THE FINAL WORD

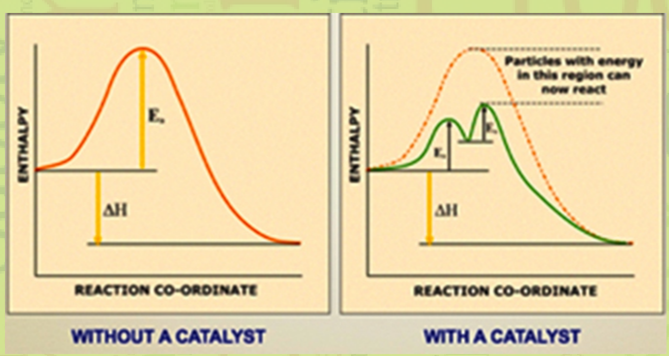
The official e-newsletter of Industrial chemistry(IC) department, V.V.Nagar, Anand, Gujarat

CATALYTIC PROCESSES IN CHEMICAL INDUSTRIES

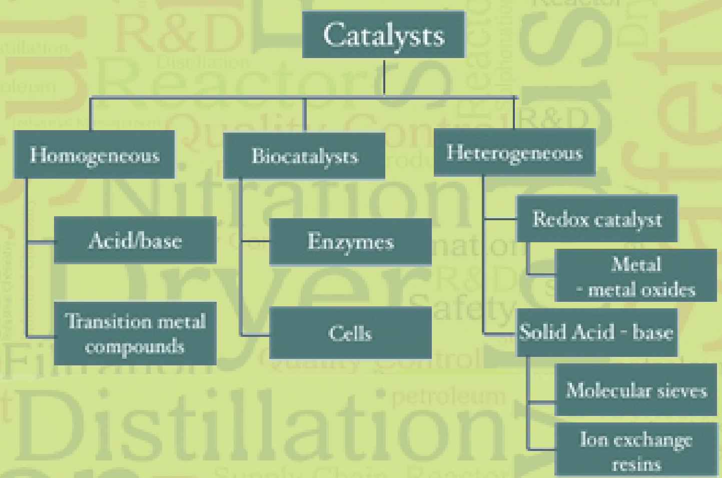
Catalytic processes are backbone of chemical industries. Roughly 65% of all chemical products are made by catalytic processes. ~ 90% of all industrial chemical processes are catalytic processes. It is estimated that catalytic processes contributes to greater than 35 % to the world GDP.

Global catalyst revenue in various field is shown in pie charts in fig 1, should not confuse with the product value catalyst creates. Total global catalyst trading value is $20.6 billion (2017), but still it accounts to <0.1% of the sales revenue from the products it creates. The value addition it does in petroleum, petrochemicals, basic and fine chemicals, monomers, polymers, automotive, environment, detergent etc industries is beyond imaginations.

Catalysts are substances that speed up reactions by providing an alternative pathway for the breaking and making of bonds. Key to this alternative pathway is a lower activation energy than that required for the uncatalyzed reaction (fig 1). We can say that catalysts are 'Chemical Brokers', as catalysts have active reaction sites on surface which facilitates bond breaking, transition states and bond formation at lower activation energy, while does not take part directly in the reaction or being consumed.

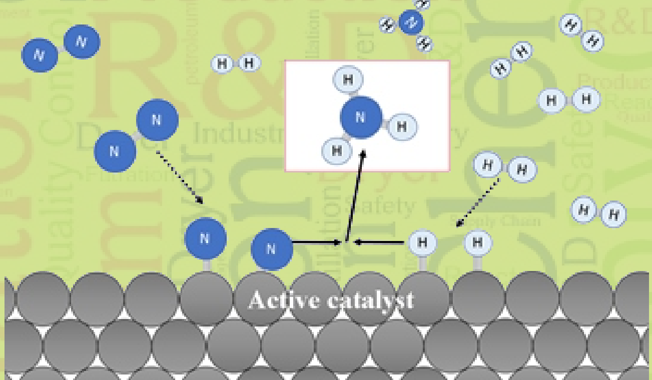


Catalysts are classified based on phase of catalyst and reactants. If the catalyst is in the same phase as the reactants (mostly both are liquid and / or gases), it is referred to as a homogeneous catalyst. Heterogeneous catalyst is mostly solid while reactants and products are liquid or gas. Heterogeneous catalyst often preferred in industry, as there is no separation issue of the catalyst and product at the end of reaction. Wherever possible, homogeneous catalytic processes are already replaced by heterogeneous catalytic processes.



