BUDAPEST UNIVERSITY OF TECHNOLOGY AND ECONOMICS
FACULTY OF CHEMICAL AND BIOENGINEERING
GEORGE OLAH DOCTORAL SCHOOL

THE RESOLUTION OF FIVE- AND SIX-MEMBERED P-HETEROCYCLES AND THEIR APPLICATION AS LIGANDS

Summary of PhD Thesis

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1. Introduction

The organophosphorus compounds bearing an asymmetric phosphorus atom are of great importance both in living organisms and in synthetic organic chemistry. Many biologically active organophosphorus compounds are known,[1] and the transition metal complexes of chiral P(III)-compounds are also used as catalysts in enantioselective homogeneous catalytic reactions.[2]

I have done my PhD work at Budapest University of Technology and Economics, at the Department of Organic Chemistry and Technology under the supervision of Dr. György Keglevich and Dr. Elemér Fogassy. In my work, our aim was to apply the resolution methods developed earlier in our research group[3,4] for the preparation of the enantiomers of 5- and 6-membered P-heterocycles that were unknown in optically active form. We also wished to investigate if the reactions developed for the preparation of 6-membered P-heterocycles[5] involve retention or racemization of the P-asymmetric center. We also aimed to investigate the complexation reactions of 5-membered P-heterocycles in order to prepare racemic and optically active borane- and platinum-complexes of 5-membered P-heterocycles. We have wished to apply the optically active platinum-complexes as catalysts in the hydroformilation of styrene.

2. Review of the literature

Since the first P-chiral compound was obtained in optically active form, many methods have been evolved for the preparation of enantiopure chiral organophosphorus compounds. Besides the asymmetric synthesis, many resolution methods were developed for the racemic P-chiral compounds via the formation of covalent diastereomers, diastereomeric salts, diastereomeric coordination- or molecular complexes.[6,7] Recently our research group developed a resolution method to prepare aryl-, alkyl- and alkoxy-3-methyl-3-phospholene-oxides in optically active form via the formation of diastereomeric molecular or coordination complexes using TADDOL-derivatives and the Ca^{2+}-salts of tartaric acid derivatives.[3,4]

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[1] Quin, L. D. A guide to organophosphorus chemistry; John Wiley & Sons: New York, 2000.
[2] Noyori, R. *Asymmetric Catalysis in Organic Synthesis*; John Wiley & Sons: New York, 1994.
[3] Novák, T.; Ujj, V.; Schindler, J.; Czugler, M.; Kubinyi, M.; Mayer, Z. A.; Fogassy, E.; Keglevich, G. *Tetrahedron: Asymmetry* **2007,** *18*, 2965-2972
[4] Ujj, V.; Bagi, P.; Schindler, J.; Madarász, J.; Fogassy, E.; Keglevich, G. *Chirality* **2010,** *22*, 699-705
[5] Keglevich, G. *Curr. Org. Chem.* **2006,** *10*, 93-111.
[6] Pietrusiewicz, K. M.; Zablocka, M. *Chem. Rev.* **1994,** *94*, 1375-1411.
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The optically active P(III)-compounds are widely used as ligands of transition metal catalysts. The transition metal-phosphine catalysts may be used in asymmetric catalytic reactions, such as hydrogenation or hydroformylation. The enantioselective hydroformylation has direct pharmaceutical importance, as the hydroformylation of vinyl-derivatives may lead to the intermediates of enantiopure non-steroidal anti-inflammatory drugs.[8] Rhodium- and platinum-catalysts are used for enantioselective hydroformylation. Among the P(III)-ligands, compounds with a chiral backbone or with a chiral phosphorus atom can be found. However, the utilization of transition metal catalysts incorporating P-chiral heterocyclic ligands in enantioselective hydroformilation is still a challenging area.[9,10,11]

3. Experimental methods

The structure of the new compounds was characterized by ^{31}P, ^{13}C, and ^{1}H NMR spectroscopic, as well as HRMS measurements. The stoichiometry of the diastereomers was determined by ^{1}H NMR spectroscopy. The enantiomeric excess of the optically active compounds (**1** and **15**) was determined by chiral HPLC (Perkin Elmer Series 200 instrument, Kromasil® 5-Amycoat column) or chiral GC (Agilent 4890D instrument and Supelco BETADEX^{TM} 120 column or Thermo Scientific FOCUS instrument and Cyclodex column). Optical rotations were determined using a Perkin-Elmer 241 polarimeter.

