

LigPrep 2.3

User Manual

LigPrep User Manual Copyright © 2009 Schrödinger, LLC. All rights reserved.

While care has been taken in the preparation of this publication, Schrödinger assumes no responsibility for errors or omissions, or for damages resulting from the use of the information contained herein.

Canvas, CombiGlide, ConfGen, Epik, Glide, Impact, Jaguar, Liaison, LigPrep, Maestro, Phase, Prime, PrimeX, QikProp, QikFit, QikSim, QSite, SiteMap, Strike, and WaterMap are trademarks of Schrödinger, LLC. Schrödinger and MacroModel are registered trademarks of Schrödinger, LLC. MCPRO is a trademark of William L. Jorgensen. Desmond is a trademark of D. E. Shaw Research. Desmond is used with the permission of D. E. Shaw Research. All rights reserved. This publication may contain the trademarks of other companies.

Schrödinger software includes software and libraries provided by third parties. For details of the copyrights, and terms and conditions associated with such included third party software, see the Legal Notices for Third-Party Software in your product installation at `$(SCHRODINGER)/docs/html/third_party_legal.html` (Linux OS) or `%SCHRODINGER%\docs\html\third_party_legal.html` (Windows OS).

This publication may refer to other third party software not included in or with Schrödinger software ("such other third party software"), and provide links to third party Web sites ("linked sites"). References to such other third party software or linked sites do not constitute an endorsement by Schrödinger, LLC. Use of such other third party software and linked sites may be subject to third party license agreements and fees. Schrödinger, LLC and its affiliates have no responsibility or liability, directly or indirectly, for such other third party software and linked sites, or for damage resulting from the use thereof. Any warranties that we make regarding Schrödinger products and services do not apply to such other third party software or linked sites, or to the interaction between, or interoperability of, Schrödinger products and services and such other third party software.

June 2009

Contents

Document Conventions	vii
Chapter 1: Introduction	1
1.1 The LigPrep Manual	1
1.2 The LigPrep Process	2
1.3 LigPrep Installation and Licensing	4
1.4 Running Schrödinger Software	4
1.5 Other Utilities	4
1.6 Citing LigPrep in Publications	5
Chapter 2: Running LigPrep	7
2.1 Running LigPrep From Maestro	7
2.1.1 Selecting Structure Input and Output	7
2.1.2 Setting Filter Criteria	8
2.1.3 Selecting a Force Field	11
2.1.4 Setting Stereoisomer Options	11
2.1.5 Setting Ionization State Options	11
2.1.6 Removing Cofactors	12
2.1.7 Generating Tautomers	12
2.1.8 Generating Ring Conformations	12
2.1.9 Submitting the Job	12
2.2 The ligprep Command	13
2.3 Distributing LigPrep Jobs with para_ligprep	20
2.4 LigPrep Input File	22
2.5 LigPrep Output Files	25
2.6 LigPrep Limitations	27
Chapter 3: Using LigPrep	29
3.1 LigPrep Panel Examples	29
3.1.1 Creating a Working Directory and Copying Files	29

3.1.2	Starting Maestro and Setting the Working Directory.....	31
3.1.3	Generating Variations on 2D Structures	31
3.1.4	Generating Ring Conformations of a 3D Structure	35
3.2	Command-Line Examples.....	37
3.2.1	Default Operation.....	37
3.2.2	Producing One Output Structure for Each Input Structure.....	38
3.2.2.1	Adjusting Only the Geometry.....	38
3.2.2.2	Adjusting the Chemistry	39
3.2.3	Generating Variations	39
3.2.3.1	Generating a Small Set of Low-risk Variations	40
3.2.3.2	Generating Many Variations	40
3.2.3.3	Using Meta-Options for Convenient Selection of Run Characteristics	40
3.2.4	Preparing Ligands for QikProp.....	42
3.2.5	Filtering Structures.....	42
3.2.6	Running LigPrep on a Remote Host	42
3.3	Chirality Manipulations Using Maestro and LigPrep.....	43
Chapter 4: Tools Used by LigPrep.....		45
4.1	sdconvert.....	45
4.2	smiles_to_mae.....	46
4.3	maesubset	47
4.4	applyhtreat.....	47
4.5	desalter	49
4.6	neutralizer	49
4.7	ionizer	50
4.8	tautomerizer	51
4.9	ligfilter	51
4.10	stereoizer	54
4.10.1	Stereochemical Properties.....	56
4.10.2	Known Limitations.....	57

4.11	ring_conf	58
4.12	premin	60
4.13	MacroModel (bmin)	61
4.13.1	MacroModel Opcodes Enabled for LigPrep	62
4.13.2	The LigPrep Command File for MacroModel	66
4.13.3	MacroModel Limitations and Workarounds	66
Chapter 5: The ionizer Utility		69
5.1	Running the ionizer	69
5.2	Input Structure Requirements	71
5.3	Restricting Ionization State Generation	72
5.4	Structural Output	73
5.5	Log File Output	73
5.6	Maestro Properties	74
5.7	Creating a Customized Patterns File	77
5.8	Ionizer Limitations	77
Chapter 6: The tautomerizer Utility		79
6.1	Running the tautomerizer	80
6.2	The Tautomer Database	81
6.2.1	name Data Item	81
6.2.2	clear_standard Directive	82
6.2.3	group_def Data Structure	82
6.2.4	tautomer_set Data Structure	83
6.3	Tautomer Processing	86
6.3.1	Tautomer Pattern Matching	86
6.3.2	Structure Generation	86
Getting Help		97
Index		101

Document Conventions

In addition to the use of italics for names of documents, the font conventions that are used in this document are summarized in the table below.

Font	Example	Use
Sans serif	Project Table	Names of GUI features, such as panels, menus, menu items, buttons, and labels
Monospace	<code>\$SCHRODINGER/maestro</code>	File names, directory names, commands, environment variables, and screen output
Italic	<i>filename</i>	Text that the user must replace with a value
Sans serif uppercase	CTRL+H	Keyboard keys

Links to other locations in the current document or to other PDF documents are colored like this: [Document Conventions](#).

In descriptions of command syntax, the following UNIX conventions are used: braces { } enclose a choice of required items, square brackets [] enclose optional items, and the bar symbol | separates items in a list from which one item must be chosen. Lines of command syntax that wrap should be interpreted as a single command.

File name, path, and environment variable syntax is generally given with the UNIX conventions. To obtain the Windows conventions, replace the forward slash / with the backslash \ in path or directory names, and replace the \$ at the beginning of an environment variable with a % at each end. For example, `$SCHRODINGER/maestro` becomes `%SCHRODINGER%\maestro`.

In this document, to *type* text means to type the required text in the specified location, and to *enter* text means to type the required text, then press the ENTER key.

References to literature sources are given in square brackets, like this: [10].

Introduction

LigPrep is a robust collection of tools designed to prepare high quality, all-atom 3D structures for large numbers of drug-like molecules, starting with 2D or 3D structures in SD or Maestro format. The resulting structures can be saved in either SD or Maestro format. The simplest use of LigPrep produces a single, low-energy, 3D structure with correct chiralities for each successfully processed input structure. LigPrep can also produce a number of structures from each input structure with various ionization states, tautomers, stereochemistries, and ring conformations, and eliminate molecules using various criteria including molecular weight or specified numbers and types of functional groups present.

LigPrep can be run from Maestro on UNIX or Windows platforms, or from the command line on UNIX platforms. The `ligprep` script provides an efficient way to use a set of tools for ligand preparation collectively and consistently. Some of the tools may also be used separately. The ligand preparation process typically takes about one second per output structure on a 2 GHz x86-compatible computer. Depending on the nature of the input structures and on the options selected, multiple output structures may be produced from each input structure. LigPrep calculations can be distributed across multiple processors to increase throughput using the `para_ligprep` script.

1.1 The LigPrep Manual

This manual explains how to use LigPrep, a program suite designed to prepare high quality, all-atom 3D structures for large numbers of drug-like molecules, starting with 2D or 3D structures. The manual is organized as follows:

- [Chapter 1](#) provides an overview of LigPrep and the process it uses to prepare ligands.
- [Chapter 2](#) explains how to run LigPrep from Maestro and from the command line.
- [Chapter 3](#) provides instruction on the use of LigPrep in several scenarios.
- [Chapter 4](#) describes the tools used by LigPrep.
- [Chapter 5](#) describes the `ionizer` and its options, input, and output.
- [Chapter 6](#) describes the `tautomerizer` and how it generates tautomers in detail.

1.2 The LigPrep Process

The LigPrep process consists of a series of steps that perform conversions, apply corrections to the structures, generate variations on the structures, eliminate unwanted structures, and optimize the structures. Many of the steps are optional and are controlled by selecting options in the LigPrep panel or by specifying command-line options. The steps are outlined below. Each step is performed by the script or program mentioned in the step.

While the generation of ionization states and tautomers ([Step 6](#) and [Step 7](#)) can be carried out with tools that are part of LigPrep, a separate product, Epik, can be used instead to perform these structural adjustments during a LigPrep run. Epik more rigorously adjusts the tautomerization and ionization states than separate ionizer and tautomerizer treatments. However, it is slower, taking on average around 6 seconds per structure on a 2 GHz Pentium IV processor.

1. Convert the structure format.

If the input structure file is in SD format, it is converted to Maestro format by `sdconvert`. Parities specified in the SD file are converted into chiralities, which are stored as properties in the Maestro file. If the input structure file is in SMILES format, it is converted to Maestro format by `smiles_to_mae`. The input file should have one SMILES pattern per line. The SMILES pattern can be followed by an optional title string.

2. Select the structures.

A subset of the input structures can be selected for processing. The selection is done by `maesubset` for Maestro input files and by `sdconvert` for SD input files.

3. Add hydrogen atoms.

Structures that have implicit hydrogen atoms may need to have hydrogen atoms added before the 3D structures can be minimized. Hydrogen atoms are added in a manner that is consistent with a particular force field. This step is performed by `applyhtreat`, the program used by the Hydrogen Treatment panel in Maestro.

4. Remove unwanted molecules.¹

If structures have additional molecules included, such as counter ions in salts and water molecules, these may need to be removed. The `desalter` removes all but the molecule containing the most atoms from each structure.

5. Neutralize charged groups.¹

Charged groups must be neutralized before ionization states can be generated. The neutralization is performed by the `neutralizer`, which adds or removes hydrogen ions.

1. Executed by default, but optional in the LigPrep process.

6. Generate ionization states.²

For some applications, it is important that all species that exist in a given pH range are available. In this step, the `ionizer` generates various ionization states for each structure. This step should be preceded by a neutralization step.

7. Generate tautomers.¹

As with ionization, the tautomeric states with a significant population may be important for some types of calculations. The `tautomerizer` generates various tautomers for each structure.

8. Filter the structures.¹

In this step, structures that match specified conditions can be removed. The condition can be on a property, such as Molecular weight > 1000, or on the structure, such as the presence or absence of a specific functional group. This step is performed by `ligfilter`.

9. Generate alternative chiralities.¹

Since 2D structures do not always have complete chirality information, it can be useful to vary the chiralities of the atoms to find all the low-energy structures or to provide a range of possible structures for investigation. This step identifies additional chiral atoms in the structures and generates additional structures with the same molecular formula but different chiral properties. The step is performed by `stereoizer`.

10. Generate low-energy ring conformations.¹

When ring conformation information is not available, it can be important to specifically generate low-energy ring conformations. Ring conformations are generated for each structure by `ring_conf`.

11. Remove problematic structures.

Structures that could cause subsequent processing failures either in the energy minimization of the structures or in other applications are removed by `premin`.

12. Optimize the geometries.

The geometries of the generated structures are optimized using a restricted version of the MacroModel™ computational program, `bmin`, or a short conformational search is performed to relax the structure into 3 dimensions while strongly encouraging chiral centers to adopt the proper chiralities (if the structure is highly strained).

13. Convert the output file.

If output in SD format was requested, `sdconvert` is run to perform the conversion.

2. Not executed by default, but can be enabled in the LigPrep process by setting the appropriate options.

1.3 LigPrep Installation and Licensing

LigPrep is licensed separately from other Schrödinger products. The MacroModel commands `premin` and `bmin` require LigPrep licenses when run in a LigPrep context, and are limited to a restricted set of commands when run using a LigPrep license. For details on the available commands, see [Section 4.13 on page 61](#).

