齐鲁工业大学（山东省科学院）
QILU UNIVERSITY OF TECHNOLOGY SHANDONG ACADEMY OF SCIENCES

本科毕业设计（论文）

电催化4-苯基-1-丁烯的研究

学院名称 化学与化工学院

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Study on Electrocatalysis of 4-Phenyl-1-Butene

学 院 名 称 化学与化工学院

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CONTENT

Abstract in English

In recent years, the electrochemistry has been greatly developed.In particular, electrocatalytic strategies have been used to achieve C−C,C−O,C−N and C−S bond formation reactions. As is known to all, oxyhalogenation unsaturated hydrocarbon with halide ions has also been reported. So we would like to try nitrogen halogenation unsaturated hydrocarbon with halide ions. Traditional compositing conditions are usually limited, these include excessive use of strong oxidants, these kinds of reagents were often required in stoichiometric quantity and some of them were expensive and toxic, higher reaction temperature and lower atom efficiency.

The development of electrochemical organic synthesis is a testimony to the gentleness and sustainability of electrochemistry. Compared with traditional reactions, electrochemical solutions do not require the use of toxic or other dangerous oxidants. The revival of electrochemical organic synthesis technology is of great significance and demonstrates the gentleness and sustainability of electrochemistry. Compared with traditional oxidation reactions, electrochemical protocols do not require the use of toxic or dangerous oxidants.

In general, LiCIO4 as electrolyte, DMF as solvent, Chlorine source from MgCI2.6H2O, CeCI3 as catalyst, RVC(+)RVC(-) as electrodes in this laboratory work. The advantage of electrochemistry is environmental protection, easy to handle, low consumption and non-toxic.

Key words： MS, electrochemistry, electrocatalytic synthesis

摘 要

近年来，电化学技术得到了长足的发展，特别是采用电催化策略来实现 C-C，C-O，C-N 和 C-S 键的形成反应。众所周知，具有卤离子的卤代氧不饱和烃也有报道。因此，我们想尝试用卤离子卤化氮不饱和烃。传统的合成条件通常受到限制，其中包括过量使用强氧化剂，通常需要化学计量数的这类试剂，其中一些昂贵且有毒，反应温度较高，原子效率较低。

电化学有机合成的发展证明了电化学的温和性和可持续性。与传统反应相比，电化学溶液不需要使用有毒或其他危险的氧化剂。电化学有机合成技术的复兴具有重要意义，并证明了电化学的温和性和可持续性。与传统的氧化反应相比，电化学方法不需要使用有毒或危险的氧化剂。

总的来说，在此实验室工作中，以 $LiClO_4$为电解质，DMF 为溶剂， 氯源为五水合氯化镁，$CeCl_3$为催化剂，RVC（+）RVC（-）为正负电极。电化学的优点是环保，易于处理，低消耗和无毒。

关键词：质谱，电化学，电催化合成

INTRODUCTION

With the progress of the times, human civilization and the level of science and technology have promoted the development of various social production undertakings, making citizens' lives more abundant, efficient and convenient, and many companies and enterprises have also maximized the interests they pursue. While enjoying the results of development, we should also face up to the price paid for rapid social development. The most obvious and most serious of these is the destruction of the natural environment by development. In order to meet human needs, more and more factories have been established. With the increasing number of factories, the problem of environmental pollution and water pollution is also coming.

Environmental issues have gradually developed into issues that must be considered for the advancement of various fields. Fortunately, human beings are a highly intelligent group. Through the cultivation of awareness and the implementation of corresponding measures, the situation of environmental damage can be controlled. Under the current new situation, environmental protection has become an indispensable control link in any production and living activities.

The destruction of soil resources is not only affects itself but also poses a serious threat to freshwater resources. On the other hand, due to the excessive development of the soil in recent years, the original soil structure has been destroyed to a large extent and the increase in the chemical composition of pesticides has directly led to the reduction of the nutrient content of the cultivated soil. At the same time, soil erosion continues to be serious, pushing the severe situation and facing soil pollution to an unprecedented height. The main reason for this situation is that the solid waste produced by the rapid development of industry can not be properly treated and can only be simply stacked on the surface of the soil. Waste water penetrates into the soil, floats dust and gas in the air. These reasons have affected the normal use of soil to a certain extent, not only affecting the yield of crops, but also the harvested food, fruits and other foods affect human health is also an issue worthy of attention.

In the sewage treatment industry, due to the secondary treatment methods that limit the improvement of discharge water indicators, it is usually difficult to meet the national requirements for Class I Grade A standards, and the electrochemical treatment method upgrades the discharge water indicators of the secondary treatment system. The effect is quite satisfactory.

Electrochemical sewage treatment uses electrolysis to carry out high-concentration treatment and advanced treatment of various types of sewage in the early stage, as well as treatment to improve the quality of surface water use. It is mainly carried out by using the electric energy and magnetic effect generated by the reactor and in the process of reaction. The special electric energy is uniformly applied to the inside of the water body in a large area, stimulates the resonance of various particles in it, destabilizes the aqueous solution, separates the solute and the solvent (water) through ionization, electron action, electrode chemical reaction, electric floatation, and electric excitation. The resonance effect makes the suspended solids in the water form large flocs to achieve the purpose of separation and purification. Therefore, the electrochemical waste water treatment process is designed for the electrochemical waste water treatment method. The electrochemical waste water treatment process is flexible. The electrochemical waste water treatment process has the advantages of flexibility, stability, easy installation, simple operation, and ideal treatment effect. It is not only suitable as a small-displacement complete set of equipment, but also suitable for large-displacement units for secondary system upgrades.(电化学污水处理方法, 2021) Catalytic electrode has long service life and electrocatalysis lab is less equipment, fewer control points, simple process and simple operation.

Especially in recent years, as people's awareness of environmental protection has increased, people have realized that environmental protection and pollution control can not be ignored and the concept of green chemistry is also proposed under this background. Green chemistry also known as environmentally friendly chemistry or environmentally friendly chemistry, it mainly refers to reducing the use of harmful substances and reducing the use of harmful chemical substances. (Ligka, 1990)

Chapter 1

1.1Electrochemical

Chlor-alkali industry is the largest electrochemical industry in the world. It is the process of electrolyzing salt water to obtain chlorine and caustic soda. Chlorine is used to prepare vinyl chloride and then to synthesize PVC. It can also be used as a bleaching agent for pulp and paper. There are three kinds of electrolytic cells commonly used in industry: mercury electrolytic cell, separator electrolytic cell and ion selective electrolytic cell.