The determinantion of absolute configuration based on UV, CD spectroscopy, and quantum chemical calculations was perfomed by *Dr. Miklós Kubinyi*, *Dr. Mihály Kállay* és *Dóra Hessz*. The UV-VIS spectra were recorded on an Agilent 8453 diode array spectrometer, the CD spectra were registered on a Jasco J-810 spectropolarimeter. In the molecular mechanistic conformational analysis the MMFF94 force field was used. The DFT and TD-DFT calculations were carried out using the PBE0 functional and the 6-311++G** basis set.

The single crystal X-ray diffraction analyses were carried out on a R-AXIS Rapid diffractometer (graphite monochromator; Cu-Kα radiation) by *Dr. Mátyás Czugler* and *Tamás Holczbauer*.

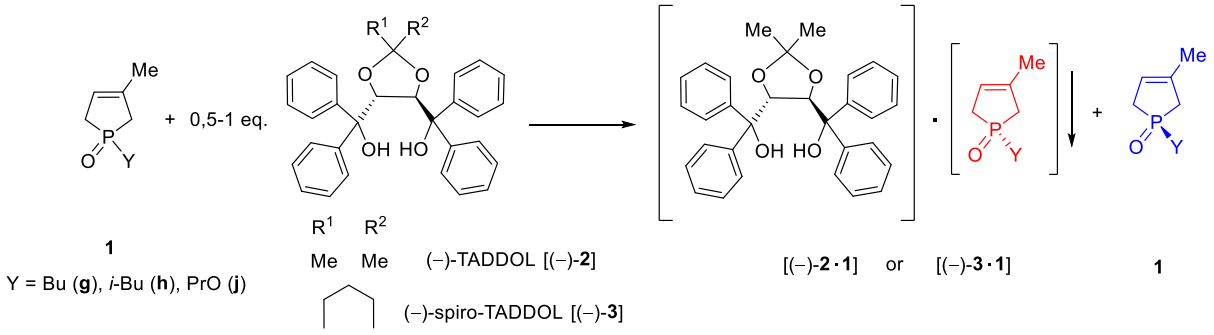
[8] Botteghi, C.; Paganelli, S.; Schionato, A.; Marchetti, M. Chirality 1991, 3, 355-369.
[9] Agbossou, F.; Carpentier, J.-F.; Mortreux, A. *Chem. Rev.* **1995,** *95*, 2485-2506.
[10] Kollár, L.; Keglevich, G. Chem. Rev. 2010, 110, 4257-4302.
[11] Franke, R.; Selent, D.; Börner, A. *Chem. Rev.* **2012,** *112*, 5675-5732.

The quantum chemical calculations using RI-B97-D/6-31G(d) and ωB97X-D/cc-pVTZ methods, as well as cc-pVTZ-PP pseudopotential were performed by *Dr. Tamás Körtvélyesi* and *Tibor Szilvási*.

4. New scientific results

4.1. The resolution of 1-butyl-, 1-i-butyl- 1-i-pentyl- and 1-propoxy-3-methyl-3-phospholene-1-oxide (1g-j); XRD and CD spectroscopical analyses of the 3-phosphelene oxide (1g-j) enantiomers

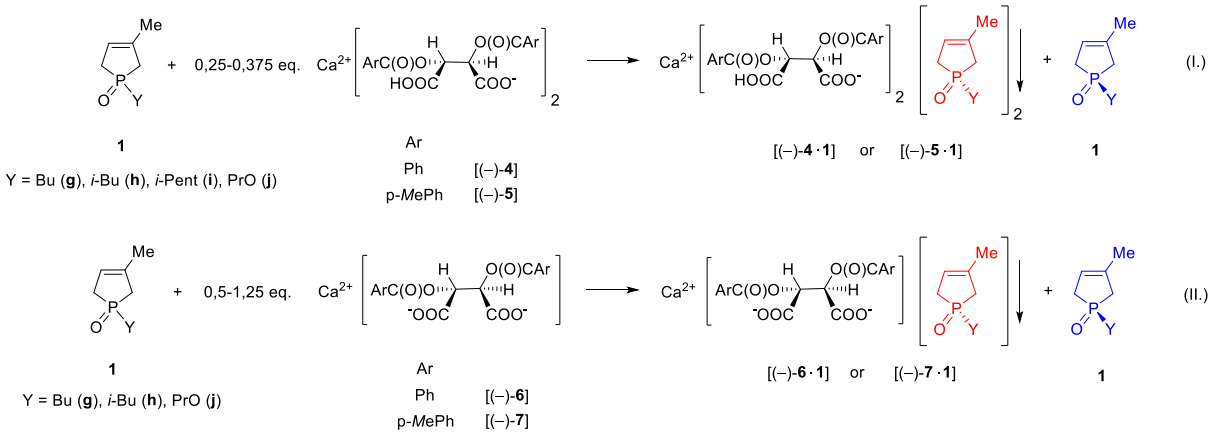
We elaborated resolution methods for the preparation of the enantiomers of 1-butyl-, 1-*i*-butyl- and 1-propoxy-3-methyl-3-phospholene-1-oxide (**1g**, **1h** and **1j**) applying TADDOL and spiro-TADDOL [(−)-**2** and (−)-**3**] as the resolving agent. The corresponding 3-phospholene-oxide enantiomers (**1g**, **1h** and **1j**) were prepared in an ee above 95%.[4,5,7]



