Fuzionaire
DIAGNOSTICS

Catalysis is a fundamental process that drives our world.

Catalysis is responsible for the production of the most important industrial chemicals. It is employed in manufacturing over 80% of the products that people use every day, including pharmaceuticals, fertilizers, ethanol, and plastics. Catalysts even turn milk into yogurt.

Catalysis is also relevant to many aspects of environmental science. Catalytic converters use expensive metals like platinum and palladium as catalysts in a reaction that changes poisonous molecules from a vehicle's exhaust – like carbon monoxide and nitrogen oxides – into less harmful carbon dioxide and nitrogen.

Catalytic processes are relied upon globally for **trillions of dollars** per year of industry

15 Nobel Prizes have been related to catalysis.

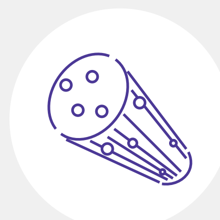
90% of all commercially produced chemical products involve catalysts at some stage of their manufacturing.

Materials You Touch Everyday

Nitrogen and hydrogen combine under pressure to form ammonia—one of the world's most widely used chemicals.

To make ethanol, ethene is mixed with steam and passed over a catalyst of silicon dioxide coated with phosphoric acid.

Nickel is used to transform inedible plant oils to margarine and shortening.



The catalytic converter in a car contains platinum, which serves as a catalyst to change carbon monoxide, which is toxic, into carbon dioxide.

Polyethylene is used to make everything from to garbage bags and grocery bags, to squeezable bottles, to cable insulation.

History of Catalysis

1817
Sir Humphry Davy observed that platinum accelerated certain organic reactions without itself undergoing any change.

1834
Davy's student Michael Faraday demonstrated the ability of platinum to recombine hydrogen and oxygen that had been separated by the electrolysis of water.

1908
The German chemist Fritz Haber combined nitrogen and hydrogen under pressure to form ammonia.

1918
Haber won the 1918 Nobel Prize in Chemistry for his invention of the Haber–Bosch process, an industrial method of synthesizing ammonia.

2001
The 2001 Nobel Prize in Chemistry was awarded to William S. Knowles, Ryoji Noyori and K. Barry Sharpless for their development of catalytic asymmetric synthesis.

2005
Yves Chauvin, Robert H. Grubbs, and Richard R. Schrock won the Nobel Prize in chemistry for discoveries that are now used daily in the chemical industry.

2010
Richard F. Heck, Ei-ichi Negishi, and Akira Suzuki were awarded the 2010 Nobel Prize in Chemistry for palladium-catalyzed cross-couplings in organic synthesis.

How Catalysis Works

Chemical reactions are processes of molecular transformation. The speed at which a chemical reaction happens is typically dependent on temperature, as a specific amount of heat is needed to overcome the “activation energy barrier” required to break bonds between atoms, and execute the transformation.

In the simplest terms, catalysis makes an otherwise impossible transformation occur by helping the reaction overcome the free energy barrier. The energy it takes to make and break bonds is often too high to happen without catalysis.

The other way to think of catalysis is as an alternate route. Catalysts provide a new, lower energy path for the chemical reaction to follow than if the catalyst were not present.

There are several key players in the process:

- The catalyst is a substance that speeds up a chemical reaction by lowering the amount of activation energy needed, without itself undergoing any permanent chemical change.
- A reactant, simply defined, is a substance that takes part in and undergoes change during a reaction. It is represented on the left side in a chemical equation.
- When the catalyst and a reactant associate, an 'activated complex' is formed. In this high energy state, the reactant has two choices: it can revert back its original state or it to can undergo a chemical transformation to a product, such as by interacting with another reactant.

Heterogenous and Homogenous Catalysts

There are two types of catalytic reactions, **heterogenous** and **homogenous.**

In a heterogeneous catalytic reaction, the catalyst and the reactants are in **different phases** (ie. liquid in the presence of solid catalysts).

In a homogeneous catalytic reaction, the catalyst in the **same phase** as the reactants (ie. all liquid or all gas).

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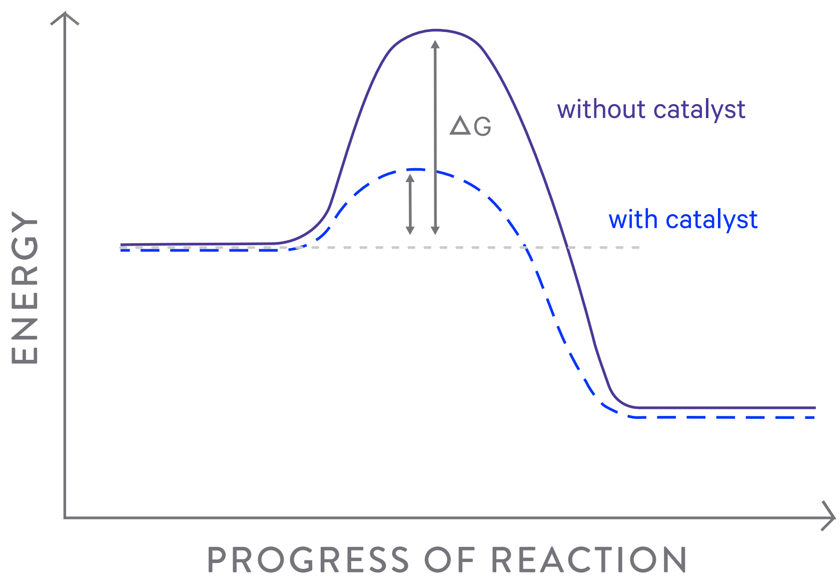