Electrochemical research stretches across many different fields (as is evidenced by the numerous applications listed here). While many are unique, there is often a great deal of overlap. (物理电化学-Electrochemical Research, 2021). For more than a century, electrochemistry uses the manual force of electrons, electrons and electron holes as reagents, which has aroused the interest of synthetic chemists.(Faraday, M. 1834). Electrochemistry provides a unique and direct means to generate free radicals and it is usually impossible to improve efficiency or reduce costs through chemical oxidants or reducing agents. The applied electromotive force can make the substrate have enough strength to undergo redox process on the electrode surface. In addition, the ability to accurately control signal amplitude can apply electromotive force to specific redox events without blowing dust. Therefore, electrochemistry is very important provide effective direct access to highly reactive free radicals.(Moeller, K. D. 2000)

Electrochemical is a science that researches the formation and changes of two conductors. At present, electrochemistry includes semi-conductor, spectroeleochemistry, synthetic electrochemistry, organic conductor, bioelectrochemistry, physical electrochemistry and so on. Electricity as a non-toxic, harmless, high efficiency, no pollution renewable energy and it is more and more widely used in this world. Electrochemistry also has many natural advantages, such as conveniently used, easy to extent, recyclable electrode and so on.

1.1.1The future of electrochemistry

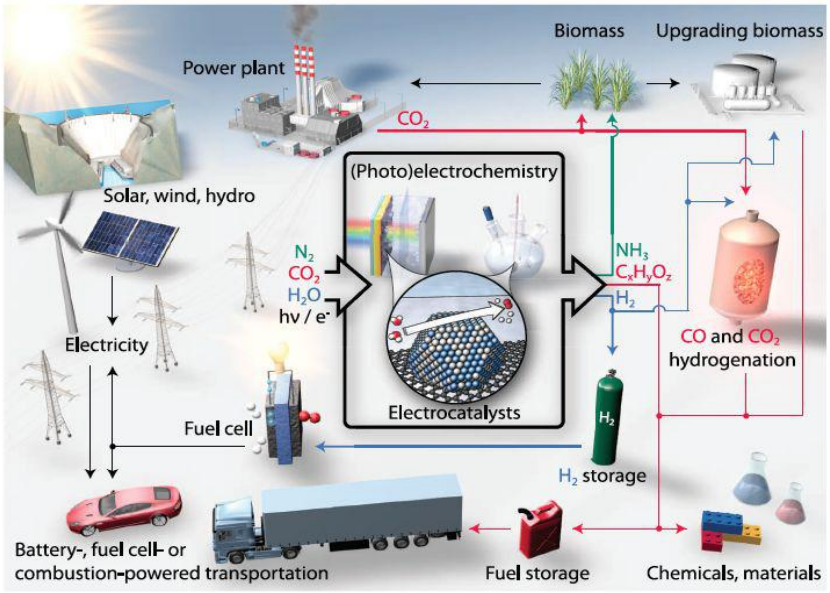
Electrochemical analysis technology is an ancient and young technology. It originated in 1791 when an Italian professor of medicine discovered the phenomenon of “animal electricity” that metal can contract frog leg muscles. In 1800, the first practical battery was made by volts, which turned on the electricity. A new era of chemistry research. After more than two centuries of development, the achievements of electrochemical technology have attracted worldwide attention, which has greatly promoted the progress of science and the development of society. Over the past 40 years of China’s reform and opening up, electrochemical technology has developed rapidly and has gradually become a wide range of analysis tools in the fields of chemistry, life, materials, physics, energy, transportation, environment, and information.It is of vital significance to the national economy, national defense construction, and scientific research. (古老而又年轻的技术 电化学发展趋势展望, 2021)

Electricity is a renewable resource, but many chemical substances are very rare. Using renewable resources-electricity, many normal chemical reactions can save raw materials and react more thoroughly, so that chemical substances that can not be reacted can react to obtain the target product. Electrochemistry can protect the environment to a certain extent. For example, ordinary reactions require some toxic reactants to react. Electrochemistry can allow non-toxic reactants to replace toxic reactants to make the reaction go smoothly. Therefore, to a certain extent, the electrochemical method can not only save resources but also protect the environment.

When it comes to environmental protection, as the country pays more and more attention to environmental protection, people are beginning to think of ways to protect the environment. Such as, farmers do not burn straw, factories do not discharge waste water, chemists study how to treat waste water and so on. Although these methods have reduced environmental pollution to a certain extent, they are also a very small part. The factory does not discharge waste water at will, how do they deal with it? So, there is a saying that goes well: money is not saved, but earned. The same is true for environmental protection. The fundamental solution is how to deal with it, electrochemistry has solved this problem

to a large extent. Electrochemistry must be an indispensable part in the future, electrochemical researchers are also emerging in endlessly.

1.2 Electrocatalysis



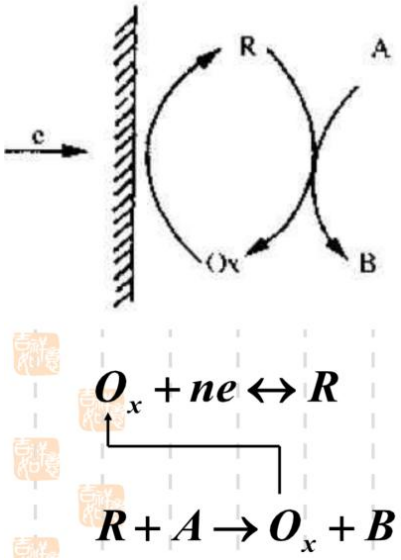
Picture 1. Sustainable energy future (让我们聊聊电催化, 2021)

The molecular catalysis of electrochemical reactions can be divided into two categories according to the role of catalysts.In terms of regulating responsiveness, the first category is a catalyst process in which oxidation-reduction reactions do not directly participate in electrode-mediated reactions. On the contrary, they either promote the transfer of electrons to or from the matrix through the activation front line (ie acid/base catalysis) or the chemical step after the promotion of electron transfer contains a redox active catalyst, which is directly connected to the electrode and the mediator. The transfer of these catalysts may also be involved in subsequent chemical steps.(Sauer and Lin, 2018)

What is a electrocatalysis?

Under the action of an electric field, the modification present on the electrode surface or in the solution can promote or inhibit the electron transfer reaction that occurs on the electrode, while the modification on the electrode surface or in the solution does

not react.（like picture 2)



Picture 2. Electrocatalysis

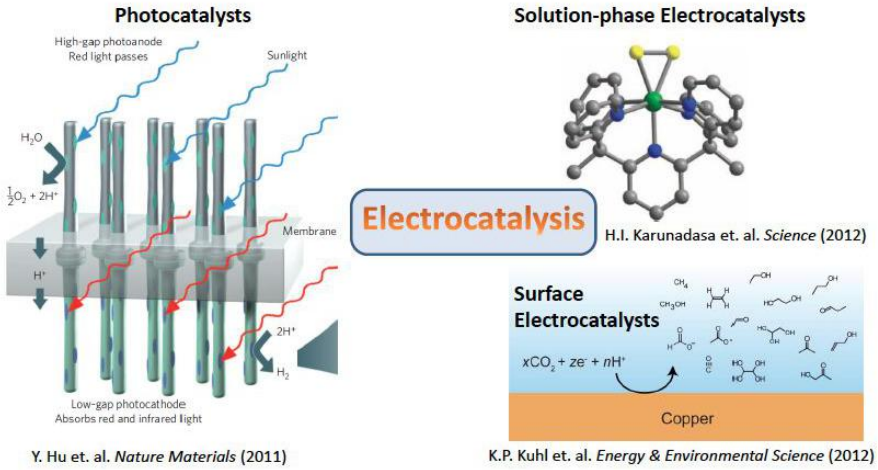
What is the use of electrocatalysis?

