSIS**

Catalysts can be divided into two types: homogeneous and heterogeneous.

Homogeneous catalysts occupy the same phase as the reaction mixture, while heterogeneous catalysts occupy a different phase.

Homogeneous catalysts allow for greater interaction with the reaction mixture than heterogeneous catalysts.

**Terms**

Homogeneous mixture A substance that is uniform in composition.

Catalyst. A substance that increases the rate of a chemical reaction without being consumed in the process.

Catalysts are compounds that, when added to chemical reactions, reduce the activation energy and increase the reaction rate. The amount of a catalyst does not change during a reaction, as it is not consumed as part of the reaction process. Catalysts lower the energy required to reach the transition state of the reaction, allowing more molecular interactions to achieve that state. However, catalysts do not affect the degree to which a reaction progresses. In other words, though catalysts affect reaction kinetics, the equilibrium state remains unaffected.

Catalysts can be classified into two types: homogeneous and heterogeneous. Homogeneous catalysts are those which exist in the same phase (gas or liquid) as the reactants, while heterogeneous catalysts are not in the same phase as the reactants. Typically, heterogeneous catalysis involves the use of solid catalysts placed in a liquid reaction mixture.

**Transition metal-catalysis**

Mechanism for the hydrogenation of an alkene catalyzed by the homogeneous catalyst [Wilkinson's catalyst](https://en.wikipedia.org/wiki/Wilkinson%27s_catalyst).

**Hydrogenation and related reactions**

A prominent class of reductive transformations are [hydrogenations](https://en.wikipedia.org/wiki/Hydrogenation). In this process, H2 added to unsaturated substrates. A related methodology, [transfer hydrogenation](https://en.wikipedia.org/wiki/Transfer_hydrogenation), involves by transfer of hydrogen from one substrate (the hydrogen donor) to another (the hydrogen acceptor). Related reactions entail "HX additions" where X = silyl ([hydrosilylation](https://en.wikipedia.org/wiki/Hydrosilylation" \o "Hydrosilylation)) and CN ([hydrocyanation](https://en.wikipedia.org/wiki/Hydrocyanation" \o "Hydrocyanation)). Most large-scale industrial hydrogenations - margerine, ammonia, benzene-to-cyclohexane - are conducted with heterogeneous catalysts. Fine chemical syntheses, however, often rely on homogeneous catalysts.

**Carbonylations**

[Hydroformylation](https://en.wikipedia.org/wiki/Hydroformylation), a prominent form of [carbonylation](https://en.wikipedia.org/wiki/Carbonylation), involves the addition of H and "C(O)H" across a double bond. This process is almost exclusively conducted with soluble rhodium- and cobalt-containing complexes.[[6]](https://en.wikipedia.org/wiki/Homogeneous_catalysis#cite_note-6)

A related carbonylation is the conversion of alcohols to carboxylic acids. [MeOH](https://en.wikipedia.org/wiki/Methanol" \o "Methanol) and [CO](https://en.wikipedia.org/wiki/Carbon_monoxide) react in the presence of homogeneous catalysts to give [acetic acid](https://en.wikipedia.org/wiki/Acetic_acid), as practiced in the [Monsanto process](https://en.wikipedia.org/wiki/Monsanto_process) and [Cativa processes](https://en.wikipedia.org/wiki/Cativa_process" \o "Cativa process). Related reactions include [hydro carboxylation](https://en.wikipedia.org/wiki/Hydrocarboxylation) and [hydroesterifications](https://en.wikipedia.org/wiki/Hydroesterification).