A Popular Example: Haber-Bosch

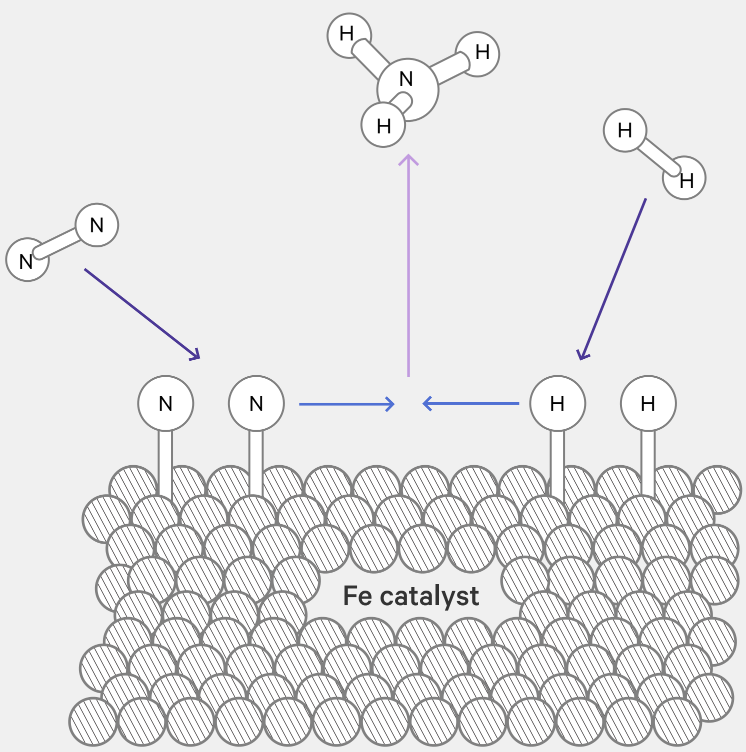
$$N_2 + 3\,H_2 \rightarrow 2\,NH_3 \quad (\Delta H = -92.4\ \text{kJ·mol}^{-1})$$

Haber-Bosch is one of the most important inventions of our modern world. It is responsible for producing 500 million tons of nitrogen-based fertilizer each year, which feeds almost half of the world's population.

Three to five percent of the world's natural gas production is consumed in the Haber-Bosch process (around 1-2% of the world's annual energy supply).

In this process, nitrogen and hydrogen gas react to form ammonia using an iron-based catalyst.

The challenge with this process is that it requires increased pressure to yield more ammonia. At room temperature and pressure there is not much ammonia generated. However, conducting the reaction at 450°C and 200 atm yields much more.



Step 1: An Fe catalyst is added.

Step 2 : Nitrogen and Hydrogen atoms bond to the surface of the Fe catalyst. This bond is still reactive, allowing the N and H atoms to move around.

Step 3: The Nitrogen and Hydrogen atoms react, bond to form NH^3.

As fundamental as catalysis is to our modern society, it is inefficient, expensive, and dirty.

For one, bulk chemistry (e.g., Haber–Bosch, fuels and fertilizers) typically relies on catalysts made from abundant materials, although they require high temperature and pressures. This is polluting and, in addition, the high temperatures and pressures necessary limit the kinds of processes that can be accomodated and products that can be manufactured.

On the other hand, synthesizing complex chemicals (e.g., medicines and certain materials) must be done at low temperature and pressure and this often requires precious metal catalysts, which are expensive, rare, polluting to mine, and have volatile global availability.

The Fuzionaire Way: Solving the Fundamental Limitations of Chemistry

Fuzionaire's core technology enables a new branch of catalysis that is based on Earth-abundant metals like potassium and sodium and can occur under ambient conditions.

These catalysts are up to 10,000x cheaper than state-of-the-art precious metal catalysts and have the potential to address these previously unsolved problems in a large range of innovations across industries, which could ultimately improve the vast majority of products people use every day.

The new way in which we make and break bonds is dramatically more powerful, efficient, and clean than anything done today.

The company's technology is founded on a series of discoveries by Chief Scientist Anton Toutov while he was a Caltech PhD candidate in the lab of Nobel Laureate Robert Grubbs, along with scientists at Caltech, UCLA, and other leading institutions.

Learn more at: www.fuzionairedx.com

To start, we are applying this breakthrough in catalysis to molecular imaging, and diagnostics specifically. Our radiolabeling platform is able to radiolabel any molecule at record-breaking speed, resulting in lower-cost, more targeted, and more effective radiopharmaceuticals.

Comparison Factors	Standard ^{18}F Moiety	Fuzionaire Dx HetSiFAs™
Bond type/strategy	C-F bond	C-Si-F bond
Manufacturing	Challenging; often impractical for large and/or complex molecules	Facile using Fuzionaire alkali metal catalysis
Literature	Many reports	Novel compositions and methods; several patents pending
Radiolabeling time	Typically >20 min	Seconds
Radiosynthesis time	Typically 1-3 hours	<15 minutes
Radiochemical yield	Highly variable (often <50%); acknowledged reproducibility issues	>90% (facile, highly reproducible)
HPLC purification?	Yes	No
Metals required for synthesis?	Typically	No
Personnel	Generally trained chemists	Accessible to medical technicians
Synthesis temperature	up to 150℃	Typically 23℃
Precursor loading	15,000-60,000 nmol	≤50 nmol