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Introduction

1.1 MOTIVATION

Pharmachemicals and agrochemicals are very important to human beings. Chiral compounds are precursors of pharmaceutical, pesticides and fine chemicals. Most of the components of living organisms on earth include chiral compounds such as left handed amino acids, right handed sugars, proteins, enzymes, DNA and RNA. These form the skeleton of the human body. Thus the human body is more sensitive towards chiral compounds, for example, one isomer can have a beneficial effect while the other enantiomer can have a damaging effect. It means that the biological actions are a result of the enantiomeric interactions with receptors in different ways, depending on their absolute configuration. Therefore, it is a global demand to produce 100 % pure single enantiomers. Asymmetric catalysis, racemic resolution and fermentation are some important methods to produce chiral compounds. The overall enantiomeric excess is not high in case of racemic resolution and fermentation. Asymmetric catalysis has been proved to be the best way to produce pure enantiomers. Asymmetric catalysis is shared by homogeneous and heterogeneous catalysis. The major part of asymmetric catalysis is apportioned by homogeneous catalysis because it facilitates molecular reactions in an efficient manner with high chirality transfer. The success of homogeneous catalysis was proved in 2001 when Knowles, Noyori and Sharpless won a Nobel Prize for their contribution in the field of homogeneous asymmetric catalysis [Knowles *et al,* 1972, Knowles 2002]. Knowles et al. produced 95 % pure L-DOPA drugs using asymmetric hydrogenation over rhodium-phosphine complex [Knowles and Sabacky 1968, Knowles *et al,* 1975, Vineyard *et al,* 1983] (Figure 1.1). L-DOPA is useful for the treatment of the Parkinson disease [Noyori 2002]. It is produced in the human body by oxidation of tyrosine by enzyme tyrosinase. Tyrosinase is an expensive enzyme. There are other methods also to develop L-DOPA but either they are expensive or produce the less enantiomerically pure compound. Homogeneous catalysis is able to produce a 100 % pure enantiomeric compound in some cases. In contrast, heterogeneous catalysis has so far failed to make the substantial impact in terms of practical enantioselective impact. The key advantage of the homogeneous system is that it tends to possess single active site to control stereoselectivity, whereas heterogeneous systems have more different active sites, making it difficult to control the stereoselectivity of a reaction. Despite the demerit, heterogeneous catalysis has many advantages over homogeneous catalysis [Corma and García 2002]. Homogeneous catalysis encounters many problems such as separation, purification and recycling of catalysts. Heterogeneous catalysis overcomes such problems and proves to be an alternative attractive way to produce chiral compounds from a commercial point of view [Corma 2016].

Thus, heterogeneous catalysts hold the solution of many problems related to food, energy, drugs and others. The complexity of heterogeneous catalysts makes it interesting to understand their surface reaction and intermediate structure of reaction, which is necessary for the synthesis of better catalysts. Every improvement in heterogeneous catalysis brings immense advancements in industrial processes to operate at large scale. The motivating part is to produce new catalyst preparation methods and develop new catalytic reactions using renewable resources that must possess specific features, including low preparation cost, high activity, great selectivity, high stability, efficient recovery and good recyclability, which are advantages for the chemical industry.

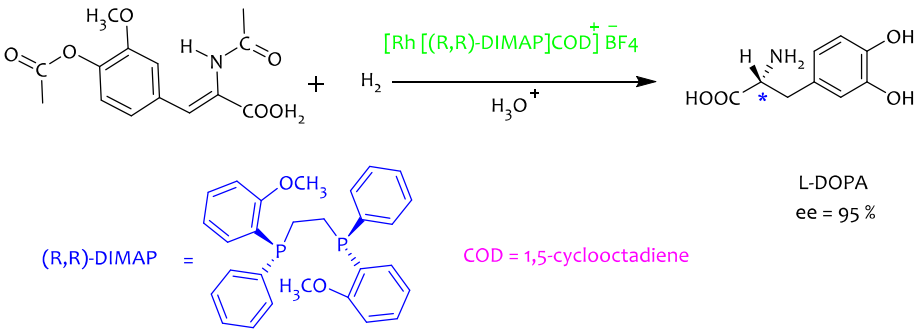

Figure 1.1 L-DOPA synthesis [Knowles and Sabacky 1968]

Asymmetric hydrogenation and allylation are challenging catalytic reactions because of their broad utility in production of the variety of useful optically active compounds at various scales [Venugopal 2016, Yasukawa *et al,* 2016]. Out of various chiral compounds, α-hydroxiesters are model chiral compounds for synthesis due to their great importance in making intermediates of pharmaceutical drugs and also used as solvents [Drapeau *et al,* 2009, Tulashie *et al,* 2009]. The asymmetric hydrogenation of α-ketoester is the best part to make α-hydroxiesters by using different metal catalysts [Blaser *et al,* 1997]. α-hydroxiester are key intermediates of pharmaceutical drugs [Ruey and Van Scott 2010, Le and Gan 2012] like Pumiliotoxin, Cefamandole, Dolasetron, L-DOPA and Naproxen (Figure 1.2). Pumiliotoxin is used as a powerful myotonic and cardiotonic agent in hypertension patients. A Cefamandole antibiotic is used for the treatment of bacterial infection and Dolasetron prevents vomiting after surgery in humans, and Naproxen shows anti-inflammatory activity.