Polymerization and metathesis of alkenes

A number of polyolefins, e.g. polyethylene and polypropylene, are produced from ethylene and propylene by [Ziegler-Natta catalysis](https://en.wikipedia.org/wiki/Ziegler-Natta_catalysis). Heterogeneous catalysts dominate, but many soluble catalysts are employed especially for stereospecific polymers.[[7]](https://en.wikipedia.org/wiki/Homogeneous_catalysis#cite_note-7) [Olefin metathesis](https://en.wikipedia.org/wiki/Olefin_metathesis) is usually catalyzed heterogeneously in industry, but homogeneous variants are valuble in fine chemical synthesis.[[8]](https://en.wikipedia.org/wiki/Homogeneous_catalysis#cite_note-8)

**Oxidations**

Homogeneous catalysts are also used in a variety of oxidations. Is the [Wacker process](https://en.wikipedia.org/wiki/Wacker_process" \o "Wacker process), acetaldehyde is produced from [ethylene](https://en.wikipedia.org/wiki/Ethylene) and [oxygen](https://en.wikipedia.org/wiki/Oxygen). Many non-organometallic complexes are also widely used in catalysis, e.g. for the production of [terephthalic acid](https://en.wikipedia.org/wiki/Terephthalic_acid" \o "Terephthalic acid) from [xylene](https://en.wikipedia.org/wiki/Xylene). Alkenes are epoxidized and dihydroxylated by metal complexes, as illustrated by the [Halcon Process](https://en.wikipedia.org/w/index.php?title=Halcon_Process&action=edit&redlink=1" \o "Halcon Process (page does not exist)) and the [Sharpless dihydroxylation](https://en.wikipedia.org/wiki/Sharpless_dihydroxylation" \o "Sharpless dihydroxylation).

**Enzymes (including metalloenzymes)**

[Enzymes](https://en.wikipedia.org/wiki/Enzyme) are homogeneous catalysts that are essential for life but are also harnessed for industrial processes. A well-studied example is [carbonic anhydrase](https://en.wikipedia.org/wiki/Carbonic_anhydrase), which catalyzes the release of CO2 into the lungs from the bloodstream. [Enzymes](https://en.wikipedia.org/wiki/Enzyme) possess properties of both homogeneous and heterogeneous catalysts. As such, they are usually regarded as a third, separate category of catalyst. Water is a common reagent in enzymatic catalysis. Esters and amides are slow to hydrolyse in neutral water, but the rates are sharply affected by [metalloenzymes](https://en.wikipedia.org/wiki/Metalloenzyme), which can be viewed as large coordination complexes. Acrylamide is prepared by the enzyme-catalyzed hydrolysis of [acrylonitrile](https://en.wikipedia.org/wiki/Acrylonitrile).[[9]](https://en.wikipedia.org/wiki/Homogeneous_catalysis#cite_note-Ullmann-9) US demand for acrylamide was 253,000,000 pounds (115,000,000 kg) as of 2007.

**Advantages and Disadvantages**

**Advantages**

• Homogeneous catalysts are generally more selective than heterogeneous catalysts.  
• For exothermic processes, homogeneous catalysts dump heat into the solvent.  
• Homogeneous catalysts are easier to characterize precisely, so their reaction mechanisms are amenable to rational manipulation.[[10]](https://en.wikipedia.org/wiki/Homogeneous_catalysis#cite_note-10)

**Disadvantages**

• The separation of homogeneous catalysts from products can be challenging. In some cases involving high activity catalysts, the catalyst is not removed from the product. In other cases, organic products are sufficiently volatile than they can be separated by distillation.  
• Homogeneous catalyst have limited thermal stability compared to heterogeneous catalysts. Many organometallic complexes degrade <100 °C. Some [pincer-based catalysts](https://en.wikipedia.org/wiki/Pincer_complex), however, operate near 200 °C.[[1](https://en.wikipedia.org/wiki/Homogeneous_catalysis#cite_note-11)]

Examples of Homogeneous Catalysts

Acid catalysis, organometallic catalysis, and enzymatic catalysis are examples of homogeneous catalysis. Most often, homogeneous catalysis involves the introduction of an aqueous phase catalyst into an aqueous solution of reactants. In such cases, acids and bases are often very effective catalysts, as they can speed up reactions by affecting bond polarization.

An advantage of homogeneous catalysis is that the catalyst mixes into the reaction mixture, allowing a very high degree of interaction between catalyst and reactant molecules. However, unlike with heterogeneous catalysis, the homogeneous catalyst is often irrecoverable after the reaction has run to completion.

Homogeneous catalysts are used in variety of industrial applications, as they allow for an increase in reaction rate without an increase in temperature.