We have thoroughly investigated how the solvent affects the outcome of the resolution. Methanol, ethanol and isopropyl-alcohol were also suitable solvents to perform resolutions with spiro-TADDOL [(−)-**3**]. We have found that the solvent influenced not just only the efficiency of the resolution, but also which 3-phospholene-oxide enantiomer (**1g**, **1h** and **1j**) was incorporated into the corresponding diastereomeric complex.[4,5,7]

In case of the 1-butyl- and 1-propoxy-3-methyl-3-phospholene-1-oxide (**1g** and **1j**), resolution procedures were developed to prepare both antipodes of the 3-phospholene-oxides from the corresponding racemic compounds. Both enantiomers of the butyl-3-phospholene-oxide (**1g**) could be prepared with the same resolving agent, with spiro-TADDOL [(−)-**3**] in different solvents. One propoxy-3-phospholene-oxide (**1j**) enantiomer could be obtained with TADDOL [(−)-**2**], while the resolution with spiro-TADDOL [(−)-**3**] afforded the other antipode (**1j**).[4,5]

The resolution of 1-butyl-, 1-*i*-butyl- 1-*i*-pentyl- and 1-propoxy-3-methyl-3-phospholene-1-oxide (**1g-j**) was also studied applying the acidic and neutral Ca^{2+}-salts of the (−)-*O*,*O*'-dibenzoyl- and (−)-*O*,*O*'-di-*p*-toluoyl-(2*R*,3*R*)-tartaric acid [(−)-**4** - (−)-**7**] in different solvents. Although only moderate results were accomplished using the Ca^{2+}-salts of tartaric acid derivatives [(−)-**4** - (−)-**7**], but the (*S*)-1-*i*-pentyl-3-methyl-3-phospholene-1-oxide [(*S*)-**1i**] was prepared in an ee of 95% using the acidic Ca^{2+}-salt of (−)-*O*,*O*'-di-*p*-toluoyl-(2*R*,3*R*)-tartaric acid [(−)-**4**] as the resolving agent.[3-5,7]



In case of butyl-, *i*-butyl- and propoxy-3-phospholene-oxides (**1g**, **1h** and **1j**) single crystals were grown in the presence of the corresponding resolving agent. The X-ray analyses of the single crystals allowed us to determine the absolute configuration of the 3-phospholene-oxides (1g, 1h and 1j), as well as the intermolecular interactions between the molecules composing the corresponding diastereomeric complexes.

In case of the (−)-**1g**·spiro-TADDOL and the (+)-**1h**·(spiro-TADDOL)$_2$ diastereomers, the main intermolecular interaction was a H-bond between the hidroxyl-group of the spiro-TADDOL [(−)-**3**] and the P=O function of the 3-phospolene-oxide (**1g** or **1h**). Isopropyl-alcohol was also incorporated into the (+)-**1h**·(spiro-TADDOL)$_2$ diastereomer (Fig. 1.), what suggested a feasible hypothesis for the lower efficiency of that particular resolution process.[5,7]

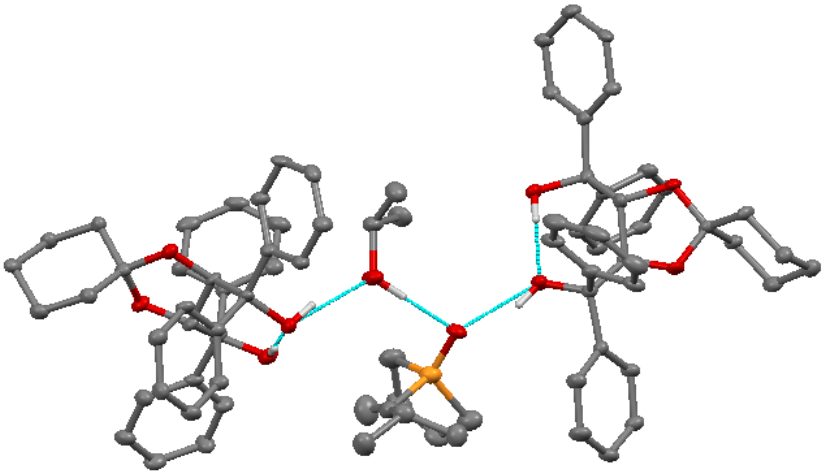


Figure 1. The X-ray structure of the diastereomer incorporating (+)-*i*-butyl-3-phospholene-oxide [(+)-**1h**], spiro-TADDOL [(−)-**3**] and isopropyl-alcohol in a ratio of 1:2:1.