Energy production: At present, it is more commonly obtained through the combustion of fossil fuels (coal, oil, natural gas), but in the future, people hope to use electrocatalysis/photocatalysis technology to reduce sunlight, and air CO2, H2O to form fuel (fuel): CXHYOZ, H2.

Energy transportation: If we can mass-produce these fuels, their transportation is also very important. However, due to the relatively mature H2 liquefaction technology, most of the organic matter is liquid and for the time being, it will not have a big impact on the transportation problem.

Energy consumption: The ideal situation in the future is to use high-power, high-efficiency fuel cells (fuel cells) to convert the generated fuel into [formula] through an electrocatalytic reaction. Of course, this can continue to be a reactant in our energy production.

Why is it so interesting and important?

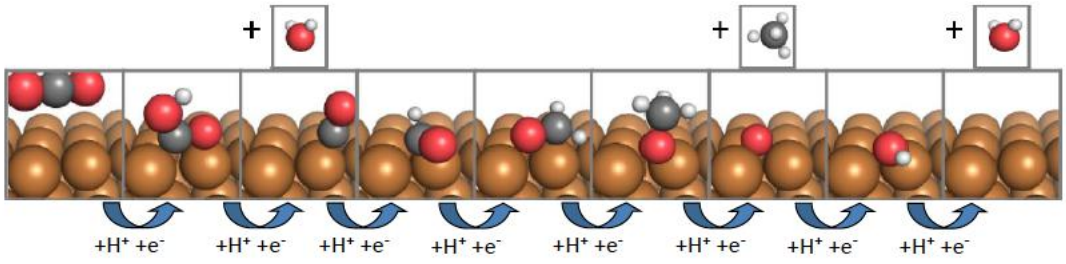


Picture 3. Electrocatalysis comes in different forms(Thomas J, 2012)

Changing the electrode potential on the electrode, the structure of the electric double layer at the electrode/solution interface, the free energy of the reactants/products, the adsorption energy of some characteristic adsorbed ions, and the equilibrium coverage will all change greatly. From the Butler-Volmer equation, we know that this effect is exponential, so a slight change in electrode potential will have a huge change.

The reaction is often multi-step, multi-proton-electron transfer. There are too many possible intermediate states and their corresponding reaction paths, which cause great difficulties for theoretical modeling and analysis. For example CO2 reduction. In order to reduce it to methane (CH4), 8 protons and 8 electrons must be added:

CO2 + 8H+ +8e- = CH4+ 2H2O(a possible reaction)



Picture 4. One possible mechanism step(Thomas J, 2012)

1.3 Electrocatalytic Bifunctional group

Scientists have developed many methods to study olefin difunctional group. However, the use of electrochemistry method is more green, environmentally friendly and effective. Because electrochemistry methods have non-toxic of metal and without photosensitizer in photoreaction process. For example in traditional methods,we need to add equivalent chemical oxidant to produce substances harmful to the environment. However, in electrochemistry methods, more and more toxic and some substances which are not environmental friendly are not a necessity. Therefore, electrochemistry methods are more better than traditional methods.

The traditional olefin bifunctional energy condensation method include transition metal catalysis, cheap metal catalysis, and photochemistry catalysi and so on . In order to make the reaction more green and sustainable, people are more actively exploring, the advantages of electrocatalytic olefin oxidation bifunctionalization.

Like olefins or alkynes in unsaturated hydrocarbons, their direct bifunctionalization reaction can synthesize a variety of organic compounds, some of which are biologically active or pharmaceutically active compounds, which are closely related to our human life and can also promote the entire human life. Development plays an important role in the field of organic synthesis. At present, many reactions related to the bifunctionalization of olefins have been studied. Such as dichlorination, diamination, carbonization, carbon hybridization and so on.

1.4 Unsaturated hydrocarbon

The double bond is composed of one σ bond and one π bond, while the triple bond is composed of one σ bond and two π bonds. The electron group of the π bond is exposed to the periphery of the bond, which is easy to attract the electrophile to carry out the electrophilic substitution reaction and the electrophilic addition reaction. Therefore, in general, the double bonds and triple bonds of unsaturated hydrocarbons are not too strong and are easier to break.

Chapter 2 DEVELOPMENT AND APPLICANTION

2.1 Development

Electrochemical reactions are the basic source of energy for all life on Earth. For example, photosynthesis begins with an electrochemical reaction when electrons are released from the electronic structure of chlorophyll molecules, entering an excited state when they absorb photons. (David, 2021)

Electrochemistry represents one of the most inherent interaction way between molecular, the electrostatic force between molecular and atom is the most basic force in chemistry. Electrochemistry need though direct application electric potential so that increase electronics or reduce electronics by interaction. Therefore, electrochemistry is also one of the oldest reaction setting situation.(Lund, 2002)

In 1780, Galvani discovered in the frog planing experiment that when the frog’s four legs violently spasm, it would cause the motor to emit sparks. From this unexpected discovery, Galvani published the existence between biology and electrochemistry in 1791.

In 1799, the Italian physicist Volta invented the first chemical power source. He stacked many pairs of round silver and zinc flakes alternately. Between each pair of silver and zinc flakes, a piece of linen cloth soaked in salt water was placed. The zinc flakes are welded to the silver flakes on the bottom surface and the two metal ends will produce smoke. The more pairs of metal sheets, the stronger the electrons. For the first time, human beings have obtained practical continuous current. Before the invention of the DC motor, the chemical power supply was the only power supply that could provide a stable current. To commemorate his great achievements, the scientific community simplified his surname into the unit of voltage Volt (Volt). (电化学的发展, 2021)

In 1800, when Nichoson used a voltaic stack to electrolyze an aqueous solution, he discovered that gas had evolved on both electrodes. This is the first attempt to electrolyze water. (So far people continue to explore HER and OER). (电化学的发展, 2021)

In 1803, David successfully obtained metallic potassium and metallic sodium by electrolysis, and it became possible to obtain active metal element by electrochemical method. The discovery of Faraday's law of electrolysis in 1834 laid a quantitative foundation for electrochemistry. (电化学的发展, 2021)

In 1833, the genius experimenter Faraday put forward the "law of electrolysis" after a lot of experiments: m=QM/nF. As the basis of electrochemistry, the "law of electrolysis" pointed out the direction for the development of iodine chemistry.

In 1839, Grove invented the fuel cell. The hydrogen-oxygen fuel cell using platinum black as the electrode ignited the lighting in the lecture hall, since then, the fuel cell has entered the stage of history.