Instructions for installing LigPrep and obtaining a license are given in the *Installation Guide*.

1.4 Running Schrödinger Software

To run any Schrödinger program on a UNIX platform, or start a Schrödinger job on a remote host from a UNIX platform, you must first set the `SCHRODINGER` environment variable to the installation directory for your Schrödinger software. To set this variable, enter the following command at a shell prompt:

```
csh/tcsh:      setenv SCHRODINGER installation-directory
bash/ksh:     export SCHRODINGER=installation-directory
```

Once you have set the `SCHRODINGER` environment variable, you can start Maestro with the following command:

```
`${SCHRODINGER}/maestro &
```

It is usually a good idea to change to the desired working directory before starting Maestro. This directory then becomes Maestro's working directory.

For more information on starting Maestro, including starting Maestro on a Windows platform, see [Section 2.1](#) of the *Maestro User Manual*.

1.5 Other Utilities

A number of utilities that are provided with LigPrep, but are not part of LigPrep itself, might be useful in conjunction with LigPrep. These utilities are available in ``${SCHRODINGER}/utilities`, and include:

- `propmaster`—extracts requested properties from Maestro-formatted files
- `propfilter`—selects structures from Maestro-formatted files using the properties stored in the files
- `maemmod` and `mmodmae`—converts files between Maestro and MacroModel formats
- `mmodmol` and `molmmod`—converts files between MacroModel and Sybyl Mol2 formats

- `pdbconvert`—converts files between Maestro or MacroModel and PDB formats
- `maesubset`—selects a subset of the structures in a Maestro-formatted file
- `sdssubset`—selects a subset of the structures in an SD-formatted file

More information on these utilities is available in the [Appendix D](#) of the *Maestro User Manual*.

1.6 Citing LigPrep in Publications

The use of this product should be acknowledged in publications as:

LigPrep, version 2.3, Schrödinger, LLC, New York, NY, 2009.

Running LigPrep

The main objective of LigPrep is to take 2D or 3D structures and produce corresponding low-energy 3D structures for use in further computational studies. The input and output files can be in SD or Maestro format. LigPrep can also produce multiple output structures for each input structure, a process referred to as *expansion*, by generating variations on the ionization state, tautomers, stereochemistry, and ring conformations.

2.1 Running LigPrep From Maestro

You can set up a LigPrep job from the LigPrep panel in Maestro. To open the LigPrep panel, choose LigPrep from the Applications menu in the main window.

2.1.1 Selecting Structure Input and Output

The upper portion of the LigPrep panel contains settings that control the input structures.

Use structures from

The input for LigPrep can come from the Workspace, selected entries in the Project Table, or from a file. If you select *Workspace (included entries)* or *Project Table (selected entries)* as the source of job input, the structures are written to a file in Maestro format, named *jobname.mae*. If you select *File*, you can type a file name in the File name text box, or click *Browse* to navigate to the file and select it. The file can be in Maestro or SD format, compressed or uncompressed, or it can be in one of two SMILES formats:

- *.smi* file—Text file with one SMILES string and an optional title per line
- *.csv* file—Comma-separated file with the SMILES string as the first field, title as the second, followed by optional properties

If you decide to use a file for your job input, the results are written to a file in the format you specify under *Output format* (in the lower left of the panel). The file name is *jobname.ext*, where *ext* is *mae* for Maestro format, or *sdf* for SDF format.

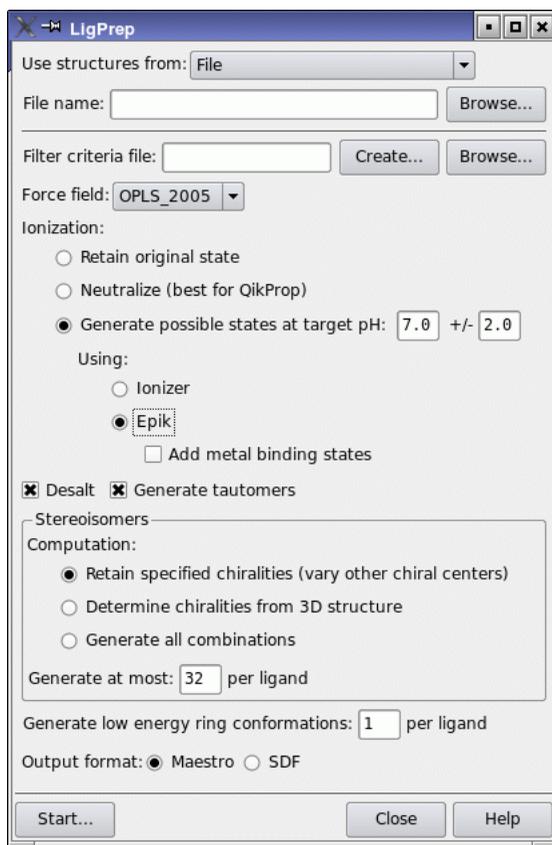


Figure 2.1. The LigPrep panel.

2.1.2 Setting Filter Criteria

The structures that are produced can be filtered on the basis of various predefined descriptors, using `ligfilter`. These descriptors are counts of various kinds of structural components, including a range of functional groups. You can filter the structures generated by LigPrep using a file that defines conditions on these descriptors. The descriptors are listed on [page 10](#).

This file can be created by clicking `Create`, and constructing the list of criteria in the `Create Filter Criteria File` panel. You can also read an existing file by clicking `Browse`, and navigating to the file in the file selector that opens. The following instructions describe how to create a filter in the `Create Filter Criteria File` panel.

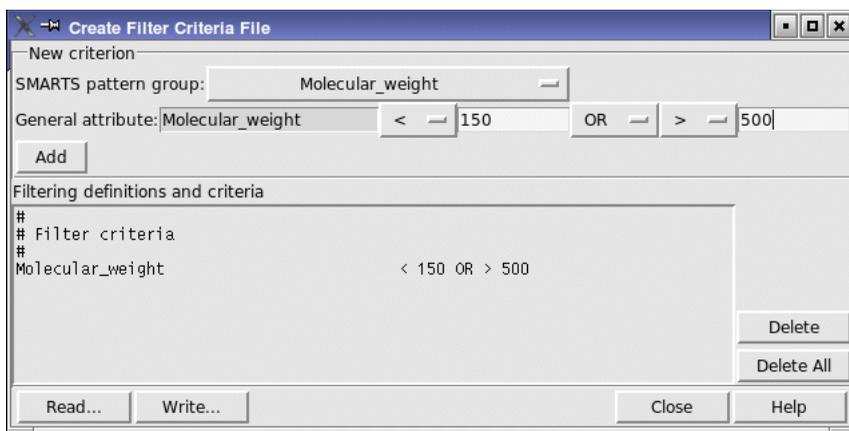


Figure 2.2. The Create Filter Criteria File panel.

To create a simple filter criterion:

1. Select a descriptor from the SMARTS pattern group option menu.
The descriptor is added to the General attribute text box.
2. Choose a relational operator from the first option menu to the right of the General attribute text box.
3. Enter a value in the text box immediately to the right.
4. Click Add.

The new criterion is added to the Filtering conditions and criteria text area.

To add a second condition, do the following before clicking Add:

1. Choose a Boolean operator from the option menu in the middle.
2. Choose a relational operator from the next option menu.
3. Enter a value in the text box immediately to the right.

Adding the second condition allows you to specify a range of values. For example, the following criterion excludes ligands with molecular weights that are not in the range 150–500:

```
Molecular weight          < 150 OR > 500
```

If you add a criterion when one already exists for a particular SMARTS pattern group, the existing criterion is overwritten with the new one. You can delete individual criteria by selecting them in the list and clicking Delete. The Delete All button clears the entire list.

The SMARTS pattern group list has the following descriptors:

Acceptor_groups	Num_aliphatic_rings
Acidic_hydrogens	Num_aromatic_rings
Amide_hydrogens	Num_atoms
Charged_acceptor_groups	Num_chiral_centers
Charged_donor_groups	Num_heteroaromatic_rings
Divalent_oxygens	Num_negative_atoms
Donor_groups	Num_positive_atoms
Molecular_weight	Num_rings
Neutral_acceptor_groups	Num_rotatable_bonds
Neutral_amines	Reactive_groups
Neutral_donor_groups	Total_charge

When you have finished creating the list of criteria, you can write the list to a file in the current directory by clicking **Write**. A dialog box opens, in which you can specify the file name. When you click **OK**, the file is created and the file name is displayed in the **Filter criteria file** text box in the **LigPrep** panel.

Existing filter criteria file can be read (replacing the existing list contents) by clicking **Read** and navigating to the desired file. You then can modify the criteria list and write out a new file.

An example filter criteria file is given below. Comment lines start with **#**. The files generated from the panel only have a generic comment at the top, but you can add comments if you want.

```
# Remove molecules that have a molecular weight of greater than 650
Molecular_weight > 650
# Remove molecules with too many H-bond acceptor and donor atoms
Acceptor_groups > 3
Donor_groups > 3
# Remove molecules with fewer than 10 atoms
Num_atoms < 10
```

If you want to use other descriptors than those listed above, you can create a filter criteria file from the **Ligand Filtering** panel in **Maestro**, which you open from the **Tools** menu. You can then import this file by clicking **Browse** in the **LigPrep** panel to select a filter criteria file. For more information on the **Ligand Filtering** panel, see [Section 9.7](#) of the *Maestro User Manual*.

For more information on **ligfilter**, see [Section 4.9](#) on page 51.

2.1.3 Selecting a Force Field

You can choose a force field from the Force field option menu. This force field is used in the MacroModel (`bmin`) step. The choices are `OPLS_2005` and `MMFFs`.

2.1.4 Setting Stereoisomer Options

The option you select affects the treatment of stereochemical information in the input and the generation of stereoisomers in the output.

- **Retain specified chiralities** keeps the information on chiralities from the input file and fixes these chiralities for the entire calculation. Chirality information includes parities and bond directions from SD files and the chirality and atom numbering chirality properties from Maestro files. (Maestro chiralities are written only by `sdconvert` and the `stereoizer`.) If the configuration or chirality of a chiral center is not specified, the two possible chiralities are generated internally.
- **Determine chiralities from 3D structure** discards any information from the input file and determines the chirality from the 3D geometry. These chiralities are held fixed. For centers whose chirality is indeterminate, the two possible chiralities are generated internally.
- **Generate all combinations** discards chirality information and internally generates all possible configurations that result from the combination of chiralities on each chiral center.

For any of these settings, the internally generated stereoisomers are subjected to a filtering step to eliminate some structures that either violate geometric restrictions for fused ring systems or conflict with natural product chiralities (e.g. the pattern of chiralities in steroid frameworks).

You can limit the number of stereoisomers generated for the atoms whose chiralities are not assigned by entering a limit in the `Generate at most N per ligand` text box.

2.1.5 Setting Ionization State Options

The option you select controls the generation of ionization states of the ligand. The ionization states are generated by adding or removing protons from the ligand. Some programs require neutral molecules as input. For these programs, you should select `Neutralize`. For other programs, such as `Glide`, it can be useful to generate a range of ionization states that are populated in a given pH range. The `Generate possible states` option selects the generation of ionization states that are significantly populated in the specified pH range. If you do not want the ionization states to be altered, choose `Retain original state`. However, even if you select `Retain original state`, deprotonated acids can still be protonated by `applyhtreat` if the formal charges in the acid are incorrect.

To perform the ionization, you can select either the Ionizer or Epik. Epik is a separate product, and must be purchased and installed if you want to use it with LigPrep. The Ionizer is included with LigPrep.

Epik can generate ionization and tautomeric states for molecules in aqueous solution (the default), and also for molecules bound to metals in metalloproteins. Extra structures are generated and an alternate ranking scheme is used for states of molecules that are bound to metals in a protein. The option to account for metal binding is set by selecting **Add metal binding states**. These states can be used by Glide when docking ligands to metalloproteins, for example.

2.1.6 Removing Cofactors

Structures from some databases can consist of multiple molecules, one of which is the ligand. In many cases, the extra molecules are water molecules or counter ions. To remove these molecules, select the **Desalt** option. LigPrep removes all but the largest molecule when this option is selected. In most cases, this procedure removes the correct molecules. If the desired molecule is not the largest, you may have to edit the structure in Maestro before passing it to LigPrep.