In case of the Ca[(−)-**1j**]$_2$(H-DPTBA)$_2$ diastereomer, the carboxyl-groups of the (−)-*O*,*O*'-di-*p*-toluoyl-tartaric acid molecules coordinated to the Ca^{2+}-ions creating an endless catena-like structure. The coordination of the oxygen atom of the (−)-propoxy-3-phospholene-oxide [(−)-**1j**] to the Ca^{2+}-ions was the main intermolecular interaction between the P-heterocycle [(−)-**1j**] and the resolving agent[(−)-**5**] (Fig. 2.).[4]

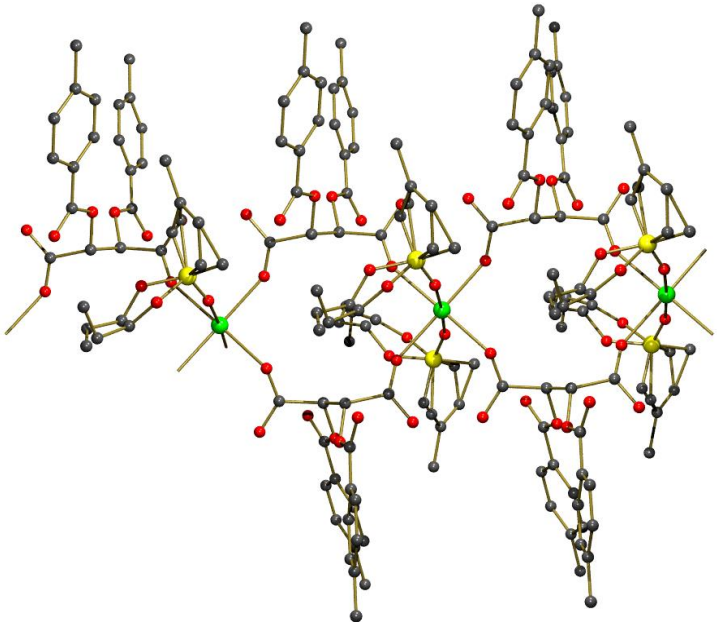


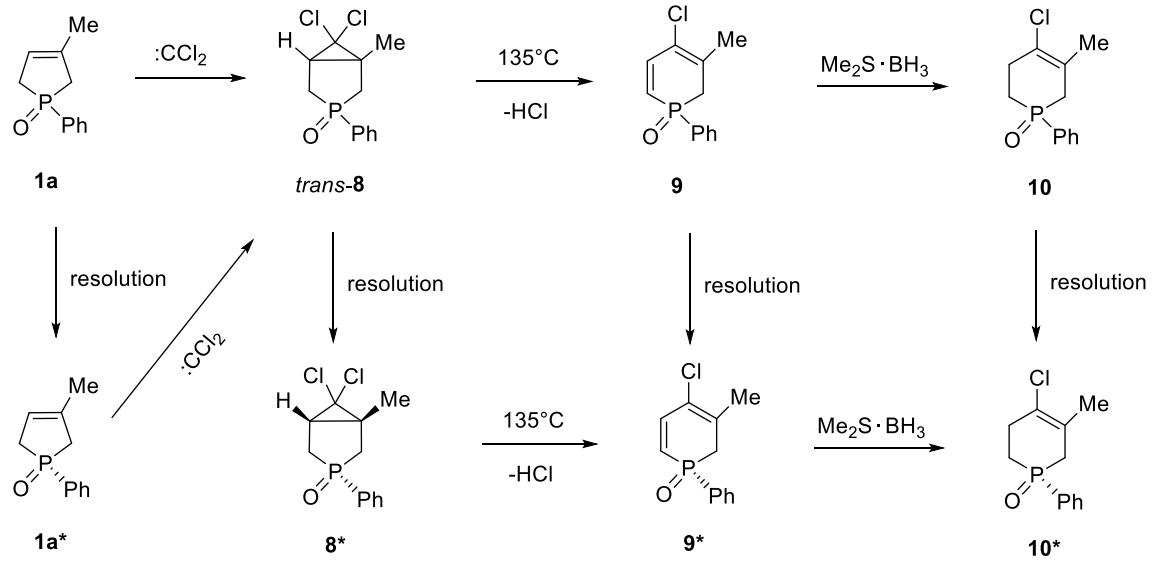
Figure 2. The X-ray structure of the Ca[(−)-**1j**]$_2$(H-DPTBA)$_2$ diastereomer