In 1889 Nernst used thermodynamics to derive the relationship between the concentration of the substance participating in the electrode reaction and the electrode potential, namely the famous Nernst formula.

In 1923 Debye and Huckel proposed the generally accepted electrostatic theory of strong electrolyte dilute solutions, which greatly promote the development of electrochemistry in theoretical discussion and experimental methods.

As time goes by, more and more people like to study electrochemistry because of the development trend of organic synthesis. As I mentioned before electrochemistry is more green, safer, more efficient and so on.

2.2 Application

Electrochemistry is a university subject, which is supported and supplemented by many other basic disciplines. The applications of electrochemistry are mainly divided into the following applications:

Used in the electrolysis industry;
Various analytical methods that requiring the use of electrochemistry;

A variety of pollutants often exist in the environment, such as cyanide ions, the use of electrodialysis method can protect the environment to a certain extent;

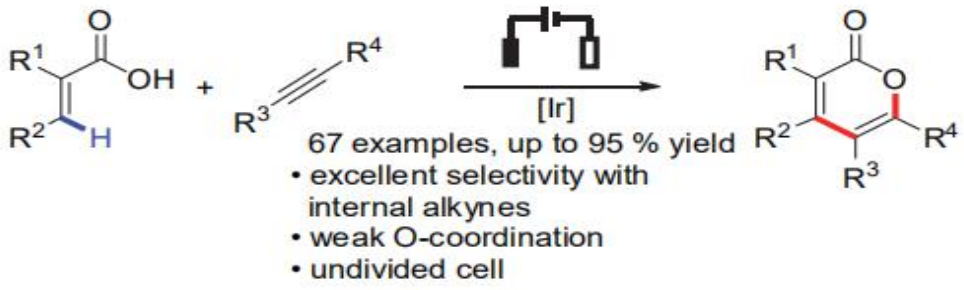
Apply to some fields closely related to life phenomena;

For metal anti-corrosion, because most of the metal corrosion we see is formed by electrochemical corrosion;

It is used in some mechanical fields, such as electroplating. Because these applications are developed through electrochemical applications, this makes them essential in laboratory and industrial applications.

Compared with conventional chemical reactions, the advantage of electrochemical methods is that we use electric current instead of common chemical reducing agents or oxidants to stimulate chemical reactions by adjusting the electric potential obtain unique chemical selectivity and reactivity. Generally, traditional C-H functionalization methods require high temperature conditions, but also rely on expensive stoichiometric oxidants and metal catalysts. In addition, many toxic reagents and other wastes are generated during the reaction.

Recently, Mei Tiansheng ’ s research team also studied the use of electrochemistry to promote the functionalization of vinyl C-H catalyzed by iridium （Yang, Q.-L.et.2019). The research experiment finally successfully realized the coupling of acrylic acid and alkyne and effectively constructed the coupling system of acrylic acid and alkyne α-pyran compound, although the existence of the skeleton is very important for biologically active small molecules and natural products. The electrochemical method is more selective to symmetric alkynes than traditional chemical methods (10:1～30:1)



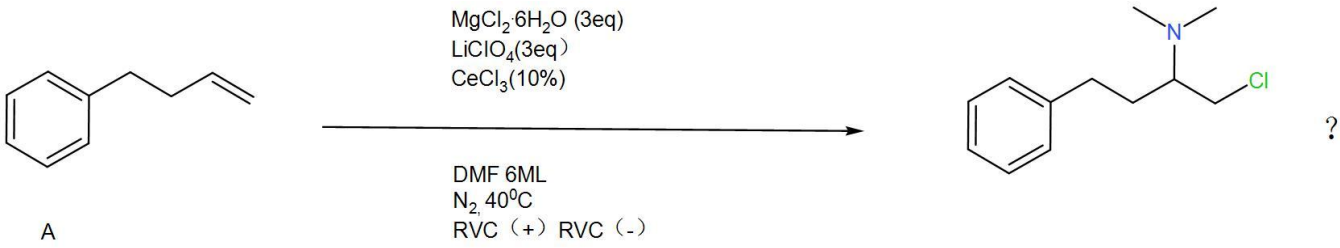
Scheme 1. the reaction

Organic electrochemistry provides a very useful method for traditional organic synthesis, making electrochemical method one of the very useful tools in organic chemistry. Electrochemistry provides another environmentally friendly method for the realization of C-H functionalization, through direct electrolysis and indirect electrolysis and direct electron transfer between the electrode and the substrate. At present, electricity is acting as an electron transfer agent instead of a redox catalyst.

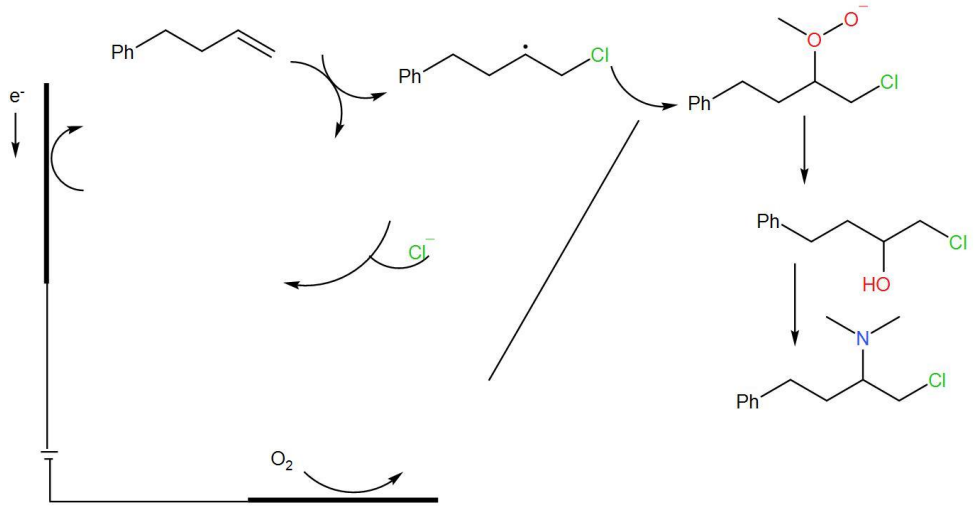
In particular among many applications, the application of electrocatalysis has the potential to greatly improve the electrochemical range of synthesis and provide a wide range of useful conversions. In 2018, Lin's group used electrocatalysis to difunctionalize olefin radicals (Sauer G S , Lin S. 2018). The bifunctionalization and diazotization of free radicals make this experiment demonstrate the strategy synthesis of electrocatalysis to expand the scope of organic chemistry and electrochemistry. Therefore, this electrocatalytic platform has been proven to be used for homobifunctional and heterobifunctionalization of olefins. Its substrate acceptance range is very large and the compatibility of functional groups is also very strong. In particular, as a new strategy, anode-coupled electrolysis has been promoted for highly selective halogenated trifluoromethylation of olefins.