2.1.7 Generating Tautomers

For some ligand molecules, a tautomer of the commonly-given structure binds to the active site. To generate up to 8 tautomers per input structure, select **Generate Tautomers**. LigPrep performs keto-enol tautomerization and the analogous sulfur and nitrogen tautomerizations, and histidine and DNA base tautomerizations. For more information, see [Chapter 6](#).

2.1.8 Generating Ring Conformations

From a 2D structure, it is not immediately obvious which ring conformations give the lowest energy or are preferred for binding to an active site. LigPrep can generate ring conformations and evaluate an approximate conformational energy to determine which conformations are likely to be the lowest in energy. The value in the **Generate low energy ring conformations** text box determines how many conformations are kept, counting from the lowest in energy.

2.1.9 Submitting the Job

Once you have selected the structural variation options, click **Start** to open the **Start** dialog box (see [Figure 2.3](#)) and choose options for how and where the job is run. This dialog box is a common interface for submitting jobs from Maestro. For details of its features, see [Section 2.2](#) of the *Job Control Guide*.

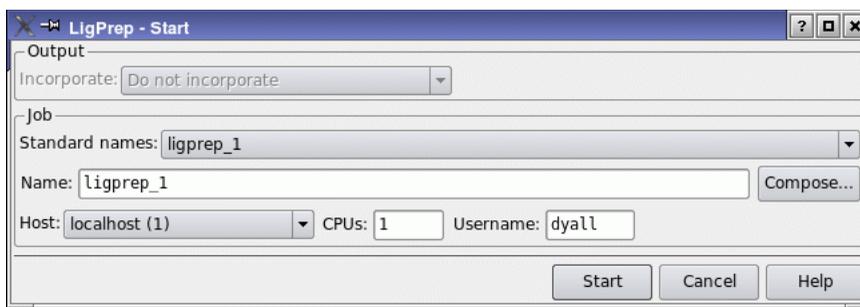


Figure 2.3. The LigPrep - Start dialog box.

- If your job input came from a file, the results are written to a file in the format you specified under Output format (see [Section 2.1.1 on page 7](#)). The file name is *jobname.ext*, where *ext* is *mae* for Maestro format or *sdf* for SD format.
- If you want to run the job on a remote host, choose a host from the Host option menu, and enter your user name in the Username text box if it is different on the remote host. You can distribute the job across multiple processors by selecting a multiprocessor host and entering the number of CPUs in the CPUs text box. For more information on hosts, host settings, and configuring this file, see [Chapter 6](#) of the *Installation Guide*.

When you have finished choosing settings, click Start to start the job. The LigPrep job is submitted to the selected host, and the Maestro Monitor panel is displayed. This panel provides information on the status of the job. Output for each step of the LigPrep process is stored in a temporary directory. The log file for the job is stored in the job submission directory (the Maestro current working directory). This file is updated as the job progresses and is displayed in the Monitor panel. For more information on job monitoring, see the [Job Control Guide](#).

2.2 The ligprep Command

To run LigPrep from the command line, use the `ligprep` command. This command is only available on UNIX platforms. The syntax of the `ligprep` command is as follows.

```
$SCHRODINGER/ligprep [options | meta-options] {-imae|-isd|-ismi}
input_filename{-omae|-osd} output_filename
```

You must specify an input structure file using either `-imae` for input files in Maestro format, `-isd` for input files in SD file format, or `-ismi` for input files in SMILES format, either as a list of SMILES strings (`.smi`) or as a CSV file containing a SMILES string with optional title and properties on each line, separated by commas (`.csv`). The output file is specified with `-omae` for Maestro format or `-osd` for SD format. Maestro input and output files can be in uncompressed (`.mae`) or compressed (`.maegz` or `.mae.gz`) form.

The `ligprep` command has a number of options for controlling the stages of the process. The options and their descriptions are listed in [Table 2.1](#) and can be displayed by entering the command `ligprep -h`. The standard Job Control options, for setting the user name, selecting the host, defining a scratch directory, and so on, are supported—see [Section 2.3](#) of the *Job Control Guide* for a complete listing. In particular, you should note the syntax of the `-HOST` option, which is used to specify the list of hosts used for the job. In addition to these options, the `ligprep` command supports some other job options, which are listed in [Table 2.2](#).

The `ligprep` command also has a number of *meta-options*, which set a group of options with particular values. The meta-options are listed in [Table 2.3](#), and their actions are described in [Table 2.4](#). You can use options together with meta-options; the options override any values set by the meta-options.

The options can also be specified in an input file that contains keyword-value pairs to set the options—see [Section 2.4 on page 22](#) for details.

Table 2.1. Options for the ligprep command

Option	Definition
<i>General</i>	
<code>-a</code>	Append structures to the output file. Default is to overwrite the output file if it already exists.
<code>-inp filename</code>	Use input file to obtain values for options.
<code>-kp -keep_props</code>	Transmit properties from input to output at each stage, and retain properties in the output structure file. The <code>ionizer</code> and <code>bmin</code> delete properties by default.
<code>-ma number</code>	Skip over structures containing more than this number of atoms in some steps. Default: 150.
<code>-n structs</code>	Specify a comma-delimited series of colon-separated ranges and single values to convert. For example: 1:10,14 Structures 1 through 10, and 14 2: Structures 2 through end of file :5,13:18 Structures 1 through 5, and 13 through 18 Default: 1: (convert all structures)
<code>-nc</code>	Do not remove intermediate files. Default is to remove intermediate files.
<code>-np</code>	Remove files containing problematic structures. Default is to keep problematic structure files.
<code>-nz</code>	Do not create tar archive of intermediate files. Default is to create a tar archive.

Table 2.1. Options for the `ligprep` command (Continued)

Option	Definition																								
-R {b c d e f h i n p r s t}	Run only the stage of ligand preparation specified by the letter code: <table border="0"> <tr> <td>b</td><td>bmin minimization</td> <td>i</td><td>ionizer</td> </tr> <tr> <td>c</td><td>sdconvert</td> <td>n</td><td>neutralizer</td> </tr> <tr> <td>d</td><td>desalter</td> <td>p</td><td>premin</td> </tr> <tr> <td>e</td><td>epik</td> <td>r</td><td>ring_conf</td> </tr> <tr> <td>f</td><td>filter (ligfilter)</td> <td>s</td><td>stereoizer</td> </tr> <tr> <td>h</td><td>applyhtreat</td> <td>t</td><td>tautomerizer</td> </tr> </table>	b	bmin minimization	i	ionizer	c	sdconvert	n	neutralizer	d	desalter	p	premin	e	epik	r	ring_conf	f	filter (ligfilter)	s	stereoizer	h	applyhtreat	t	tautomerizer
b	bmin minimization	i	ionizer																						
c	sdconvert	n	neutralizer																						
d	desalter	p	premin																						
e	epik	r	ring_conf																						
f	filter (ligfilter)	s	stereoizer																						
h	applyhtreat	t	tautomerizer																						
-sif_docs	Display documentation for the simplified input file, and exit.																								
-verb	Report on the progress of the ligand preparation.																								
-W <i>string</i>	Options for various stages of ligand preparation. <i>string</i> consists of comma-separated designators. The first designator specifies the program that options are to be passed to and must be one of: <table border="0"> <tr> <td>ci</td><td>sdconvert on input structures</td> </tr> <tr> <td>co</td><td>sdconvert on output structures</td> </tr> <tr> <td>e</td><td>epik</td> </tr> <tr> <td>f</td><td>filter (ligfilter or ligparse)</td> </tr> <tr> <td>i</td><td>ionizer</td> </tr> <tr> <td>qp</td><td>qikprop</td> </tr> <tr> <td>r</td><td>ring_conf</td> </tr> <tr> <td>s</td><td>stereoizer</td> </tr> </table> <p>The remaining designators are passed to the program in the order specified with the commas removed. For example: <code>r,-1,1,-n,16</code> passes the arguments <code>-1 1 -n 16</code> to <code>ring_conf</code>. Multiple <code>-W</code> options are permitted, but only the last one pertaining to a particular program is used. For <code>ring_conf</code> and <code>stereoizer</code>, these options are used in addition to the default options and override redundant specifications. When <code>ligparse</code> is in use, it is passed the following arguments by default: <code>-any -j 5</code> (filter by rejecting structures if any criteria listed in the filter file are matched). If the <code>-W</code> option is used to pass arguments to <code>ligparse</code>, the default set of arguments is not used by <code>ligparse</code>.</p> <p>Note: Not all ionizer options are supported with the <code>-W</code> option. See Section 5.1 on page 69 for more information.</p>	ci	sdconvert on input structures	co	sdconvert on output structures	e	epik	f	filter (ligfilter or ligparse)	i	ionizer	qp	qikprop	r	ring_conf	s	stereoizer								
ci	sdconvert on input structures																								
co	sdconvert on output structures																								
e	epik																								
f	filter (ligfilter or ligparse)																								
i	ionizer																								
qp	qikprop																								
r	ring_conf																								
s	stereoizer																								
Desalting																									
-nd	Do not use the desalter. Default is to use the desalter.																								
Ionization																									
-epik	Use Epik for the ionization and tautomerization stages.																								
-emb	Use the Epik metal binding option for ionization and tautomerization, so that states appropriate for interacting with metal ions in protein binding pockets are also generated. An alternative form of this option is <code>-epik_metal_binding</code> .																								

Table 2.1. Options for the `ligprep` command (Continued)

Option	Definition
<code>-es filename</code>	Use the specified nonstandard Epik pK_a file.
<code>-i number</code>	Ionization treatment. 0 Do not neutralize or ionize. 1 Neutralize only. 2 Neutralize and ionize. Default: 1. If <code>-epik</code> is used, this option only controls neutralization. If <code>ionizer</code> is used, both ionization and neutralization are affected.
<code>-is filename</code>	Use non-standard ionizer specification file, named <i>filename</i> .
<code>-mbs filename</code>	Use the specified nonstandard Epik metal binding file.
<code>-mg number</code>	Instruct <code>ionizer</code> to skip structures that have more than this number of ionizable groups. Default: 10
Tautomerization	
<code>-epik</code>	Use Epik for the ionization and tautomerization stages.
<code>-emb</code>	Use Epik metal binding mode for ionization and tautomerization, so that states appropriate for interacting with metal ions in protein binding pockets are also generated. An alternative form of this option is <code>-epik_metal_binding</code> .
<code>-mbs filename</code>	Use the specified nonstandard Epik metal binding file.
<code>-nt</code>	Do not generate tautomers. Default is to generate tautomers.
<code>-t number</code>	Generate up to <i>number</i> tautomers per input structure. Default: 8
<code>-tp number</code>	Set the minimum tautomerization probability to <i>number</i> , where $0 < number < 1.0$. Structures with net tautomerization probabilities lower than this value are not retained. Default: 0.01
<code>-ts filename</code>	Specify a custom tautomer database.
Stereoisomers	
<code>-ac</code>	Do not respect existing chirality properties or use chiralities from the input geometry. Generate stereoisomers for all chiral centers up to the number permitted (specified using the <code>-s</code> option).
<code>-g</code>	Respect chiralities from input geometry when generating stereoisomers. For chiral centers whose chirality cannot be determined from the input geometry, stereoisomers will be generated.
<code>-ns</code>	Do not generate stereoisomers. Chiral properties in the input file are still enforced. Default is to generate stereoisomers.
<code>-s number</code>	Generate up to <i>number</i> stereoisomers per input structure. Default: 32

Table 2.1. Options for the `ligprep` command (Continued)

Option	Definition
Ring conformations	
<code>-l number</code>	Control how <code>ring_conf</code> handles atoms that are not in flexible rings. <ol style="list-style-type: none"> 1 Use input geometries. 2 Use idealized geometries even for rigid rings. 3 Use idealized geometries for non-ring portions and input geometries for rigid rings. Default: 3
<code>-r number</code>	Generate up to <i>number</i> ring conformations per input structure. Default: 1
<code>-re number</code>	Generate ring conformations with energies lower than <i>number</i> (kJ/mol) relative to the lowest energy conformer. This number sets the maximum number of ring conformers to 8 unless a different number is provided using the <code>-r</code> option.
Filtering	
<code>-f filename</code>	Filter structures using filtering criteria from <i>filename</i> . Default: do not filter.
<code>-fc filename</code>	Use custom composite descriptors for <code>ligparse</code> from <i>filename</i> . Only valid when used with <code>-f</code> and <code>-use_ligparse</code> . Default: use composite descriptors from <code>composite.types</code> file in the installation. See Section A.1 on page 89 for more information.
<code>-fs filename</code>	Use custom SMARTS patterns (descriptors) for <code>ligparse</code> from <i>filename</i> . Only valid when used with <code>-f</code> and <code>-use_ligparse</code> . Default: use composite descriptors from <code>str_keys.types</code> file in the installation. See Section A.1 on page 89 for more information.
<code>-lp</code>	Include calculated properties from <code>ligfilter</code> in the output structure file. Not valid with <code>-use_ligparse</code> , which includes properties by default.
<code>-lab</code>	Add an internal tracking label that can be used for filtering.
<code>-lab_filter options</code>	Filter the output based on the tracking labels introduced with <code>-lab</code> , which is turned on by this option. The filtering process is controlled by the options. Only one option is supported: <code>ionizer:n</code> —select at most <i>n</i> output structures for each ionizer input structure such that the formal charge on each ionizable group is minimized.
<code>-use_ligparse</code>	Use <code>ligparse</code> for filtering. Default: use <code>ligfilter</code> .
Minimization	
<code>-bff number</code>	Instruct <code>bmin</code> to use the force field specified. Only 10 (MMFFs), 11 (OPLS_2001), and 14 (OPLS_2005, default) are supported.
<code>-bvac</code>	Perform <code>bmin</code> minimization in a vacuum. By default <code>bmin</code> minimizations are carried out using a distance-dependent dielectric.