The absolute configuration of the corresponding 1-butyl-, 1-*i*-butyl- 1-*i*-pentyl- and 1-propoxy-3-methyl-3-phospholene-1-oxide (**1g-j**) enantiomers was also determined by comparing the experimentally obtained and the calculated CD spectra.[4,5,7]

4.2. The preparation of 6-membered P-heterocycles (8-10) in optically active form

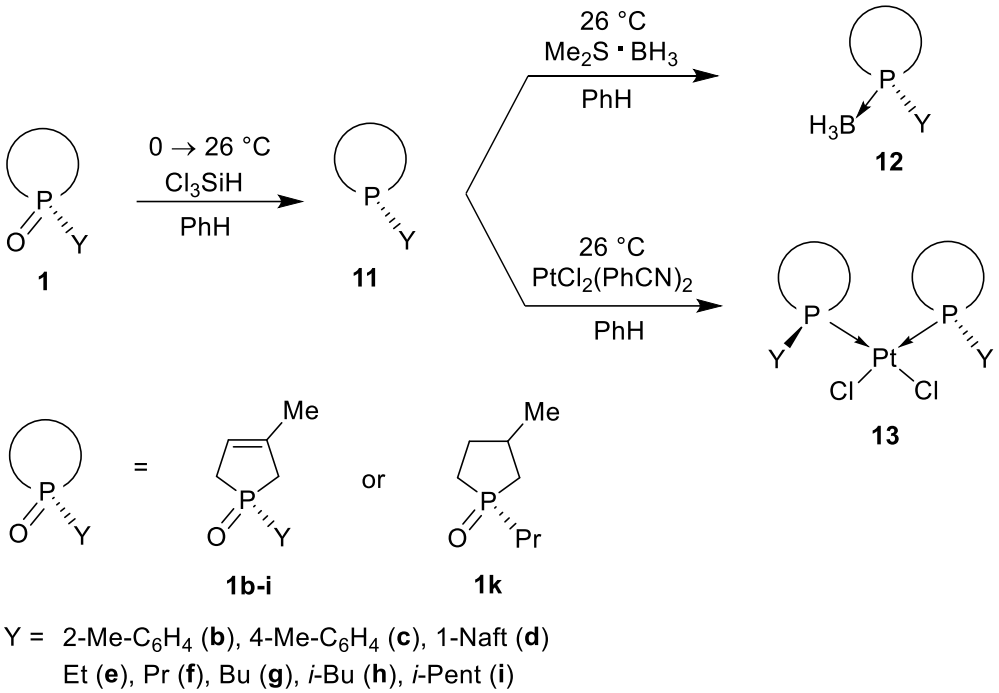
Applying the TADDOL-derivatives [(−)-**2** and (−)-**3**] and the Ca^{2+}-salts of tartaric acid derivatives [(−)-**4** and (−)-**5**] as the resolving agents, the resolution of 6-membered P-heterocycles including the 6,6-dichloro-1-methyl-3-phenyl-3-phosphabicyclo[3.1.0]hexane 3-oxide (**8**) and the 4-chloro-5-methyl-1-phenyl-1,2,3,6-tetrahydrophosphinine 1-oxide (**10**) was also elaborated. Both enantiomers of the 3-phenyl-3-phosphabicyclo[3.1.0]hexane-oxide [(−)-**8** and (+)-**8**] were prepared in an ee of 67% and 55%, respectively. Both antipodes of the 1-phenyl-1,2,3,6-tetrahydrophosphinine-oxide [(−)-**10** and (+)-**10**] were obtained in ee of 99% and 65%, respectively.[2]

It was proved that among the methods developed earlier in our research group for the preparation of the 6-membered P-heterocycles (**8-10**), the phenyl-3-phospholene-oxide (**1a**) → 3-phenyl-3-phosphabicyclo[3.1.0]hexane-oxide (**8**) reaction involves racemization. However, the phenyl-3-phosphabicyclo[3.1.0]hexane-oxide (**8**) → phenyl-1,2-dihydrophosphinine-oxide (**9**) → phenyl-1,2,3,6-tetrahydrophosphinine-oxide (**10**) reactions can be accomplished by preserving the configuration of the chiral P-centers. On the basis of the above experiences, resolution is the only way for the preparation of the optically active phenyl-3-phosphabicyclo[3.1.0]hexane-oxide (**8**). Both the resolution of the racemic compounds and the reaction of the corresponding optically active starting materials are suitable for the preparation of the enantiomers of phenyl-1,2-dihydrophosphinine-oxide (**9**) and phenyl-1,2,3,6-tetrahydrophosphinine-oxide (**10**).[2]