Chapter 3 THEORY AND METHOD

3.1Theory



Scheme 2. Theoretical Chemical Equation



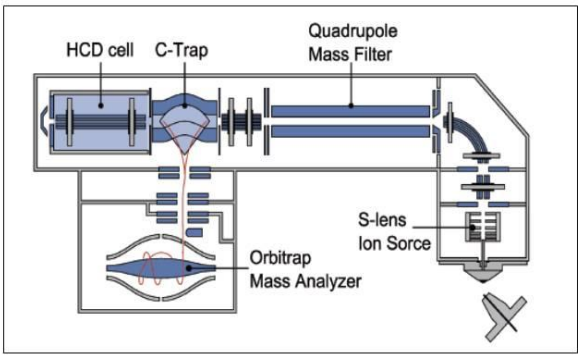
Scheme 3. Proposed mechanism(Scheme 2)

Electrolysis cell: the anode loses electrons and the cathode gains electrons. Oxidation reaction occurs at the anode and reduction reaction occurs at the cathode. The reaction can be initiated by anode oxidation of cerium(III) chloride to Cerium(II) Chloride releases chloride ions controlled way. 4-Phenyl-1-butene reacts with chlorine. At the same time, the oxygen reduction reaction takes place at the cathode produce persistent free radicals - superoxide ion.

3.2 Methods

3.2.1 Gas Chromatography - Mass Spectrometry (GC-MS)

Picture 5. Machine of GCMS



Picture 6. MS principle

GC separates the compounds and mass spectrometry (MS) breaks the molecules into fragments to determine the molecular weight of the molecule. Gas chromatography (GC) mainly make use of characteristic difference in mixture boiling point, polarity and adsorption to achieve separation of the mixture. Waiting for analyze samples be vaporized of inert gas in vaporization chamber and bring in column. Inside the column have liquids or solids stationary phase. Due to difference in samples each component boiling point, polarity or adsorption, each component more like make balance and distribution in mobile phase and stationary (GCMS, 2021). Gas chromatography refers to chromatography that uses gas as a mobile phase, due to the fast transfer speed of the sample in the gas phase, the sample components can be instantly balanced between the mobile phase and the stationary phase. In addition, there are many substances that can be used as the stationary phase, so the gas chromatography analysis speed is fast and the separation efficiency is high. Mass spectrometry (MS) is one of the most powerful techniques in chemical and biological analysis. Mass spectrometry (MS) not only has high specificity,sensitivity but also has precision. To date, Mass spectrometry (MS) has been combined with gas chromatography (GC) to identify and classify gasoline samples from a variety of sources.(Zhao et al. 2021)

3.2.2 Unique variable principle

The univariate principle is to control the unique variable, eliminate the interference of other factors and verify the role of the unique variable. Experimental variables refer to related quantities that change during the experiment. If there are multiple changes in the experiment, the controlled variable method must be used to observe the experiment and summarize the law.(唯一变量原则_百度百科, 2021)

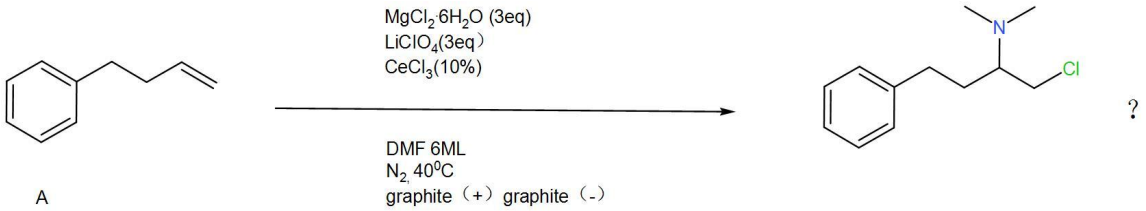
In the lab, more people would like to use unique variable principle to prove which factor affects the experimental date. Such as Niankai Fu, Gregory S. Sauer, Song Lin those people use this method in Electrocatalytic Radical Dichlorination of Alkenes with Nucleophilic Chlorine Sources this article to get biggest yield.(Fu, Sauer and Lin, 2017)

Since the test has more than one influencing factor, it is necessary to keep the other variables constant when studying one influencing factor, otherwise it is not known which factor caused the change in test results during the test analysis. However, unique variable principle also have many advantages, like simplify complex problems. When a problem is related to many factors, use the controlled variable method to explore one of the factors at a time.

Chapter 4 PROCESSING AND RESULTS

4.1 Processing

The reaction was conducted under constant current electrolysis at -5 mA in the presence of 4-phenyl-1 butene (0.02 mol, 26ul), CeCl3(10%, 5.0mg), LiClO4(3eq, 63mg) and magnesium chloride hexahydrate MgCl2.6H2O(3eq, 121mg) in DMF(6ml)under nitrogen atmosphere in Graphite electrodes at 40℃ temperature.



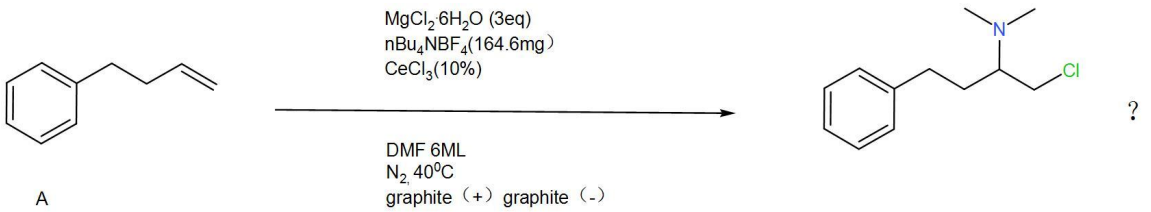
Scheme 4. Reaction Condition of the first group

Name	Mass
A(0.02mol)	26ul
$MgCI_2.6H_2O$ (3eq)	121mg
$LiCIO_4$(3eq)	63mg
$CeCI_3$(10%)	5.0mg
DMF	6.0 ml
Graphite(+) (-)	2 kpl

Table 1. reactants mass and electrodes of the first group

At the first, we found the reaction voltage was really high, V≈-11. At the same time we also noticed a strange phenomenon that the reaction liquids turned yellow-green. As we all known, CI2 dissolves in water and presents yellow-green, the chemical equation: Cl2+H2O=HCl+HClO and the composition of chlorine water is HCl, HClO, Cl2, H+, ClO-, Cl-, OH-.

As the reaction progresses, the reaction voltage became more and more higher than before and the electrode with a graphite electrode was damaged, we guessed that electrolyte was too strong so that caused the electrode to be slightly damaged. Finally, we used MS machine to monitor solution but we did not get our target product. According to this reaction, we would like to change the electrolyte (LiCIO4 3eq) to nBu4NBF4 164.6mg.