Table 2.1. Options for the `ligprep` command (Continued)

Option	Definition
<code>-br</code>	Instruct <code>bmin</code> to retain structures with incorrect chiralities.
<code>-bns</code>	Instruct <code>bmin</code> to perform minimizations only. By default, <code>bmin</code> performs short conformational searches on distorted structures.
<code>-btc number</code>	Torsional constraints to use in <code>bmin</code> . -1 Do not use torsional constraints. 0, 1 Torsional constraints for C=C, carboxylic acids, esters and amides. 2 Torsional constraints for C=C.
<code>-bts number</code>	Torsional sampling level to use in <code>bmin</code> . Overrides the <code>-btc</code> option and sets it to 1. 0 Restricted 1 Intermediate 2 Enhanced 3 Extended For a definition of the levels, see page 80 of the <i>MacroModel User Manual</i>

Table 2.2. Other job options supported by the `ligprep` command.

Option	Description
<code>-HOSTFILE filename</code>	The name of the hosts file to use for this run. The default hosts file is the installed version of <code>schrodinger.hosts</code> .
<code>-INTERVAL sec</code>	The maximum time in seconds between updates of the <code>jobname.log</code> file.
<code>-LOCAL</code>	Do not use a temporary directory for intermediate files. Keep files in the current working directory.
<code>-NICE</code>	Run the job at reduced priority.
<code>-WAIT</code>	Do not return a prompt until the job finishes.

The `adjust`, `vary` and `expand` meta-options control the range of structures generated. You can use all three of these meta-options in the same `ligprep` command, but `c`, `i` and `t` must not appear more than once. For instance, you could use `-adjust_t -vary_c -expand_i`, but not `-adjust_t -vary_c -expand_it`.

The `retain` meta-option requires that at least one structure produced for each input structure retains the characteristics denoted by the suffix. For instance, `-retain_t` means that the tautomerization state in the input structure will be present in at least one of the output structures for that molecule. The `retain` meta-option can be used with any of the `adjust`, `vary` and `expand` meta-options.

Table 2.3. Meta-options for the `ligprep` command. Suffix values are given for each meta-option that requires a suffix.

Option	Description
<code>-adjust_suffix</code>	Adjust to a suitable state. Any combination of <code>c</code> (chirality), <code>i</code> (ionization states) or <code>t</code> (tautomers) can be used for <i>suffix</i> .
<code>-expand_suffix</code>	Aggressively expand states. Any combination of <code>c</code> (chirality), <code>i</code> (ionization states) or <code>t</code> (tautomers) can be used for <i>suffix</i> .
<code>-retain_suffix</code>	Retain the original state in the output. Any combination of <code>c</code> (chirality), <code>i</code> (ionization states) or <code>t</code> (tautomers) can be used for <i>suffix</i> . Suffix values determine which state is kept. If <i>suffix</i> is <code>i</code> , both the original ionization state and the original tautomer are retained.
<code>-pcp</code>	Run CombiGlide protocoore preparation.
<code>-qik</code>	Set defaults appropriate for QikProp. Turns on the <code>desalter</code> and the <code>tautomerizer</code> .
<code>-unt</code>	Run <code>premin</code> and <code>bmin</code> to untangle structures. Used by CombiGlide.
<code>-vary_suffix</code>	Generate a small number of states. Any combination of <code>c</code> (chirality), <code>i</code> (ionization states) or <code>t</code> (tautomers) can be used for <i>suffix</i> .
<code>-vcs functional-group</code>	Run CombiGlide reagent preparation.

Table 2.4. Action performed by meta-options.

Suffix	Action of <code>adjust</code>	Action of <code>vary</code>	Action of <code>expand</code>
<code>c</code>	Produce only one stereoisomer	Produce at most 2 stereoisomers	Produce at most 32 stereoisomers
<code>i</code>	Produce the ionization state with the lowest overall penalty	Set pH threshold (<code>-pht</code>) to 1.0	Set pH threshold (<code>-pht</code>) to 2.0
<code>t</code>	Produce only the most probable tautomer	Produce at most the 2 most probable tautomers	Produce at most the 8 most probable tautomers

LigPrep jobs run in the background under Schrödinger's Job Control facility. The job output is normally written to a temporary directory and then copied back to the job submission directory when the job finishes. You can direct the temporary files and the output to the job submission directory with the `-LOCAL` option of the `ligprep` command. The `.log` file is written to the job submission directory and is updated during the run. For more information on the Job Control facility, see the *Job Control Guide*.

2.3 Distributing LigPrep Jobs with para_ligprep

You can significantly reduce the amount of time for LigPrep tasks involving many ligands by distributing these jobs across multiple processors. The `para_ligprep` utility is provided to facilitate this task. You can also use `para_ligprep` to split very large input structure files into smaller files that can be processed separately without exceeding the 2 GB file size limit that is in effect on some hosts (see [page 28](#)). The number of tasks may be greater than or equal to the number of processors requested, so that processors carry out more than one task before the job finishes. By distributing the overall calculation across multiple processors (a form of parallel processing), you can significantly reduce the wall-clock time.

To run the `para_ligprep` script from the command line, use the following syntax:

```
$SCHRODINGER/utilities/para_ligprep [options]
```

The options are described in [Table 2.5](#), including job options. You can also use the standard Job Control options—see [Section 2.3](#) of the *Job Control Guide*.

Table 2.5. Options for the para_ligprep command, including job control options.

Option	Description
<code>-first firstlig</code>	First ligand to include. Default: 1.
<code>-HELP</code> <code>-h[elp]</code>	Print usage message and exit.
<code>-HOSTFILE filename</code>	The name of the hosts file to use for this run.
<code>-INTERVAL sec</code>	The maximum time in seconds between updates of the <code>job-name.log</code> file.
<code>-j jobnum</code>	Subjob number to prepare. Default: 0, meaning all subjobs. Must not be negative.
<code>-JOBCTS maxcstsjob</code>	Ensure that each subjob has no more than this many structures to process. Default: 10000.
<code>-last lastlig</code>	Last ligand to include. Default: 0, meaning the last ligand in the file.
<code>-LOCAL</code>	Do not use a temporary directory to store the files. Store files in the local directory.
<code>-nproc njobs</code> <code>-NJOBS njobs</code>	Divide the overall job into <code>njobs</code> subjobs.
<code>-nx</code>	Just create input files for subjobs.

Table 2.5. Options for the `para_ligprep` command, including job control options. (Continued)

Option	Description
<code>-OUTPUT_ORG BY_SUBJOB</code>	Produce one output file for each subjob.
<code>-v[er[sion]]</code>	Report the version number for <code>para_ligprep</code>
<code>-WAIT</code>	Do not return a prompt until the job finishes.

Any other options or arguments you enter on the command line are passed to the `ligprep` command for each subjob. The LigPrep input structure files must be specified with `-isd`, `-imae`, or `-ismi`, and the output structure file must be specified with `-omae` or `-osd`. Maestro input and output files can be in uncompressed (`.mae`) or compressed (`.maegz` or `.mae.gz`) form. The jobname for the overall `para_ligprep` run is derived from the output structure file name by removing everything after the last “.” if present. The `-n` option in `ligprep` cannot be used with `para_ligprep`, but you can use the `maesubset` or `sdssubset` commands to select the desired ligands before running `para_ligprep`.

`para_ligprep` splits an input ligand file into *njobs* smaller input files, each of which is automatically processed in a separate `ligprep` calculation. The ligands between *firstlig* and *lastlig* (inclusive) are separated into *njobs* equal-sized batches. `para_ligprep` starts up a parent process on the first computer listed after `-HOST` (or the local host if `-HOST` is not used). This parent process runs the subjobs as child processes and organizes the output when all subjobs are completed.

Often there is a distinct advantage in setting the number of tasks to a small multiple (e.g. greater than 3) of the number of processors requested, particularly when the processors differ in inherent speed and load (number of programs contending for CPU time). When a processor finishes a task, it is assigned a new one from the pool of unprocessed tasks until the overall calculation is complete. As a result, processors that return results faster are assigned a greater portion of the overall calculation, which in turn is completed sooner.

For instance, if the input structure file, `many.sd`, contains 100,000 structures, then the command:

```
$SCHRODINGER/utilities/para_ligprep -NJOBS 20 -HOST big_host:5
-isd many.sd -osd many-out.sd
```

produces 20 subdirectories, each containing a separate 5,000-structure portion of the input file. Up to five subjobs at a time run on the computer `big_host` until all 20 subjobs are completed.

The `-j` option is useful for preparing and running a single subjob. A value of 0 is equivalent to not specifying `-j` at all, and all subjobs are processed. If the `-nx` option is given, the subjob files are prepared but not run.

The jobname for `para_ligprep` is the stem of the output structure file name, formed by removing any `.mae`, `.sd`, or `.sdf` extension. By default, all output structures are placed in the output structure file listed on the command line. If the total size of the output structures would exceed 2GBytes, it is better to retain a separate output structure file, named `jobname_subjob_subjobnum.mae`, for each subjob by using the `-OUTPUT_ORG BY_SUBJOB` option.

Behind the scenes, `para_ligprep` jobs can involve many files in a number of remote directories (one for each subjob), which you usually do not need to examine. However, sometimes you may wish to examine these files. `para_ligprep` saves all these files in a single gzipped tar file called `jobname.tar.gz`. The job files can be extracted using the commands:

```
gunzip jobname.tar.gz
tar -xvf jobname.tar
```

2.4 LigPrep Input File

As an alternative to specifying options on the command line, you can set the options in a LigPrep input file. This file is optional, and can be used with the following syntax:

```
$SCHRODINGER/ligprep -inp filename
$SCHRODINGER/utilities/para_ligprep -inp filename
```

where *filename* is the name of the input file. You can specify options on the command line in addition to the input file. These options take precedence over the settings from the input file.

The input file uses a keyword-value syntax. The keywords are listed in [Table 2.6](#), along with the type of value and the equivalent command-line option. The values accepted by the keyword are the same as for the equivalent option. Options that do not have a corresponding value are set as Booleans in the input file. Boolean values must be specified as `True` or `False`.