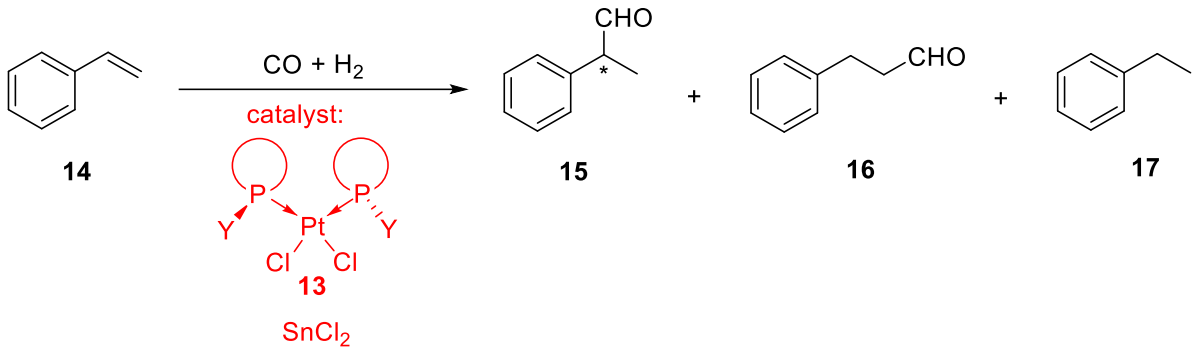
4.3. The synthesis of the borane- and platinum-complexes of 5-membered P-heterocycles (12 and 13)

The racemic and optically active aryl- and alkyl-3-phospholene-oxides (**1b-i**) and propyl-phospholane-oxide (**1k**) were deoxygenated and then converted to the corresponding borane- and platinum-complexes (**12** and **13**). These compounds were unknown in the literature, so their structures were characterized by spectroscopical methods. The stereospecific $^{1}J_{Pt\text{-}P}$ coupling constants determined by ^{31}P NMR specroscopy proved that all of the platinum-complexes (**13**) had *cis*-structure, which was also confirmed by the quantum chemical calculations.[1,3,6]



4.4. The application of the platinum-complexes incorporating 5-membered P-heterocyclic ligands (13) as catalysts in enantioselective hydroformylation

The racemic and optically active platinum-complexes (**13**) were used as catalysts in the hydroformylation of styrene (**14**). It was found that the conversion obtained with the aryl-substituted derivatives (**13b-d**) is higher than the ones obtained with the corresponding alkyl-derivatives (**13e-i** és **13k**). These results may be explained by the different Lewis-character of the ligands. Although direct correlation was not found between the structure of the aryl- or alkyl-substituents and the chemo-or regioselectivity values, but in most cases the alkyl-phospholene-platinum-catalysts (**13e-i**) led to higher enantioselectivity.[1,3,6]



5. Theses

1. The resolution butyl-, *i*-butyl- and propoxy-3-phospholene-oxides was elaborated applying TADDOL-derivatives as the resolving agent. The corresponding 3-phospholene-oxide enantiomers were obtained in an ee about the above 95%.[4,5,7]

2. The resolution of butyl-, *i*-butyl- *i*-pentyl- and propoxy-3-phospholene-oxide was also accomplished with the acidic and neutral Ca^{2+}-salts of the (−)-*O*,*O*'-dibenzoyl- and (−)-*O*,*O*'-di-*p*-toluoyl-(2*R*,3*R*)-tartaric acid. The (*S*)-*i*-pentyl-3-phospholene-oxide was prepared in an ee of 95% using the acidic Ca^{2+}-salt of (−)-*O*,*O*'-di-*p*-toluoyl-tartaric acid as the resolving agent.[3-5,7]

3. Resolution procedures were developed to prepare both antipodes of the butyl- and propoxy-3-phospholene-oxide. Both enantiomers of the butyl-3-phospholene-oxide could be prepared with the same resolving agent, with spiro-TADDOL in different solvents. One propoxy-3-phospholene-oxide enantiomer could be obtained with TADDOL, while the resolution with spiro-TADDOL afforded the other propoxy-3-phospholene-oxide antipode.[4,5]

4. We proved that 3-phenyl-3-phosphabicyclo[3.1.0]hexane-oxide can be prepared in optically active form only by resolution using TADDOL-derivatives and the Ca^{2+}-salts of tartaric acid derivatives, because the dichlorocarbene addition to the double bond of the optically active phenyl-3-phospholene-oxide involves racemization.[2]

5. We found that the enantiomers of the phenyl-1,2,3,6-tetrahydrophosphinine-oxide can be prepared from optically active phenyl-1,2-dihydrophosphinine-oxide, and with the resolution of the corresponding racemic compound applying TADDOL and the Ca^{2+}-salt of (−)-*O*,*O*'-di-*p*-toluoyl-tartaric acid.[2]