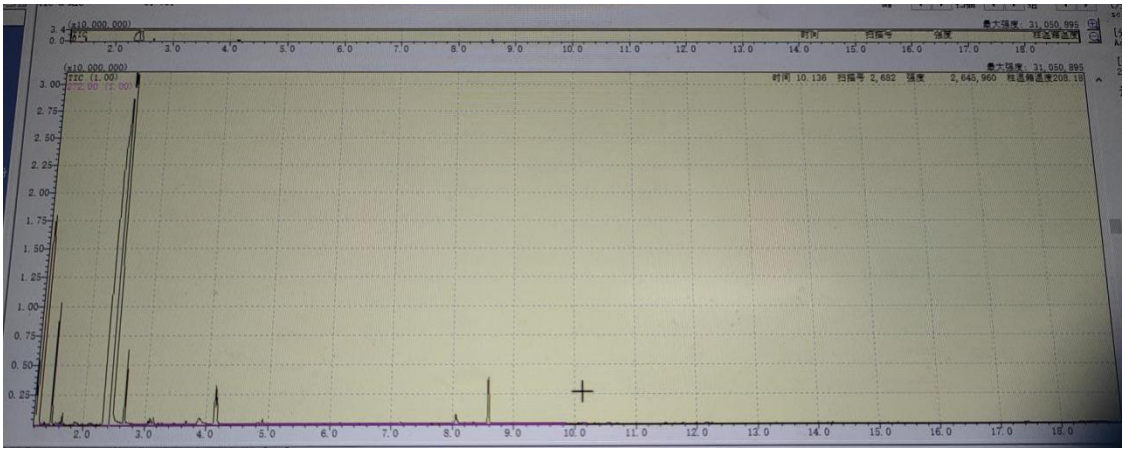


NAME	MASS
（A）	26ul
$MgCl_2$.6H2O (3eq)	120mg
nBu_4NBF_4(164.6mg）	164.6mg
$CeCl_3$(10%)	5.0mg

Scheme 5. Change the electrolyte as control group(Second group)

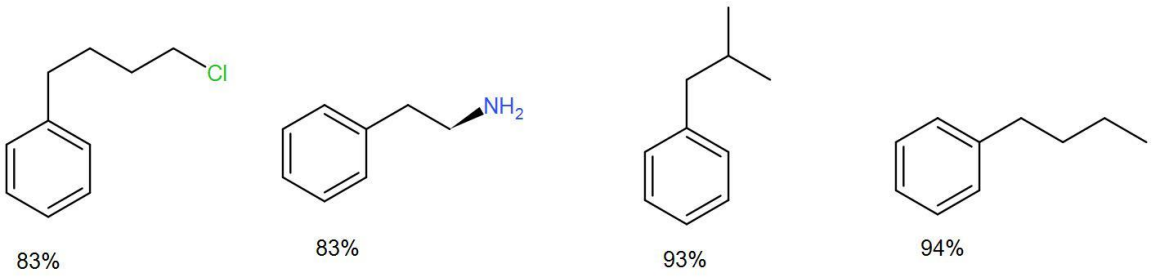
The reaction was conducted under constant current electrolysis at -5 mA in the presence of 4-phenyl-1 butene (0.02 mol, 26ul), CeCl3(10%, 5.0mg), nBu4NF4(3eq, 164.6mg) and magnesium chloride hexahydrate MgCl2.6H2O(3eq, 121mg) in DMF(6ml)under nitrogen atmosphere in Graphite electrodes at 40℃ temperature.

When the reaction has proceeded for 7 hours, we perform a drip plate on the reactants and we find that the reactants have been reacted. So we carried out mass spectrometry detection on the product.



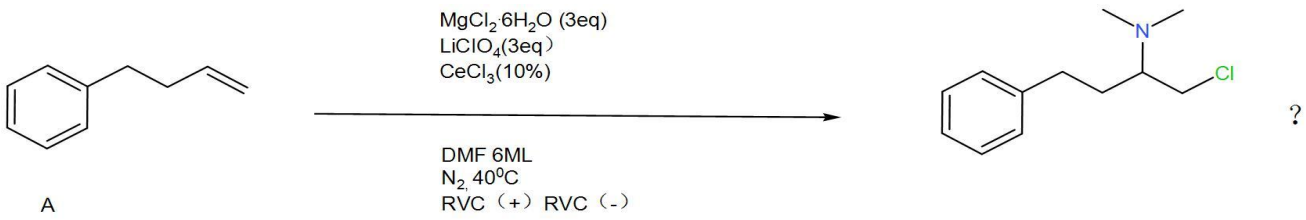
Picture 7. The GCMS of second group

Actually, we tested the similarity of the peaks and did not get the product we need. It mean that we changed the electrolyte before as control group is not right. The picture below is the product we may get and the similarity.



Picture 8. Similarity detection of picture 7 peaks

We decided to change the graphite electrode to magnesium chloride hexahydrate - RVC electrode as both anode and cathode in solvent.In addition to electrodes, the reactants and reaction conditions as same as the first reaction. It means that we just changed the electrodes as the control group. We assumed if we get the target products from the second group, it means that the RVC electrode in this reaction were better than graphite electrode.



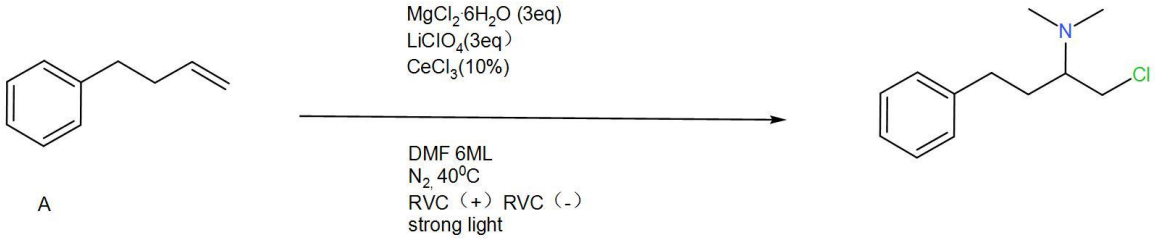
Scheme 5. Reaction Condition of the last group

Name	Mass
A(0.02mol)	26ul
$MgCI_2.6H_2O$	121mg
$LiCIO_4$(3eq)	63 mg
$CeCI_3$(10%)	5.0mg
DMF	6.0 ml
RVC(+)(-)	2kpl

Table 2. Reactants mass and electrodes of last group

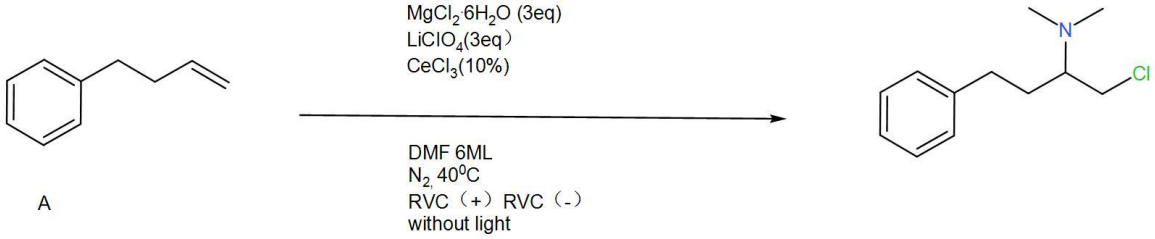
Standard conditions: constant current = -5 mA, A (0.02mmol) 26 μl , LiClO4(3 equiv) 63mg, CeCl3(10%) 5.0mg, MgCl2.6H2O(3 equiv) 121mg, DMF 6 ml with two RVC electrodes.