Table 2.6. LigPrep input file keywords

Keyword	Value Type	Equivalent command line option
<i>Input and output</i>		
INP_MAE	string	-imae
OUT_MAE	string	-omae
INP_SD	string	-isd
OUT_SD	string	-osd
INP_SMI	string	-ismi

Table 2.6. LigPrep input file keywords

Keyword	Value Type	Equivalent command line option
General		
APPEND_STRUCTURES	boolean	-a
KEEP_PROPS	boolean	-kp, -keep_props
MAX_ATOMS	integer	-ma
STRUCTS_TO_CONVERT	integer	-n
NO_CLEANUP	boolean	-nc
REMOVE_PROBLEMS	boolean	-np
RUN_ONLY_ONE_STAGE	string	-R
VERBOSE	boolean	-verb
OPTION_TO_PASS	string	-W
Desalting		
NO_DESALTER	boolean	-nd
USE_DESALTER	boolean	-d
Ionization		
EPIK	boolean	-epik
EPIK_FILE	string	-es
EPIK_METAL_BINDING	boolean	-emb, -epik_metal_binding
EPIK_METAL_BINDING_FILE	string	-mbs
IONIZATION	integer	-i
IONIZER_FILE	string	-is
MAX_ION_SITES	integer	-mg
Tautomerization		
EPIK	boolean	-epik
EPIK_METAL_BINDING	boolean	-emb, -epik_metal_binding
EPIK_METAL_BINDING_FILE	string	-mbs
NO_TAUTOMERIZER	boolean	-nt
MAX_TAUTOMERS	integer	-t
TAUTOMERS_SPEC_FILE	string	-ts

Table 2.6. LigPrep input file keywords

Keyword	Value Type	Equivalent command line option
TAUTOMERIZER_PROB	float	-tp
<i>Stereoisomers</i>		
IGNORE_CHIRALITIES	boolean	-ac
RESPECT_CHIRALITIES	boolean	-g
NO_STEREOIZER	boolean	-ns
NUM_STEREOISOMERS	integer	-s
<i>Ring conformations</i>		
NUM_RING_CONF	integer	-r
RING_CONF_REL_EN	integer	-re
LINEAR_MOLECULE_TREAT	integer	-l
<i>Filtering</i>		
FILTER_FILE	string	-f
FC_FILE	string	-fc
FS_FILE	string	-fs
TRACKING_LABEL	boolean	-lab
LAB_FILTER	string	-labfilter
LIGFILTER_PROPS	boolean	-lp
<i>Final optimization</i>		
FORCE_FIELD	integer	-bff
BMIN_MINI_IN_VAC	boolean	-bvac
BMIN_RETAIN	boolean	-br
BMIN_MINI_ONLY	boolean	-bns
BMIN_TORS_CONSTRAINTS	integer	-btc
BMIN_TORS_SAMPLING_LEVEL	integer	-bts
<i>Meta-options</i>		
ADJUST	string	-adjust
EXPAND	string	-expand
RETAIN	string	-retain

Table 2.6. LigPrep input file keywords

Keyword	Value Type	Equivalent command line option
VARY	string	-vary
QIKPROP	boolean	-qik
UNTANGLE	boolean	-unt
VCS	string	-vcs
Job options		
INTERVAL	integer	-INTERVAL
JOBCTS	integer	-JOBCTS
LOCAL	boolean	-LOCAL
NICE	boolean	-NICE
NUM_JOBS	integer	-NJOBS
NUM_PROCS	integer	-nprocs
OUTPUT_ORG	string	-OUTPUT_ORG
STRICT_END	boolean	-STRICT_END
TMPDIR	string	-TMPDIR
WAIT	boolean	-WAIT

2.5 LigPrep Output Files

LigPrep generates many temporary files due to the many stages of the LigPrep process. Most of these files are automatically deleted unless the program is instructed to keep them.

At each stage there is usually one input structure file, one output structure file, and one log file. For some stages the log files are normally empty, while for others they can be large. In general, the output structure file from one stage is used as the input structure for the next stage. When a stage is complete, the input structure file is removed unless it is the first stage in the process, the only stage that has been requested (with the `-R` option), or the `-nc` option (do not clean up files) has been given. If a stage fails in a manner that causes `ligprep` to terminate, none of the files for that stage are deleted. Log files from all stages are retained.

Most intermediate files are named by adding a suffix to the job name. The job name for all tasks in the LigPrep process is the stem of the output structure file name (the part prior to the last `.` or the entire name if no `.` is present). For example, the name of the output structure file for `sdconvert` is `jobname_sdout.mae`. File name suffixes and other files used are described

in Table 2.7. Compressed output is produced for intermediate files unless you specify `-mae_uncompressed` on the command line. The output structure file for the last stage of a successful LigPrep run is renamed to the output structure file name specified on the command line.

Table 2.7. File name suffixes

Stage	Log File	Output Structure Files	Other Files
sdconvert	_sd.log	_sdout.maegz	None
maesubset	None	_msout.maegz	None
applyhtreat	_ht.log	_htout.maegz	None
desalter	_ds.log	_dsout.maegz	None
neutralizer	_nu.log	_nuout.maegz	None
ionizer	_ion.log	_ionout.maegz	Output: <code>_ionout-bad.maegz</code> This file contains structures flagged as problematic by ionizer. These structures do not appear in the final LigPrep output structure file.
tautomerizer	_ta.log	_taout.maegz	None
epik	_epik.log	_epikout.maegz	None
ligfilter	_lf.log	-lfout.maegz	Input: <code>ligfilter.lff</code> . This file contains the conditions used to eliminate molecules and must follow the <code>-f</code> command-line option.
stereoizer	_st.log	_stout.maegz	None.
ring_conf	_rc.log	_rcout.maegz	Output: <code>_rcout_tmpl_att_prob.maegz</code> . This file contains copies of structures with missing ring system templates or missing attachment axial vs. equatorial energies. <code>_rcout_misc_prob.maegz</code> This file contains copies of structures with other types of problems. <code>ring_conf</code> tries to include all structures in the <code>_rcout.maegz</code> file, even those for which copies are saved in these two problem files.

Table 2.7. File name suffixes (Continued)

Stage	Log File	Output Structure Files	Other Files
premin	_pr.log	_prout.maegz	Output: _prout_bad.maegz This file contains structures flagged as problematic by premin. These structures do not appear in the final LigPrep output structure file.
bmin	_bm.log	_bmout.maegz	Output: _bmout.ouL This file becomes _bmout.maegz at the end of a successful bmin run. If bmin fails, then the structures processed up to the failure are present in the former file. Output: _bmout-bad.maegz. This file contains structures that bmin eliminated from further processing, usually because of incompatible chiralities or due to severe distortions.
sdconvert	_sdout.log	_sdout.sdf	None
smiles_to_mae	_smi.log	_smiout.maegz	None

2.6 LigPrep Limitations

The limitations in this sections apply to the LigPrep process as a whole. Information on the limitations of individual tools is given in the sections for each tool.

Target Molecule Classes

LigPrep is intended for use with largely organic, drug-like molecules. While it may be useful for molecules outside this class of compounds it has not been developed for or extensively tested with such systems.

By default some stages of LigPrep pass over molecules containing more than 150 atoms. This limit can be adjusted using the `-ma` option.

Processing Problems May Eliminate Molecules From the Output Data Set

It may not be possible for the various stages in the LigPrep process to accommodate all input structures. Under such circumstances, these problematic structures might not be retained in the output structure file for that stage and thus might be absent in the final output structure file

from the LigPrep process. To learn more about this issue, see the descriptions of the individual programs within this document.

File Size Limits

While most computers can work with large files, such as those exceeding 2 GBytes, working with them often puts heavy strains on operating systems and hardware. Maestro files of this size can contain about 150,000 ligand-like molecules. Some LigPrep process and option selections can significantly increase the number of output structures. Given these considerations we recommend processing around 50,000 structures in a single LigPrep run.

The utility `para_ligprep` provides a convenient way to split and process a large structure file. For more information see [Section 2.3 on page 20](#).

Using LigPrep

Although LigPrep contains a variety of options, you will probably use only a subset of them regularly. The options you choose will depend on your goals, the types of input structures you are processing, and the types of subsequent processing that will be carried out. For a complete list of LigPrep options, see [Section 2.2 on page 13](#). A general description of how LigPrep processes structures is provided in [Section 1.2 on page 2](#).

This chapter provides a few examples showing how to use LigPrep. The first section demonstrates the use of the LigPrep panel in Maestro, with input structure files provided in `$SCHRODINGER/macromodel-vversion/ligprep/samples/examples`. A range of command-line examples is given in the second section.

In general, we recommend limiting the size of the input structure file to 20,000 to 50,000 structures. For larger input files, we recommend using `para_ligprep` to split up and process the structures in smaller batches. Some LigPrep stages do not adjust structures with more than 150 atoms, to avoid spending excessive processor time on molecules that are atypical for ligands. This limit is adjustable using the LigPrep `-ma` option. However, increasing it significantly will result in the processing of ligands larger than LigPrep is tested for, and you can encounter problems, including much slower processing of structures. For information on file size issues, see [Section 2.6 on page 27](#).

Since LigPrep uses Schrödinger's job control facility, jobs are run in the background and the command-line prompt returns immediately after you enter the `ligprep` command. Processing continues until the job has finished, at which time the output files appear in the job submission directory. For more information on the Job Control facility, see the [Job Control Guide](#).

3.1 LigPrep Panel Examples

The LigPrep panel in Maestro enables you to prepare and run a variety of ligand preparation jobs. This section provides examples of three ligands and illustrates the effect that LigPrep has on their structure.

3.1.1 Creating a Working Directory and Copying Files

Before you begin the tutorial you need to create a working directory to keep all your input and output files, and then copy the files for the tutorial.

UNIX:

1. Change to a directory in which you have write permission.

```
cd mydir
```

2. Create a directory by entering the command:

```
mkdir directory-name
```

3. Copy the files `2D_variations.sdf` and `3D_rings.mae` from the directory `$SCHRODINGER/macromodel-vversion/ligprep/samples/examples/` to your working directory.

Windows:

1. Open the folder in which you want to create the folder that serves as your working directory.

The default working directory used by Maestro is your user profile, which is usually set to `C:\Documents and Settings\username`. To open this folder, do the following:

- a. Choose **Run** from the **Start** menu.
 - b. Enter `%USERPROFILE%` in the **Open** text box and click **OK**.
2. Click **Make a new folder** under **File and Folder Tasks**.
You can also choose **Folder** from the **New** submenu of the **File** menu.
 3. Enter a name for the folder.
If you want to create a folder inside this folder, repeat steps 1 – 3.
 4. Open the folder that contains the tutorial files:
 - a. Choose **Run** from the **Start** menu.
 - b. Enter `%SCHRODINGER%` in the **Open** text box and click **OK**.
 - c. Open the `macromodel-vversion` folder (*version* is the 5-digit LigPrep version number), then open the tutorial folder, the `samples` folder, and finally the `examples` folder.
 5. Select the files `2D_variations.sdf` and `3D_rings.mae`, and drag them to the folder you created in [Step 3](#).

3.1.2 Starting Maestro and Setting the Working Directory

Once you have created the working directory you can start Maestro, and set the Maestro working directory. By default, Maestro writes job files to its working directory. You can change the default in the Preferences panel—see [page 30](#) of the *Maestro Overview*. If you have changed the default, you should change it back for this tutorial.

UNIX:

1. Set the SCHRODINGER environment variable to the installation directory:

```
csh/tcsh:      setenv SCHRODINGER installation_path
```

```
bash/ksh:      export SCHRODINGER=installation_path
```

This environment variable is also required to run LigPrep jobs.

2. Change to the desired working directory.

```
cd directory-name
```

3. Enter the command:

```
$SCHRODINGER/maestro &
```

The Maestro main window is displayed, and the working directory is Maestro's current working directory. If you are using an existing Maestro session, you can change the directory by choosing Change Directory from the Maestro menu, navigating, to the appropriate directory and clicking OK.

Windows:

1. Double-click the Maestro icon on the desktop.

You can also use the Start menu. Maestro is in the Schrödinger submenu.

2. Choose Change Directory from the Maestro menu.
3. Navigate to the appropriate directory and click OK.

3.1.3 Generating Variations on 2D Structures

The two structures provided in this example illustrate the variations that are generated with the default LigPrep options.

To import and examine the structures:

1. Click the Import structures button on the toolbar.



The Import panel is displayed.

2. Choose SD from the Files of type option menu.
3. Select the file `2D_variations.sdf`.
4. Click Options.

The Import Options dialog box opens.

5. Ensure that Import all structures is selected, and click Close.

The Import Options dialog box closes.

6. In the Import panel, click Open.

The first structure should be displayed in the Workspace. This structure has two ionizable groups—a carboxylic acid and a pyridine—and a quaternary ammonium counter ion. There are three chiral centers, of which two have chirality information, and the hydrogen atoms are implicit.

7. To verify that this structure is indeed two-dimensional, click the Rotate around Y axis by 90 degrees button on the toolbar, then click the Reset Workspace button.