Type of Catalyst

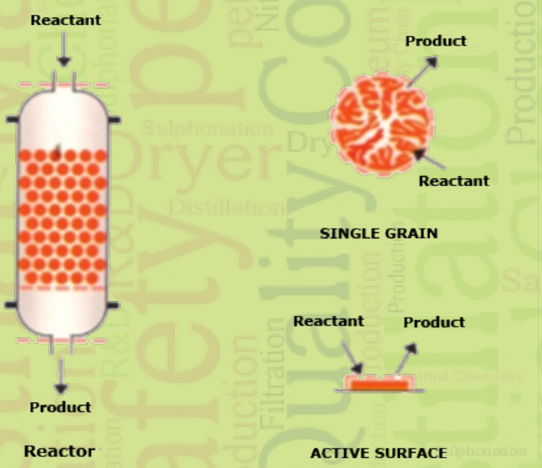
Heterogeneous catalysts are backbone of petroleum, petrochemicals and basic chemicals industries. Research and development on catalysts are continuous processes and still companies are working on catalyst development and optimization of very old and mature processes like ammonia (Haber) process (fig 3), Fischer-Tropsch process or Methanol synthesis.

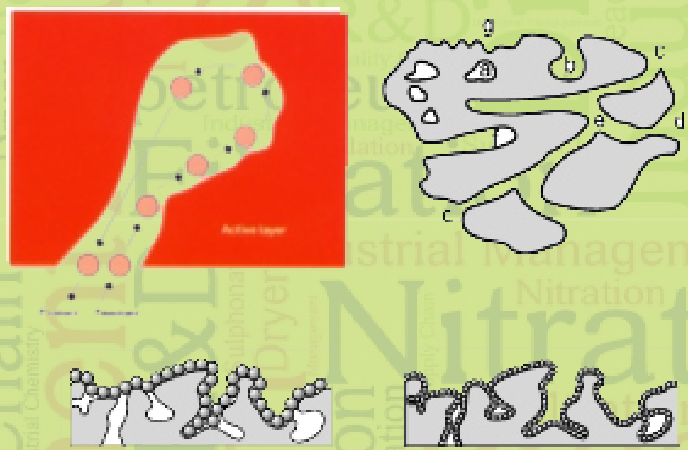


Schematic of ammonia synthesis over catalyst surface

Heterogeneous Catalyst R&D is multidisciplinary science and required interdisciplinary skills like organic chemistry, inorganic chemistry, material, surface and interfacial science, kinetics and thermodynamics including reactor engineering.

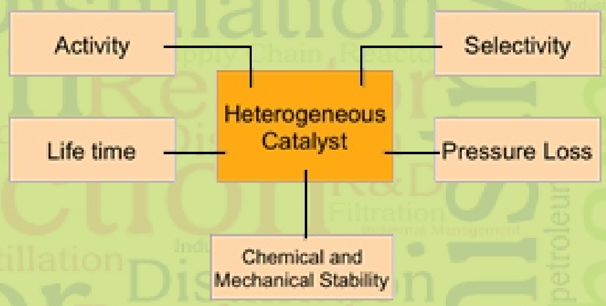
Heterogeneous catalysts are inorganic chemicals, mostly transition metals with or without refractory oxide (silica, alumina etc) support. Transition metals have unique tendency to have multiple valance state and change its valance easily to facilitate redox reactions (catalytic reactions are redox reactions). Role of support is mostly to increase surface area and facilitate active metal loading, while decreasing cost of catalysts by having maximum exposure of relatively costly active metals to reactants.





Steps involved in catalytic reactions are: adsorption of reactions on catalyst surface > diffusion of reactant and making intermediate bonds (transition state) > new bond formation (product) > desorption of product from surface.

Since catalytic reactions occurs on surface of catalysts. They are having large surface area, sometimes up to 800-1000 m^2/g. Surface of catalysts are carefully engineered to have optimum selectivity and activity. Fig 5 shows focus on catalytic development campaign.