Also, we though control unique variable method to prove does this experiment have anything to do with light.Standard conditions: constant current = -5 mA, A (0.02mmol) 26 μl , LiClO4(3 equiv) 63mg, CeCl3(10%) 5.0mg, MgCl2.6H2O(3 equiv) 121mg, DMF 6 ml with two RVC electrodes. These condition are the same, the difference is that one experiment is under strong light and the other is in the dark.



NAME	MASS
（A）	26ul
$MgCl_2$·6H2O (3eq)	120mg
$LiClO_4$(3eq）	63mg
$CeCl_3$(10%)	5.0mg

Scheme 6. Strong light lab(lab 1)



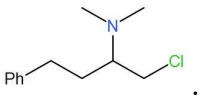
NAME	MASS
（A）	26ul
$MgCl_2$·6H2O (3eq)	120mg
$LiClO_4$(3eq）	63mg
$CeCl_3$(10%)	5.0mg

Scheme 7. Without light

4.2 Results

Picture 9. MS of the final product

After doing different condition labs, we get the optimal reaction condition (scheme 5). This reaction have lasted 8 hours, after dripping board that we found without reactants in the solution, so we took samples in the solution for mass spectrometry. As show in figure above(picture 9), we could conclude that there are several peaks and the specific details of the highest peak are shown in the figure below (picture 6). According to the similarity check, we found that the chemical product with the highest similarity is



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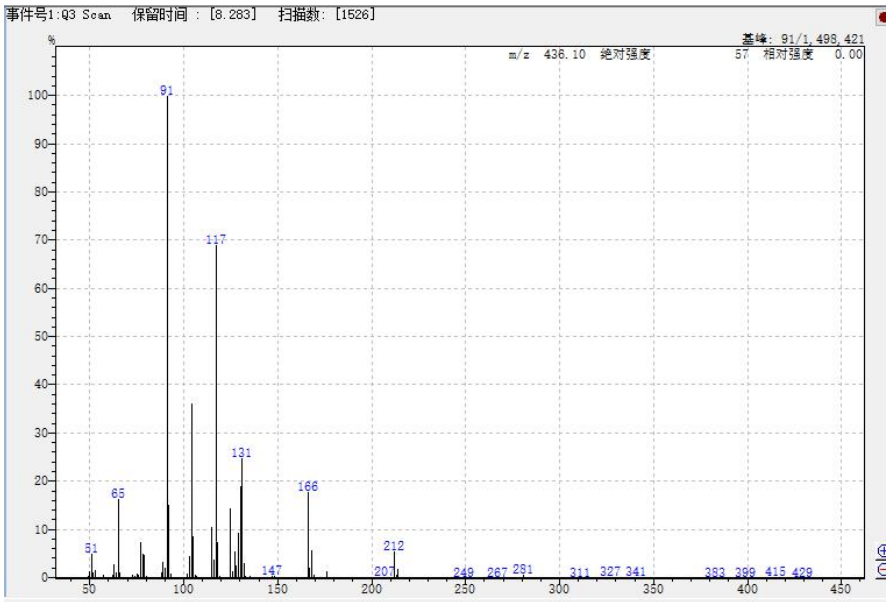

Picture 10. Peak molecular weight

Chapter 5 DISSCUSION

This review briefly introduces the advantages of electrochemical development by introducing the development of electrochemistry, the oxidation of electrochemical olefin alkynes and the electrocatalytic halogenation reaction.

Electrochemistry is to apply sufficient potential deviation to make common organic molecules lose or gain the surface of electronic electrodes and produce corresponding intermediates. Such an electron-mediated redox process can inherently promote polar reactivity, reducing the need for activators in traditional chemical synthesis. The electrocatalytic reaction has excellent chemical selectivity, the range of its substrates is very high, the compatibility of functional groups is also very strong and it can also make the reaction process greener and safer.

In recent years, with the continuous acceleration of human industrialization, people have paid more and more attention to their own living environment. However, with the increasing and chaotic reaction by-products, the complexity of the process and the deepening of environmental pollution, the problems of industrial development have become obstacles to the road of industrial development. Green chemistry has been at the forefront of chemical development in recent years can write a new direction for the development of green chemistry.

The development of chemical power sources and electrochemical metallurgy is accompanied by pollution and destruction to the environment. Only by relying on the progress of science and technology can the pollution to the environment be minimized or eliminated.

Electrochemical technology has also achieved good results in waste water, waste gas treatment and contaminated soil restoration. Electrochemical analysis methods represented by ion electrodes have been widely used in environmental monitoring! With the development and application of new electrode materials, membranes, electrolytes and reactor structures, electrochemical technology is bound to be more widely used in environmental protection and other fields.

The domestic sewage contains a lot of organic matter, such as cellulose, starch, sugar, fat protein and so on. It also often contains pathogenic bacteria, viruses and parasite eggs. Inorganic salts such as chloride, sulfate, phosphate, bicarbonate and sodium, potassium, calcium, magnesium and so on. The general feature is high nitrogen, sulfur and phosphorus content, and it is easy to produce malodorous substances under the action of anaerobic bacteria. Domestic sewage is mainly various detergents and sewage, garbage, feces and so on used in urban life, mostly non-toxic inorganic salts. Domestic sewage contains many nitrogen, phosphorus, and sulfur and many pathogenic bacteria. Domestic sewage is also a low-temperature heat source and a source of methane generation, as well as a prospective petroleum gas field. The development and progress of my country's sewage treatment industry is relatively late. Since the founding of the People's Republic of China and before the reform and opening up, the demand for my country's sewage treatment is mainly for cutting-edge use in industry and national defense. After the reforming and opening up, the rapid development of the national economy and the significant improvement of people's living standards have stimulated the demand for sewage treatment.

I am an undergraduate student, the knowledge I have learned in the university is limited and the scope of the experiment that I can complete is also very small. I can't even reach the tip of the iceberg of electrochemistry. But there are graduate students after undergraduates, doctors after graduates, and postdoctorals after doctors. Electrochemistry never ends. There are countless problems that electrochemistry can solve. Whether it is the current industrial wastewater treatment or waste recycling, electrochemistry will slowly handle it perfectly.