8. Display the Project Table by clicking the Open/Close project table button on the toolbar.



9. Click the In column for entry 2.

The second structure should be displayed in the Workspace. This structure also has two ionizable groups—an imidazole ring and a 4-nitrosophenol group. The neutral state of the imidazole ring has two tautomers.

To set up and run the LigPrep job:

1. In the Project Table, choose All from the Select menu.
2. In the main window, choose LigPrep from the Applications menu.

The LigPrep panel opens.

3. Under Use structures from, select Project Table (selected entries).
4. Check that the default options are selected:
 - Stereoisomers: Retain specified chiralities
 - Stereoisomers: Generate at most: 32 per ligand
 - Ionization: Generate possible states at target pH 7.0 +/- 2.0
 - Using: Ionizer
 - Generate low energy ring conformations: 1 per ligand
 - Desalt
 - Generate tautomers
 - Output format: Maestro

5. Click Start to open the Start dialog box.
6. Under Incorporate, select Append new entries as a new group.
7. Type variations in the Name text box.
8. Click Start.

The Monitor panel is displayed. This panel logs the progress of the job. When the job finishes, there should be 10 new entries in the Project Table.

To examine the output structures:

1. In the Project Table, click the In column for entry 3, then shift-click the In column for entry 6.

The four structures generated from the first 2D structure are displayed in the Workspace, superimposed. Note the variations in the structures and the absence of the quaternary ammonium ion, which was removed by the `desalter`.

2. Click the Tile entries button on the toolbar and click Yes in the confirmation dialog box.



The four structures are displayed in a square grid in the Workspace. Each has a full complement of hydrogen atoms. The carboxylate group is unprotonated because its pK_a lies outside the target pH range of 5 – 9. In two structures, the pyridine is protonated; in the other two it is unprotonated.

3. From the Label picked atoms button menu on the toolbar, choose Composition.



The Composition tab of the Atom Labels panel is displayed.

4. Select R/S Chirality and clear all other label options.
5. Click All in the Label atoms section.

The chiral centers are labeled R or S. Two of the chiral centers are labeled R in all structures: these chiralities were preserved from the input structures. The remaining center is labeled R in one pair of structures and S in the other. This center did not have chirality information in the input structure, and its chirality has been varied.

6. In the Project Table, click the In column for entry 7, then shift-click the In column for entry 12.

The six structures that were generated from the second 2D structure are displayed in the Workspace, superimposed. Note the variations in the structures.

7. Click the Fit to screen button on the toolbar.



8. In the Project Table panel, click the Select Only button on the toolbar.



The Entry Selection dialog box is displayed, with the Properties folder on top.

9. Choose Included State from the Properties list, then select Included (or fixed).
10. Click Add, then click OK.

The included entries are now also the selected entries.

11. Click the In column for entry 7.

This entry is displayed, and the other entries are undisplayed. The phenol group is protonated and the imidazole group is unprotonated in this structure.

12. Click the Next button on the Project Table toolbar.



The next structure is displayed in the Workspace. Note the tautomerization of the imidazole group.

- Click the Next button again.

The imidazole group is protonated in this structure.

- Click the Next button three more times to display the remaining structures.

The last three structures have the phenol group deprotonated.

3.1.4 Generating Ring Conformations of a 3D Structure

The structure in this example has two flexible rings and two chiral atoms. The ring conformations will be varied, but the chiralities will be kept.

To import and examine the structure:

- In the main window, choose Close from the Project menu.
- Click Discard in the dialog box.

The Workspace and the Project Table are cleared.

- If the Import panel is not open, click the Import structures button on the toolbar.



The Import panel opens.

- Choose Maestro from the Files of type option menu.
- Select the file 3D_rings.mae.
- Click Open.

The 3D structure is displayed in the Workspace.

- If you are continuing from the previous exercise, bring the Atom Labels panel to the front. Otherwise, do the following:
 - From the Label picked atoms button menu on the toolbar, choose Composition to display the Composition tab of the Atom Labels panel.



- Select R/S Chirality and clear all other label options.
- Click All in the Label atoms section to label the chiral atoms: one is R, the other is S.

To set up and run the LigPrep job:

1. If the LigPrep panel is not displayed, choose Applications > LigPrep from the main window.
2. Under Use structures from, select Workspace (included entries).
3. Under Stereoisomers, select Determine chiralities from 3D structure.
4. Under Ionization, select Retain original state.
5. Type 4 in the Generate low energy ring conformations text box.
The remaining options do not affect the outcome of this job.
6. Click Start to open the Start dialog box.
7. Under Incorporate, select Append new entries as a new group.
8. Type rings in the Name text box.
9. Click Start.

The Monitor panel is displayed. When the job finishes, there should be four new entries in the Project Table, with the first of the new entries displayed in the Workspace.

To examine the output structures:

1. In the Project Table, click the In column for entry 2, then shift-click the In column for entry 5 to display the four structures in the Workspace, superimposed.
2. Click the Tile entries button on the toolbar and click Yes in the confirmation dialog box.



The four entries are now displayed separately.

3. Choose Molecules from the Local transformation button menu on the toolbar.



4. As necessary, click on each molecule and rotate it (middle mouse button) so that the orientation of the 1,4-dioxane rings is the same in each molecule.

The 1,4-dioxane ring adopts the chair conformation in all four molecules but is joined to the piperidine ring in different orientations.

5. Now rotate each molecule until the orientation of the piperidine rings match.

The piperidine ring adopts the chair conformation in two molecules and the boat conformation in the other two molecules. The variation of ring conformations leads to an inversion at the N atom to generate the optimal conformation.

3.2 Command-Line Examples

The LigPrep panel in Maestro provides access to the main `ligprep` command options. For finer control of the options, you must run LigPrep from the command line. If you want to prepare a large number of ligands, you might prefer to run LigPrep from the command line. This section provides a number of examples of the `ligprep` command.

3.2.1 Default Operation

LigPrep can be run using the default settings by specifying only the input and output files. Examples follow showing syntax using different input file types; both examples include output files in Maestro format:

```
$SCHRODINGER/ligprep -isd my_2D_cts.sd -omae my_3D_cts.mae
```

In this example, the input file is in SD format.

```
$SCHRODINGER/ligprep -ismi my_1D_cts.smi -omae my_3D_cts.mae
```

In this example, the input file is in SMILES format.

The above commands do the following:

- Adds hydrogen atoms
- Neutralizes many types of charged functional groups
- Generates up to 8 tautomers for each input structure
- Generates up to 32 stereoisomers for each tautomer
- Generates one set of ring conformations for each stereoisomer
- Minimizes the energy for each stereoisomer

The resulting 3D structures are written to the output file. Only the largest molecule in each input structure is retained.³ Some of these defaults can be overridden by specifying additional command options.

Valid combinations of chiralities, recorded as parities or bond directions in the input structure file, are retained in almost all cases. Stereoisomers are generated by varying the chiralities of chiral atoms whose chiralities are not specified. It is generally advisable to produce multiple stereoisomers, especially for fused ring systems, in which some combinations of chiralities are

3. LigPrep removes all molecules except the one with the largest number of atoms in the structure to ensure that co-crystallized counter ions are removed.

unacceptable and may be eliminated from the set of output structures. For Maestro-formatted input structure files the chiralities recorded as properties are respected. To vary the chiralities of all chiral atoms present, use the `-ac` option. If you use this option, it might be desirable or necessary to increase the maximum number of stereoisomers per molecule from its default value of 32 to a higher limit. For example, the option `-s 128` permits up to 128 stereoisomers to be generated.

3.2.2 Producing One Output Structure for Each Input Structure

LigPrep is primarily designed to produce high quality 3D structures and, if possible, to produce multiple output structures for each input structure by introducing variations in the chemical nature of the structures, such as adjusting the stereochemistry or the ionization (protonation) state. However, LigPrep can be used so that it typically produces only one output structure for each input structure.

3.2.2.1 Adjusting Only the Geometry

One extended-conformation, energy-minimized 3D structure can be produced for each 3D input structure from the SD file, `my_3D.sd`, using the command:

```
$SCHRODINGER/ligprep -i 0 -nt -s 1 -g -isd my_3D.sd -omae  
my_improved_3D.mae
```

For the Maestro-formatted input file `my_3D.mae`, use the command

```
$SCHRODINGER/ligprep -i 0 -nt -s 1 -g -imae my_3D.mae -omae  
my_improved_3D.mae
```

The options selected with these commands add hydrogens to structures that lack them to produce all atom structures, but neither command should adjust the protonation state of the ionizable groups (`-i 0`). The `-nt` option instructs LigPrep not to adjust the tautomeric state. The `-g` option requests that the chiralities, which are needed for ring conformation generation, be determined from the input geometry. If parts of the molecule are quite distorted, it might not be possible to determine the chiralities of all the chiral atoms unambiguously. In such cases, LigPrep systematically varies the chiralities that could not be determined to generate possible stereoisomers (up to 32 by default). The `-s 1` option instructs LigPrep to generate only one such structure, with all undetermined chiralities set to R. If there is more than one indeterminable chirality, incompatible chiralities can be selected (for instance, in fused ring systems) and the molecule could be eliminated in subsequent processing.

For 2D input structures, the corresponding command would be:

```
$SCHRODINGER/ligprep -i 0 -nt -s 1 -isd my_2D.sd -omae  
my_improved_3D.mae
```

This command has the same options as the previous example except that the `-g` option has been removed, and therefore LigPrep looks for stereochemical specifications in the input structure file to determine chiralities. As with the 3D examples, LigPrep normally would vary the unspecified chiralities to generate multiple stereoisomers. As before, the `-s 1` option forces the output of only one stereoisomer. However, since it is quite common for 2D structures to have multiple chiral centers unspecified, the risk of eliminating structures due to incompatible chiralities is much higher than with 3D structures. You might want to compromise and permit the generation of multiple stereoisomers and thus multiple output structures for some input structures.

3.2.2.2 Adjusting the Chemistry

LigPrep can adjust the chemistry of the input structure by removing counter ions (desalting), neutralizing or ionizing ionizable groups, changing between tautomers and generating stereoisomers. Currently it is not possible to guarantee that each input structure will produce only one output structure when adjusting the chiralities or ionization states. A command that might usefully approximate the goal of producing only one output structure per input structure is:

```
$SCHRODINGER/ligprep -s 1 -i 2 -W i,-ph,7.0,-pht,0.0 -t 1 -imae  
input.mae -omae output.mae
```

As before, the `-s 1` option forces the generation of only one stereoisomer, and chiral atoms whose chiralities were not previously defined are classified as R. To avoid eliminating molecules in which such chiralities are incompatible, a practical compromise is to permit the generation of several stereoisomers (e.g., `-s 4` to generate up to 4). The desalter is run by default, so only the largest molecule in each structure is retained. The `-t 1` option results in the generation of the tautomer judged to be the most probable one.

The `-i 2` option requests the running of the `ionizer`, and options are passed to it by means of the `-W i,-ph,7.0,-pht,0.0` option. These options request that functional groups with pK_a values less than or equal to 7.0 be deprotonated, while those with pK_a values greater than or equal to 7.0 be protonated. For most input structures, this results in only one output structure. However, for molecules that have functional groups with pK_a values of exactly 7, multiple structures are produced, each with a different protonation state.

3.2.3 Generating Variations

Often it is desirable to generate a number of variations on each input structure. The main benefit is that there is a better chance that the resulting collection of structures includes the “best” form for your particular study. However, as more variations are generated, proportionately more CPU time is consumed, both in LigPrep and in subsequent processing. Another

drawback of generating more variations is that improbable states can be generated, which at present are not penalized in subsequent processing.

There are many ways to introduce variations in the structures using LigPrep. Here are a few examples showing how to do this.

3.2.3.1 Generating a Small Set of Low-risk Variations

To generate a few low-risk variations on the input structures:

```
$SCHRODINGER/ligprep -r 1 -s 8 -t 4 -i 2 -W i,-pht,1.0 -imae  
input.mae -omae output.mae
```

For each structure in the input structure file, LigPrep generates an extended conformation containing only the lowest energy ring conformation for any rings present, up to 8 stereoisomers, up to 4 tautomers, and ionization states highly populated in the pH range 6.0 to 8.0 (7.0 1.0). Typically, far fewer than 8 stereoisomers and 4 tautomers would be produced.