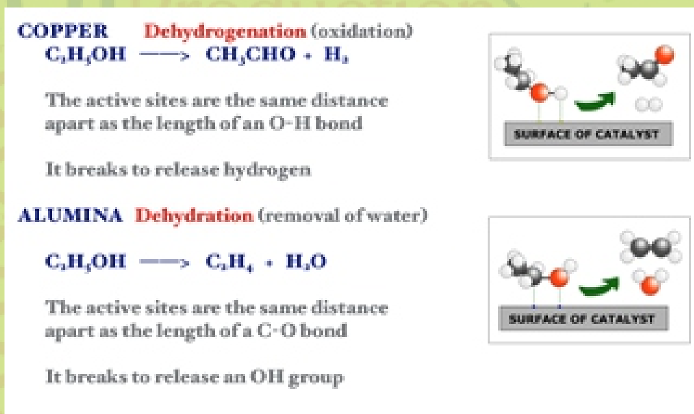


Fig 5. Focus on catalyst research (above) ethanol conversion on two different catalysts (under)

Exact mechanistic pathways of catalytic processes are still remain a mystery for researchers. But researchers try to corelate activity with catalyst surface structure by experimental and mathematical modelling experiments. Catalysts are very specific for the reaction. Same reactant at same reaction parameters yield different products with two different catalysts as shown in fig 5 and fig 6.

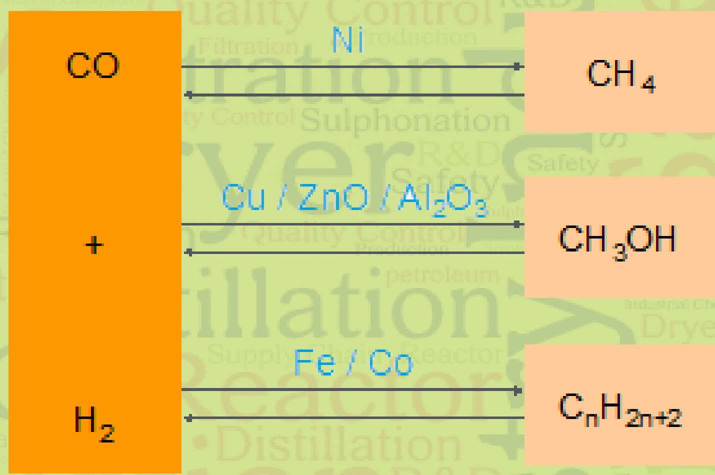


Fig 6. CO Hydrogenation

Catalysts can be prepared via co-precipitation, impregnation, fusion, hydrothermal, sol-gel etc procedures. Catalyst synthesis are relatively easier then organic synthesis, but to find out which composition, procedure with what catalyst property will work for particular reaction required thorough research, characterization followed by testing with real parameters and sometimes it takes years to several decades. As very small improvement changes process economics due to very large volume of products.

Below is an example of typical lab scale synthesis of Cu/ ZnO / Al2O3 catalyst used to make methanol from synthesis gas (CO+H2).

Step 1: Make a 1 M solution comprising zinc and copper nitrates with Cu: Zn ratio of 2:1, Also dissolve sufficient aluminium nitrate in the solution equal to 15% aluminium oxide in final catalyst.In the copper, zinc, and

Step 2: Aluminium nitrate solution at 50°C, add 10% sodium bicarbonate solution to maintain the pH to 7-7.3 range.

Step 3: Allow the slurry to react at 50°C with stirring for an additional 60 min in order to effect complete reaction and precipitation.

Step 4: Filter the slurry, wash the cake with hot water to reduce residual Na < 100 ppm.

Step 5: Dry at 120 C for 12 hours. Crush to fine powder and Calcine at 400 C for 4 h.

Usually 1-2 g of above synthesized powder is tested in lab reactor for required activity and selectivity. For commercial operation, above powder is kneaded with additives and shaped to pellets, extrudates, tablets, spheres etc as per reactor requirements and reactor pressure drop limitations.

In short, catalyst research is combination of an art and science. Some researcher truly says, "Catalytic science, which involves the invention, development and manufacturing of catalysts, is probably one of the most interesting and undoubtfully most rewarding scientific field". Scale of impact of successful research is much larger then imagination makes it one of the most rewarding scientific research area.

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Ganesh Chaturthi Celebration

Expert Talk in 'My IC'

Entrepreneurship Development
Dt.:-17/09/2018
Delivered by:-
Dr. Raju M. Rathod
(Professor in G.H. Patel P.G. Institute of MBA Programme Sardar Patel University, Chairman of Indian Society for Training and Development, Anand)

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