6. The butyl-, *i*-butyl- *i*-pentyl- and propoxy-3-phospholene-oxides, the 3-phenyl-3-phosphabicyclo[3.1.0]hexane-oxide and the phenyl-1,2,3,6-tetrahydrophosphinine-oxide were first prepared in optically active form. Analytical methods were developed to determine the enantiomeric excess of the optically active P-heterocycles.[2,3-5,7]

7. The absolute configuration of the corresponding butyl-, *i*-butyl- *i*-pentyl- and propoxy-3-phospholene-oxide enantiomers was also determined by comparing the experimentally obtained and the calculated CD spectra.[4,5,7]

8. In some instances, the structure of the diastereomers obtained during the resolution of butyl-, *i*-butyl- and propoxy-3-phospholene-oxide was analyzed with X-ray crystallography. The X-ray analyses of the single crystals allowed us to determine the absolute configuration of the 3-phospholene-oxides, as well as the intermolecular interactions between the molecules composing the corresponding diastereomeric complexes.[4,5,7]

9. The racemic and optically active aryl- and alkyl-3-phospholene-oxides and a phospholane-oxide were deoxygenated and then converted to the corresponding racemic and optically active borane- and platinum-complexes.[1,3,6]

10. The stereospecific $^{1}J_{Pt\text{-}P}$ coupling constants determined by ^{31}P NMR spectroscopy proved that all of the platinum complexes have *cis*-structure, which was also confirmed by the quantum chemical calculations.[1,3,6]

11. The racemic and optically active platinum-complexes were used as catalysts in hydroformylation. Correlations were found between the structure and the catalytic activity or selectivity of the catalysts.[1,3,6]

6. Application of the scientific results

The resolution methods used for the separation of the enantiomers of 5- and 6-membered P-heterocycles (**1g-j** and **8-10**) may be suitable for the resolution of acyclic phosphine-oxides, as only the presence of the P=O function seems to be required for efficient resolution, which was also suggested by the single crystal X-Ray crystallographic measurements.

The platinum-complexes incorporating 5-membered P-heterocyclic ligands (**13**) were used as catalysts in the enantioselective hydroformylation of styrene. The optically active 5-membered P-heterocycles (**11**) may be used as ligands in other transition metal catalysts.

7. Publications

Full scientific publications related to the PhD Thesis:

[1.] Keglevich, G.; Bagi, P.;Szöllősy, Á.; Körtvélyesi, T.; Pongrácz, P.; Kollár, L.; Drahos, L. *J. Organomet. Chem.* **2011**, *696*, 3557-3563; **IF: 2.384**; F. i.: 1.

[2.] Bagi, P.; Laki, A.; Keglevich, G. *Heteroatom Chem.* **2013**, *24*, 179.; **IF: 1.257**; F. i.: 0.

[3.] Bagi, P.; Kovács, T.; Szilvási, T.; Pongrácz, P.; Kollár, L.; Drahos, L.; Fogassy, E.; Keglevich, G. *J. Organomet. Chem.* **2014**, *751*, 306. **IF: 2.302**; F. i.: 0.

[4.] Bagi, P.; Kállay, M.; Hessz, D.; Kubinyi, M.; Holczbauer, T.; Czugler, M.; Fogassy, E.; Keglevich, G. *Tetrahedron: Asymmetry* **2014**, *25*, 318. **IF: 2.165**; F. i.: 0.

[5.] Bagi, P.; Fekete, A.; Kállay, M.; Hessz, D.; Kubinyi, M.; Holczbauer, T.; Czugler, M.; Fogassy, E.; Keglevich, G. *Chirality* **2014**, *26*, 174. **IF: 1.724**; F. i.: 0.

[6.] Bagi, P.; Szilvási, T.; Pongrácz, P.; Kollár, L.; Drahos, L.; Keglevich, G. *Curr. Org. Chem.* **2014**, *in press.* **IF: 2.537**; F. i.: 0.

[7.] Bagi, P.; Fekete, A.; Kállay, M.; Hessz, D.; Kubinyi, M.; Holczbauer, T.; Czugler, M.; Fogassy, E.; Keglevich, G. *Heteroatom Chem.* **2014**, *accepted for publication.* **IF: 1.257**; F. i.: 0.

Proceedings related to the PhD Thesis:

[8.] Ujj, V.; Bagi, P.; Laki, A.; Fogassy, E.; Keglevich, Gy. *Phosphorus, Sulfur, Silicon Relat. Elem.* **2010**, *186*, 792-793.; **IF: 0.621**; F. i.: 0.