This command assumes that the available information on the stereoisomers is recorded as R/S properties in the input structure file. If the input structures are 3D and have the correct chiralities, you could use the `-g` option to instruct LigPrep to respect the chiralities present in the 3D geometry.

3.2.3.2 Generating Many Variations

To generate many variations:

```
$SCHRODINGER/ligprep -r 4 -s 64 -t 8 -i 2 -W i,-pht,2.0  
-imae input.mae -omae output.mae
```

This command generates many variations for ring conformations, stereoisomers, tautomers, and ionization states. Not all variations are necessarily kept in the output: some may be eliminated because they have poor bonding patterns, others because they lie too high in energy. In a typical LigPrep run with these options, the number of structures increases by about a factor of 8. The actual expansion factor might be smaller or larger, depending on your data set.

3.2.3.3 Using Meta-Options for Convenient Selection of Run Characteristics

For some scenarios, a set of nondefault options is needed. Rather than having to understand and specify each option separately, you can use the `ligprep` command's more intuitive meta-options, which include:

- `-qik` Prepare structures for processing with QikProp (see [Section 3.2.4 on page 42](#))
- `-unt` Untangle structures without changing any atoms or bonds.

<code>-adjust_itc</code>	Adjust to a suitable state.
<code>-vary_itc</code>	Generate different states.
<code>-expand_itc</code>	Aggressively generate different states.
<code>-retain_itc</code>	Retain characteristics of the input structures. Specifying <code>i</code> also turns on retention of tautomers.

`itc` can be replaced by one or more of:

<code>c</code>	chiralities
<code>i</code>	ionization and neutralization
<code>t</code>	tautomerization

The `adjust`, `vary` and `expand` meta-options control the range of structures generated. All three of these meta-options may be used in the same `ligprep` command, but each of `c`, `i` or `t` must only appear in one of them: for instance, you could specify `-adjust_t -vary_c -expand_i`. See [Table 2.4](#) for details on the action of these meta-options. The `retain` meta-option requires that at least one structure produced for each input structure retains the characteristics specified by the suffix. For instance, `-retain_t` requires the tautomerization state in the input structure to be present in at least one of the output structures for that molecule. `retain` can be used with any of `adjust`, `vary`, and `expand`. `retain` can be used to produce a range of structural variations while keeping the form in the input structure—something that might be useful in lead optimization.

As an example, the following command permits the generation of moderate variations on the ionization and tautomerization state and significant numbers of stereoisomers, while ensuring that the input tautomeric form appears in the output:

```
$SCHRODINGER/ligprep -vary_it -expand_c -retain_t
    -imae input.mae -omae output.mae
```

This command is equivalent to:

```
$SCHRODINGER/ligprep -i 2 -W i,-pht,1.0 -r 1 -t 2 -s 32
    -imae input.mae -omae output.mae
```

If other options are given with a meta-option, their values override the values set by the meta-option. For instance,

```
$SCHRODINGER/ligprep -vary_it -expand_c -retain_t -W i,-pht,1.5
    -imae input.mae -omae output.mae
```

extends the pH range from that used by `-vary_i`, 1 (pH 6-8), to 1.5 (pH 5.5-8.5).

3.2.4 Preparing Ligands for QikProp

LigPrep can be used to prepare ligand structures for processing with QikProp by using the `-qik` meta-option, as shown in the following command:

```
$SCHRODINGER/ligprep -qik -isd my_2D.sd -omae my_3D.mae
```

This command creates all-atom, 3D, energy-minimized structures. Up to 8 tautomers are generated for each input structure and up to 32 stereoisomers are generated for each tautomer by default, but only one ring conformation is generated for each stereoisomer. The `-t`, `-s`, and `-r` options can be used to adjust the number of tautomers, stereoisomers, and ring conformations generated.

3.2.5 Filtering Structures

During LigPrep processing, structures matching certain conditions can be removed using `ligfilter`. A file containing a list of these conditions must be created before running LigPrep. For example, to remove molecules with a molecular weight greater than 650 and molecules that have too many hydrogen bond acceptors, you could create a file with the following content:

```
# Remove molecules that have a molecular weight of greater than 650
Molecular_weight > 650
# Remove molecules with too many H-bond acceptor and donor atoms
Acceptor_groups > 3
Donor_groups > 3
```

The following command uses `ligfilter` to filter the input structures using the above file, saved as `filter.lff`:

```
$SCHRODINGER/ligprep -f filter.lff -isd my_2D.sd
-omae my_3D.mae
```

For more information on using `ligfilter` and creating filtering files, see [Section 4.9 on page 51](#).

3.2.6 Running LigPrep on a Remote Host

One advantage of the job control facility is that jobs can be submitted to remote hosts that have been prepared to run Schrödinger software. For instance, to run LigPrep on a host called `fast_cpu`, you can add the `-HOST` option to a command:

```
$SCHRODINGER/ligprep -HOST fast_cpu -s 1 -imae my_2D.mae -omae
my_3D.mae
```

When the LigPrep job finishes on `fast_cpu`, the output files are copied back to the directory from which you started the job. For information on the Job Control facility and on preparing hosts and batch queues to run Schrödinger software, see the *Job Control Guide*.

3.3 Chirality Manipulations Using Maestro and LigPrep

Both Maestro and LigPrep have the ability to manipulate the stereogenic composition of a three-dimensional molecular structure. Maestro includes graphical features that can exchange the chirality of a single center, as well as easily generate the enantiomer of a displayed structure. Correspondingly, a LigPrep preparation has the ability to sample some or all of the chiral centers, in one or multiple input structures, during a given preparative computation. Finally, the combination of the Project Table and LigPrep enables the expansion or inversion of selected subsets of chiral centers in one or more structures easily and quickly.

Simple inversions of a single chiral center, located in a structure displayed by Maestro, can be easily accomplished with Maestro's Adjust Chirality feature. To open this panel, choose Chirality from the Adjust submenu of the Edit menu in the main window. To reverse the chirality of a given stereogenic center, just select the chiral atom, followed by selecting two other "non-moving" atoms connected to the chiral center. The remaining two groups connected to the selected chiral atom are switched, resulting in an effective inversion of the chirality at the atom. This operation can only be performed on chiral atoms that are not a part of a ring system. To invert the chirality of an individual ring system atom, use LigPrep as described below.

The same Adjust Chirality feature also enables the generation of the corresponding enantiomeric structure. Click All in the Chirality folder of the Adjust panel to generate the mirror image of the structure in the Workspace. This operation inverts all the chiral centers and produces the enantiomer. The *z*-coordinate values for each atom in the structure are inverted by this procedure.

In addition to Maestro's built-in graphical tools, which modify individual chiral centers and produce enantiomers, LigPrep can also generate and sample alternative chiralities on a broader scale. Generally, in addition to 2D to 3D conversion, LigPrep can sample and expand ionization states, tautomers, ring conformations, and alternative chiralities. For the latter, both Maestro-formatted files and SD-formatted files have the internal ability to indicate the specified chirality at some or all stereogenic centers, usually "R" or "S". LigPrep and the Stereoizer have three basic usage modes that utilize this information:

- **Retain specified chiralities**—For structures with *specified* chirality information, LigPrep attempts to generate output structures that match the chirality indications at all such stereogenic centers. LigPrep tries to match the specification whether or not the input 3D geometry about the chiral centre (if any) matches this specification. All unspecified chiral centers in the structure will be expanded.

- Determine chiralities from 3D structure—Specified chiralities are ignored, and no alternative chiralities are generated. Output structures have the same stereogenic makeup as the input, and all chiral centers have their specification changed to match the input structure.
- Generate all combinations—The input specifications are ignored, and all geometrically feasible stereoisomers (up to the maximum number requested) are generated.

The specifications discussed can be observed in the Project Table as properties with titles such as Chirality 1 and specifications like 9_R_8_13_10_37. In this example, atom number 9 has the "R" configuration based on the listed atoms with CIP priorities. MDL SD files have their own chirality-indicating format, which is converted to the Maestro format upon importing the SD-formatted structures.

If the chirality specifications were not included in the original structure file, or the molecule was constructed in Maestro, the specifications can be easily assigned by simply running LigPrep with the Stereoizer set to Determine chiralities from 3D structure, and setting the output to Replace existing entries or Append new entries. You may select to turn off the Ionizer, Tautomerizer, and Desalter if you prefer no additional expansion when only specifying chiralities. After incorporation, the chirality specifications are listed in the Project Table.

Once the chirality specifications are listed in the Project Table for the structures of interest, the combination of the Project Table and LigPrep provide a simple, easy method to invert or sample a subset of chiral centers in one or more structures.

To invert a chiral center using LigPrep, simply adjust the specification in the appropriate property cell for the structure of interest to the other "R" or "S" indication, for instance from 9_R_8_13_10_37 to 9_S_8_13_10_37. You may want to duplicate the entry in the Project Table prior to adjusting the designation. Using the modified entry in a subsequent LigPrep computation with the Retain specified chiralities mode, generates the requested chirality change. The user can make changes to multiple structures by modifying any of the specified chiralities, selecting all of the modified structures in the Project Table, and running the LigPrep preparation with Use structures from set to Selected entries.

In contrast, to sample or expand alternate chiralities once the chiral centers are specified, simply delete or remove the specification from the Project Table cell. A subsequent LigPrep preparation, using the Retain specified chiralities mode, maintains the other, indicated chiralities, but expands the chiralities of the centers with specifications removed. Multiple structures can be expanded in this way using selected entries as the input.

Tools Used by LigPrep

This chapter describes the tools used by LigPrep. A description of the purpose, the syntax, and the options is provided for each tool. The options for the tools cannot be used directly as options for `ligprep`. The `ligprep` options can be used to control the behavior of the tools, and for some tools, options can be passed from the `ligprep` script to the tool with the `ligprep -W` option. The descriptions are provided so that you can understand how these tools function in the context of LigPrep, and so that you can use these tools separately from LigPrep.

LigPrep can use a separate product, Epik, instead of the `ionizer` and the `tautomerizer`. For more information on Epik, see the [Epik User Manual](#).

4.1 `sdconvert`

This utility converts between MDL SD, Maestro, and MacroModel format files.

Syntax:

```
$SCHRODINGER/utilities/sdconvert [options]
{-isd|-imm|-imae} inputfile {-osd|-omm|-omae} outputfile
```

<code>-isd</code>	Input file in SDfile format
<code>-imm</code>	Input file in MacroModel format
<code>-imae</code>	Input file in Maestro format
<code>-osd</code>	Output file in SDfile format
<code>-omm</code>	Output file in MacroModel format
<code>-omae</code>	Output file in Maestro format

Options:

<code>-a</code>	Append structures to the output file.
<code>-all</code>	Convert all structures (synonym for <code>-n 1:</code>). This is the default.
<code>-h</code>	Show usage summary.

- `-n structs` Specify a comma-delimited series of colon-separated ranges and single values to convert, for example:
- | | |
|-----------------------|---|
| <code>1:10,14</code> | Structures 1 through 10 and 14 |
| <code>2:</code> | Structure 2 through end of file |
| <code>:5,13:18</code> | Structures 1 through 5, and 13 through 18 |
- `-noarom` Do not convert aromatic type 4 bonds to single and double bonds, according to Maestro and OPLS conventions.
- `-nolewis` Do not fix bond orders and formal charges of nitro and carboxylate groups as appropriate for OPLS use.
- `-nostereo` Do not record the atom parity information from the input file as atom chirality information in the output file. See [Section 4.10 on page 54](#) (`stereoizer`) for more information on chirality properties.
- `-title prop` For SD to Maestro conversion, define SD property *prop* as the source for assigning the Maestro title.
- `-v` Show version number.

If multiple `-n` options are given, the rightmost range takes precedence. The `-all` option overrides any `-n` settings.

Example:

```
$SCHRODINGER/utilities/sdconvert -n 1:500 -isd lig.sdf -omae  
lig.mae
```

4.2 smiles_to_mae

This utility converts a SMILES file or a CSV file with SMILES strings to a Maestro-formatted file. This utility should be used in conjunction with LigPrep.

Syntax:

```
$SCHRODINGER/utilities/smiles_to_mae [options]  
{inputfile.smi | inputfile.csv} outputfile.mae
```

The first argument is taken as the input file and the second as the output file.

If the input file is a SMILES file, each line in the file must consist of the SMILES string, followed by an optional title.