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Chapter 7 THANKS

This thesis is completed under the guidance of Jianbin Chen. Professional knowledge, rigorous academic attitude, excellent work style, unremitting noble teacher style, strict self-discipline and enthusiasm for people's noble behavior, simple and inaccessible personality charm have had a profound impact on me. I not only set up lofty learning goals and mastered basic research methods, but also made me understand the truth of many things. From the topic selection to the completion of this article, each step is completed under the guidance of the tutor and has made a lot of efforts for the tutor. Here, I would like to express my highest respect and heartfelt thanks to the instructor! In the process of writing the paper, we encountered many problems. With the patience of the teacher, the problem was solved. At the same time, I would also like to thank Dongxu Shao and Yanwei Wu, who have been guiding me seriously. No matter what problems I encountered in all aspects of the paper or in the operation of the experiment, the sub has always been very responsible, carefully taught me the knowledge and ability.

Fortunately, I never regret any of my decisions. The most memorable thing in the four years of college is that I did not hesitate to choose Applied Chemistry (International Class) in my freshman year and I studied abroad in my sophomore year. The project chose me and gave me a chance. I am very happy that I have the opportunity to participate in this study abroad program. This time studying abroad has made me more confident, taught me to be independent and let me know what I want. Compared to me who followed others’ steps before, What a big change this is.

I am very grateful that the college has this study abroad program, which satisfies our students' dreams of studying. In May 2018, I received an offer from Tampere University of Applied Sciences and my visa application passed successfully. I was really excited. In August 2018, I successfully ascended the borders of Finland and came here with my dream of studying. The different styles and customs and the European faces with different looks make me excited and a little timid. After all, I have never seen so many foreigners.

I like to live in a new city, which fills me with curiosity about this city and exercises my ability to integrate into the new life. Finland’s environment is very good. As soon as I got off the plane, I sent WeChat with my family and I said: Mom, look, they can touch the sky by looking up here." Although it is a bit exaggerated, it can’t really touch the sky, but The sky in Finland feels so low and blue.

Of course, what a student needs to talk about is learning. The study and life in Finland is really hard in some part and lazy in some part. Diligence is the attitude to learning, and laziness is the learning environment. The desks of the classmates can be moved at will and they are scattered around. There are no books on the desks, only computers and sometimes even a small mobile phone on the desk. However, under the lazy learning environment, they are all people who study hard. In the classroom, group cooperation, personal active speech, etc., the learning atmosphere is very active. In class, it is common to be classmates with uncles and aunts of parents' generation.

In November 2020, the school ended but caught up with the epidemic, the air tickets were refunded time and time again, but I also received the love and epidemic prevention health package from the China. I am very happy to be able to return to the embrace of the motherland and be more practical.

Time flies like water. In a twinkling of an eye, this is the time to graduate from university. The starting date has gradually become the gradual date and the completion of the thesis has also been completed. From the beginning of the entrance project to the successful completion of the thesis, I have been inseparable from teachers, classmates and friends, warmly welcome me. Please understand my sincere thanks! I would like to express my heartfelt thanks to all the teachers of Applied Chemistry (English) in Qilu University of technology. Thank you for your hard work in the past four years. Thank you for your teaching, but also to teach us more about life. Thank you for four years, your tireless teaching!!

Four years of cold weather not only accumulated a wealth of knowledge, more importantly, in reading and practice to cultivate a way of thinking, expression potential and broad vision. I am very grateful that I have met so many mentors and friends in the

past four years. I have given selfless help and enthusiasm to my study, life and work. I spent four years in a warm environment “college life”. Gratitude is hard to measure in words. I want to express my high respect in the simplest way.

致　谢

本文是在陈建斌的指导下完成的。专业的知识、严谨的学术态度、过硬的工作作风、坚持不懈的高尚师风、严格的自律和热情待人的高尚行为、淳朴而又高不可攀的人格魅力都对我产生了深刻的影响。我不仅树立了崇高的学习目标，掌握了基本的研究方法，而且使我了解了许多事情的真相。从选题到完成本文，每一步都是在导师的指导下完成的，为导师做了很多努力。在此，我要向老师表达我最崇高的敬意和衷心的感谢！在写论文的过程中，我们遇到了很多问题。在老师的耐心下，问题解决了。同时，我也要感谢绍东旭和吴延伟，他们一直在认真指导我。无论我在论文的各个方面遇到什么问题，还是在实验操作中遇到的问题，分总很负责，认真地教给我知识和能力。

很幸运的是我从不后悔我的任何一个决定，在大学四年最值得我回味的是，大一那年我毫不犹豫的选择了应化化学（国际班），而大二那年留学项目选择了我，给了我一个机会。我非常开心我能有机会参加这个留学项目，这次的出国留学，让我更加自信，让我学会独立自主，让我清楚什么是我想要的，相比于之前跟随别人步伐的我来说，这是多么大的变化。

很感谢学院有这个留学项目，满足了我们这些学子的求学梦。2018 年 5 月我的签证申请顺利通过了。心情非常的激动。在 2018 年 8 月份，我顺利登上了芬兰的国界，怀揣着我的求学梦想来到了这里。风格相异的风土人情，长相不同的欧洲面孔，让我满心激动也让我略显胆怯，毕竟从来没见过这么多外国人。

我喜欢在全新的城市生活，即让我充满对这个城市的好奇，又锻炼我融入新的生活的能力。芬兰环境很好，刚下飞机，我就和家里人发了微信，我说：妈，你看，他们这里抬头就能摸到天”。虽然略显夸张，并不能真的摸到天，但是芬兰的天给人的感觉就是好低，好蓝。

作为学生当然要讲的就是学习，在芬兰的学习生活很勤奋也很懒散，勤奋是学习态

度，懒散是学习环境。同学们的桌子都是可以随意挪动，七零八散的摆放着，桌子上也没有任何书籍，只有电脑，甚至有的桌子上只有一个小小的手机。但是，懒散的学习环境之下，却都是努力学习的人，课堂上小组合作，个人积极发言等，学习氛围很是活跃。在课堂上，和父母辈的叔叔阿姨为同学也是常有的事情。

2020 年 11 月，学业结束却赶上了疫情，机票被退了一次又一次，但是也收到了到了来自国家的爱心防疫健康包。很开心，能回到祖国的怀抱中，更加踏实。

光阴似箭。转眼间，就是大学毕业的时候了。开始的日期逐渐变成了渐进的日期，论文的完成也已经完成。从入学项目开始到论文顺利完成，我一直离不开老师、同学和朋友，热烈欢迎我。请理解我真诚的感谢！我要向齐鲁工业大学所有的应用化学（国际）教师表示衷心的感谢。谢谢你过去四年的辛勤工作，谢谢你的教导，也教我们更多关于生活的知识，谢谢你四年了，你孜孜不倦的教诲！！

四年的学习不仅积累了丰富的知识，更重要的是在阅读和实践中培养了一种思维方式、表达潜能和开阔视野。我非常感谢在过去的四年里我遇到了这么多的导师和朋友。我对自己的学习、生活和工作给予了无私的帮助和热情。我在温暖的环境中度过了四年大学生活。感激之情难以用言语来衡量，我想用最简单的方式表达我的崇高敬意。