[9.] Bagi, P.; Kovács, T.; Laki, A.; Fekete A.; Fogassy, E.; Keglevich, G. *Phosphorus, Sulfur, Silicon Relat. Elem.* **2013**, *188*, 36.; **IF: 0.827**; F. i.: 0.

[10.] Bagi, P.; Kovács, T.; Kollár, L.; Fogassy, E.; Keglevich, G. *Phosphorus, Sulfur, Silicon Relat. Elem.* **2014**, *submitted*, **IF: 0.827**; F. i.: 0.

Other publications related to the PhD Thesis:

[11.] Ujj, V.; Schindler, J.; Bagi, P.; Madarász, J.; Fogassy, E.; Keglevich, G. *Chirality* **2010**, *22*, 699-705; **IF: 2.892**; F. i.: 0.

[12.] Keglevich, G; Bagi, P.; Bálint, E. *Platinum Compounds, Production and Applications* Varrennikov, L., Yedemsky, E., Eds. *Nova Science Publishers* New York, **2013**, p 83.; **IF: 0**; F. i.: 0.

[13.] Keglevich, G.; Grün, A.; Bagi, P.; Bálint, E.; Kiss, N. Z.; Kovács, R.; Jablonkai, E.; Kovács, T.; Fogassy, E.; Greiner, I. *Per. Pol. Chem. Eng.* **2014**, *accepted for publication.* **IF: 0.269**; F. i.: 0.

Additional publications:

[14.] Szeleczky, Z.; Bagi, P.; Pálovics, E.; Fogassy, E. *Tetrahedron Asymmetry* **2014**, *5*, 1095. **IF: 2.165**; F. i.: 0.

[15.] Pálovics, E.; Szeleczky, Z.; Bagi, P.; Faigl, F.; Fogassy, E. *Per. Pol. Chem. Eng.* **2014**, *accepted for publication.* **IF: 0.269**; F. i.: 0.

[16.] Bagi, P. *Per. Pol. Chem. Eng.* **2009,** *53*, 19.; **IF: 0**; F. i.: 0.

Oral presentations:

[17.] Bagi, P.; Ujj, V.; Schindler, J.; Fogassy, E. *Borkősav származékok fémsóinak alkalmazása P-királis vegyületek reszolválására*, XXXII. Kémiai Előadói Napok, Szeged, 2009.

[18.] Bagi, P.; Keglevich, G.; Fogassy, E. *5- és 6-tagú P-heterociklusok reszolválása és komplexképzési reakciói*, XXXIV. Kémiai Előadói Napok, Szeged, 2011.

[19.] Bagi, P.; Keglevich, G.; Fogassy, E. *5- és 6-tagú P-heterociklusok reszolválása és komplexképzési reakciói*, XXXV. Kémiai Előadói Napok, Szeged, 2012.

[20.] Bagi, P.; Keglevich, G.; Fogassy, E. *Foszfor-heterocilusok reszolválása; racém és optikailag aktív foszfor-heterocilust tartalmazó Pt-komplexek előállítása és alkalmazása katalizátorként*, Professzorok az Európai Magyarországért Egyesület által szervezett "Nemzedékek együttműködése a tudományban" konferencia, Budapest, 2012.

[21.] Bagi, P.; Fogassy, E.; Keglevich, G. 5- és *6-Tagú P-heterociklusok reszolválása; Racém és optikailag aktív platina(II)-1-alkil-3-foszfolén komplexek szintézise, molekulaszerkezete, katalitikus aktivitása*, Oláh György Doktori Iskola X. konferenciája, Budapest, 2013.

[22.] Bagi, P.; Kovács, T.; Fogassy, E.; Keglevich, G. *Novel racemic and optically active 1-alkyl-3-phospholene platinum(II) complexes*, 10th European Workshop on Phosphorus Chemistry, Regensburg, 2013.

[23.] Bagi, P.; Kovács, T.; Szilvási, T.; Kállay, M.; Kubinyi, M.; Czugler, M.; Drahos, L.; Kollár, L.; Fogassy, E.; Keglevich, G. *5- és 6-tagú P-heterociklusok reszolválása és komplexképzési reakciói*, MTA Heterociklusos és Elemorganikus Kémiai Munkabizottságának előadóülése, Balatonszemes, 2013.

[24.] Bagi, P.; Kovács, T.; Fogassy, E.; Keglevich, G. *5- és 6-tagú P-heterociklusok reszolválása és komplexképzési reakciói*, Vegyészkonferencia 2013, Hajdúszoboszló, 2013.

[25.] Bagi, P.; Kovács, T.; Fogassy, E.; Keglevich, G. *Resolution and complexation reactions of 5- and 6-membered P-heterocycles* 15. Österreichische Chemietage 2013, Graz, 2013.

Poster presentations:

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