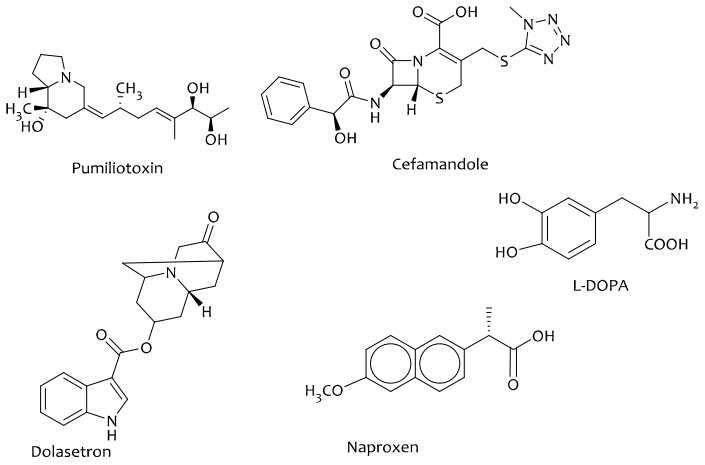

Figure 1.2 Some example of drugs used in pharmaceutical industry

Ethyl lactate is a common example of α-hydroxiester. Due to its relatively low toxicity, it is commonly used in pharmaceutical preparations, food additives, and fragrances (Figure 1.3) [Davies *et al,* 2012]. It can be presumed that ethyl lactate is readily hydrolyzed in the body to ethyl alcohol and lactic acid, both of which are common food constituents. A wide variety of foods also contains ethyl lactate naturally, such as wine, chicken, and various fruits. The motivational direction is to search new methods which should be beneficial in all perspectives, like low cost, being environment friendly, easy to handle and scalable. Various low cost metal loaded carbon catalysts have been considered as environmentally benign for heterogeneous catalysis process.

Figure 1.3 Applications of ethyl lactate [Pereira *et al*, 2011]

Asymmetric heterogeneous catalysts have been primed using carbon materials [Sharma and Sharma 2016] (carbon nanotubes, graphene, carbon fibers and activated carbon) as solid supports due to their commercial availability and ease of chemical modification [Ampelli *et al*, 2014]. Natural chiral source cinchonidine is used for asymmetric induction. Noble metals have been found to be the best catalysts for hydrogenation reactions.

Chiral nitrogen containing compounds play an important role in food chain. Stereoselective allylation reaction of imine is a common building block for a synthesis of chiral nitrogen containing compounds in pharmaceutical and natural product [Sharma and Samuelson 2007]. There still remains a challenge to produce 100 % pure nitrogen containing compounds.

1.2 OBJECTIVE OF THE THESIS

1. To develop a series of heterogeneous catalysts that possess specific features such as low preparation cost, high activity, great selectivity, high stability, efficient recovery and their application in several important asymmetric catalytic reactions.
2. To develop >99 % enantiomerically pure compounds using asymmetric catalysis processes without any tedious work.

1.3 ORGANIZATION OF THE THESIS

Chapter 1: *Introduction*
This chapter explores the motivation of this study. It explains how the ethyl lactate product is important for human life.

Chapter 2: *Literature review*
This chapter covers the literature survey of an asymmetric hydrogenation reaction of α-ketoester and allylation reaction of imine and aldehydes.

Chapter 3: *Synthesis and characterization of heterogeneous catalysis*
This chapter deals with the synthesis and characterization of heterogeneous catalysts. The synthesis of Metal/Carbon materials, Pt HNC (111), Pt/Chiral polyamide and F-CD-BF_4/MWCNT are described.

Chapter 4: *Asymmetric hydrogenation reaction*
This chapter addresses the application of the prepared heterogeneous catalysts. Pt supported catalysts are used for asymmetric heterogeneous hydrogenation reaction of α-ketoesters. Substrate-Modifier interaction is also explained.

Chapter 5: *Asymmetric allylation of imine*
Here, asymmetric heterogeneous allylation of imines is described using F-CD-BF_4 supported catalysts. Synthesis of imines and characterization of the product are also discussed.

Chapter 6: *Summary and future directions*
This chapter concludes the work of the thesis.

The important research papers, survey papers and text books that are mentioned in the thesis are listed in References.