If the input file is a CSV file, the SMILES strings must be in the first column. If the file has a header row, the first column should be labeled `SMILES`, and the title column should be labeled one of `NAME`, `title`, or `s_m_title`. If there is no header row, the second column is taken to

be the title. Any other columns are treated as properties, and are read in; if there is no header row, the properties are labeled as “smiles integer 1”, “smiles real 1”, “smiles string 1”, and so on.

Options:

- h Show usage summary.
- v Show version number.

4.3 maesubset

This utility selects a subset of the structures present in a Maestro-formatted file. The selected structures are printed on standard output.

Syntax:

```
$SCHRODINGER/utilities/maesubset [options] input_file.mae >  
output_file.mae
```

Options:

- h Show usage summary.
- n *range* Specify a comma-delimited series of colon-separated ranges and single values to process. For example:
 - 1:200 Structures 1 through 200
 - 50: Structures 50 through end of file
 - 1:5,14 Structures 1 through 5 and 14
- v Show version number.

4.4 applytreat

The `applytreat` utility can be used to delete or add hydrogen atoms and lone pairs to one or more structures in a Maestro-formatted file, consistent with the hydrogen treatment option that you provide. A *hydrogen treatment* is a protocol that determines which atoms are to have hydrogens and lone pairs attached. Several treatments are supplied. Each of these treatments is associated with a particular molecular mechanics force field, but some treatments are suitable for several force fields. See [Section 4.9](#) of the *Maestro User Manual* for information on the relationship between force fields and hydrogen treatments.

Syntax:

```
$SCHRODINGER/utilities/applyhtreat input-file output-file  
[treatment-name] [ASL-expression [adjust-chirality]]
```

The treatment name must be one of the following names, and must be enclosed in quotes:

```
All-atom with Osp3/Nsp3-Lp  
All-atom with No-Lp  
Csp3 United-atom with S-Lp  
Csp3 United-atom with No-Lp  
All-atom with S-Lp  
C sp2/sp3 United-atom with No-Lp  
C sp2/sp3, N,O,S United-atom with No-Lp
```

Default treatment: All-atom with No-Lp

The ASL expression is a Maestro Atom Specification Language expression for selecting a subset of the atoms in each structure processed. See the [Maestro Command Reference Manual](#) for information on ASL expressions.

The *adjust-chirality* argument can be set to 0 if the chirality information should not be adjusted, or to 1 for adjustment of chirality information. For LigPrep applications the chirality information should be adjusted. To use this option you must provide an ASL expression.

Example:

```
$SCHRODINGER/utilities/applyhtreat input.mae output.mae  
"All-atom with No-Lp" all 1
```

applies the "All-atom with No-Lp" treatment to all atoms and adjusts the chirality information.

Notes:

- Hydrogen atom addition or deletion takes place only as necessary to make the structure consistent with the selected hydrogen treatment. For example, if the specified treatment option calls for all atoms to have hydrogen atoms attached and the structure in the input file already has hydrogen atoms attached to all atoms, no changes are performed.
- For LigPrep processing it is important to request adjustment of chirality information, otherwise the atom numbers in the chirality properties remain unchanged. This can result in corruption of the chirality specifications and lead to incorrect results.

4.5 desalter

Individual structures present in many databases contain multiple molecules. In many cases these are co-crystallized components such as counter ions. These components often need to be removed before further calculations are performed. The `desalter` eliminates all molecules except the molecule with the largest number of atoms (including hydrogen atoms, if present) in each structure. If there is more than one molecule containing the largest number of atoms, the molecule with the lowest numbered atom within the structure is retained.

You must have a LigPrep license to run the `desalter`.

Syntax:

```
$SCHRODINGER/utilities/desalter [-h] [-v] input_file.mae  
output_file.mae
```

Options:

- h Show usage summary.
- v Show version number.

4.6 neutralizer

Ionizable groups present in structures could be in any of a number of charge states. Some programs, such as QikProp and the `ionizer`, do not successfully process input structures containing charged groups or molecules. The `neutralizer` neutralizes functional groups where possible by adding or removing protons. The following replacements and additions are made in the neutralization process:

- Sodium or potassium ions with a single bond are replaced by hydrogens bound to the same atom.
- $(R)_x-NH^+$ is replaced by $(R)_x-N$.
- A proton is added to O^- or S^- atoms bound to C, S or P atoms.
- A proton is added to O^- when it is bound to a N that has a formal charge of 0. Thus, nitro groups and pyridine N-oxides are not protonated, but a hydroxamate is protonated.
- Dummy atoms are removed.
- A proton is removed from $H-O^+R_2$.
- A proton is removed from $H-O-N^+(=O)-R$ and an electron to $O-N^+(=O)-R$, to produce $O^-N^+(=O)-R$.

- A proton is removed from a protonated pyridine N-oxide.
- A proton is added to the nitrogen in sulfonamide $\text{O}=\text{S}(=\text{O})\text{-N}^-$ anions.
- A proton is added to the negatively charged N atom in histidine anions.

You must have a LigPrep license to run the neutralizer.

Syntax:

```
$SCHRODINGER/utilities/neutralizer [options] input_file.mae  
output_file.mae
```

Options:

- d Remove dependency information for chiralities. For use only prior to an ionizer treatment.
- h Show usage summary.
- retain Retain the input structure.
- retain_lab Retain the input structure and add a label property to the retained input structure that identifies it as the input structure.
- v Show version number.

Limitations:

Some groups, such as quaternary N atoms, are not neutralized.

4.7 ionizer

The `ionizer`, or ionization state expander, produces multiple structures for each input structure with different combinations of ionized states based on the ionizable groups present. By default, the `ionizer` produces both protonated and deprotonated forms of groups that have a $\text{p}K_a$ between 5 and 9. Groups with a higher $\text{p}K_a$ are protonated; groups with a lower $\text{p}K_a$ are deprotonated. These defaults ensure that the appropriate structures are available for physiological conditions. For more information, see [Chapter 5](#).

The `ionizer` is not called from the `ligprep` script by default. To run the `ionizer` with LigPrep, select **Generate Possible States under Ionization** in the LigPrep panel, or add the `-i 2` option of the `ligprep` command. The `ionizer` is also called from `ligprep` if you use the `-expand_itc` option. The `ionizer` can be run on its own from the `ligprep` script with the `-R i` option. You can pass options to the `ionizer` from `ligprep` with the `ligprep -W i` option. Not all `ionizer` options are available from `ligprep`; see [Section 5.1 on page 69](#) for more information.

If an input structure contains more than a prescribed number of ionizable groups, the structure is skipped and passed, unchanged, to the output file. To set the limit on the number of ionizable groups, use the `-mg` option of the `ligprep` command. You cannot set the limit to a value greater than 31. The default for running the `ionizer` from `ligprep` is 10.

4.8 tautomerizer

Some isomeric forms of molecules coexist and are interchangeable under physiological conditions. Tautomers constitute an important class of such isomers. For some types of calculations, such as docking with Glide, considering the appropriate tautomeric forms of ligands is nearly as important as examining the appropriate ionization state. LigPrep uses the `tautomerizer` by default to generate probable tautomeric states. To skip the generation of tautomers, clear the `Generate Tautomers` option in the LigPrep panel of Maestro, or use the `-nt` option of the `ligprep` command.

The `tautomerizer` assigns a probability to each tautomeric form. The tautomers for a given input structure are produced in order of probability, the most probable forms first. By default, up to eight tautomers are generated for each structure. The maximum number of tautomers to generate for each structure can be specified with the `-t number` option of the `ligprep` command. In addition, the generation of improbable tautomers can be skipped by setting a threshold probability with the `-tp number` option. Only tautomeric forms with overall probabilities higher than this threshold will be produced. The default threshold is 0.01. If all forms have probabilities lower than the threshold, the most probable tautomer is still recorded to avoid eliminating that molecule completely from further consideration.

You must have a LigPrep license to run the `tautomerizer`. For more information on tautomers and the `tautomerizer`, see [Chapter 6](#).

4.9 ligfilter

`ligfilter` is a versatile utility for filtering molecules based on property values and descriptor counts. LigPrep uses `ligfilter` to filter molecules, usually to eliminate those matching certain conditions (e.g., molecular weight > 650 amu), although other types of filtering are possible. This section briefly documents `ligfilter` as it is used within LigPrep.

`ligprep` does not call `ligfilter` unless `ligprep` is given the `-f` option, which accepts the name of a file containing criteria to use for filtering. For example, to remove molecules with a molecular weight greater than 650, molecules that have too many hydrogen bond acceptors and donors, and too few atoms, you could create a file with the following content:

```
# Remove molecules that have a molecular weight of greater than 650
Molecular_weight > 650
```

```
# Remove molecules with too many H-bond acceptor and donor atoms
Acceptor_groups          > 3
Donor_groups             > 3
# Remove molecules with fewer than 10 atoms
Num_atoms                < 10
```

The spaces between the descriptors and the conditions are not significant.

The following command uses `ligfilter` to filter the input structures using the above file, saved as `ligfilter.lff`:

```
$SCHRODINGER/ligprep -f ligfilter.lff -isd input.sd
-omae output.mae
```

The command syntax for `ligfilter` is:

```
ligfilter [options] input-file
ligfilter [-h] [-v]
```

where *input-file* is the file of structures to be filtered, in Maestro or SD format, uncompressed or compressed. The options are described in [Table 4.1](#).

Table 4.1. Options for the ligfilter command.

Option	Description
-addprops	Add counts as Maestro properties to the output structure file.
-doc	Display extended documentation.
-e <i>filter-condition</i>	A single filter criterion. Multiple such criteria may be specified.
-f <i>filter-file</i>	Input file listing filter criteria to be used. Each criterion should be listed on a single line. Can also include definitions of functional groups.
-h[elp]	Show usage summary.
-n <i>nonmatch-file</i>	Filename for output of molecules that do not match the conditions.
-noout	Do not write an output structure file. This option is useful for obtaining counts of structures from the log file without generating the structure file.
-o <i>output-file</i>	Filename for filtered structure output. The default is <i>jobname-out.ext</i> , where <i>ext</i> is the extension of the input file.
-v	Show the version number of this utility.
-invert	Discard matching molecules instead of retaining them.
-any	Require match to at least one criterion instead of all criteria. Using this option is implicitly inserting an OR between each criterion, instead of an AND.
-j <i>jobname</i>	Specify job name. The default is the name of the input file, minus the extension.

The syntax of a filter criterion is as follows:

```
name [ op value [ {AND|OR} op2 value2 ... ] ]
```

Here, *name* is the full Maestro name of a property or descriptor, e.g. `r_qp_volume` or `i_qp_n_stars`. The conditional operator *op* must be one of the following:

```
> >= < <= == !=
```

and it must be surrounded by white space. If a criterion is simply *name*, then the named property is required to exist, but it may have any value. If the value for a string property contains spaces, the value must be enclosed in quotes.

Multiple conditions can be specified with the use of the AND and OR operators. For example, to specify that the property `r_user_minima` can have the values 0, 3, and 6, the filter criterion would be

```
r_user_minima = 0 OR = 3 OR = 6
```

If filter criteria are supplied in an input filter file, there must be one criterion per line. Lines that start with # are treated as comments. Blank lines are ignored.

The feature counts that can be used are as follows:

- `Molecular_weight`
- `Num_chiral_centers`
- `Num_rings`
- `Num_aliphatic_rings`
- `Num_heteroaromatic_rings`
- `Num_rotatable_bonds`
- `Num_aromatic_rings`
- `Num_negative_atoms`
- `Total_charge`
- `Num_atoms`
- `Num_positive_atoms`
-

The list of functional groups that are defined by SMARTS patterns is extensive, and can be found in the following file:

```
$SCHRODINGER/mmshare-vversion/data/ligfilter_definitions.lff
```

Each of the `DEFINE` lines in this file defines a functional group. The name of the group, which you can use in a filter criterion, is the next text field after the word `DEFINE`. You can copy this file to a local directory and modify it to customize the definitions. When `ligfilter` is run, the copy of this file in the current directory is used in preference to the copy in the installation.

It is also possible to use `ligparse` for filtering, with the `-use_ligparse` option, though its use is deprecated. `ligparse` is described in [Appendix A](#). You must have a LigPrep license to run `ligparse`. If you use `ligparse` to filter molecules, the `-any` and `-j 5` options are passed to `ligparse` by default. With these options, if any of the criteria given (`-any`) match for a particular molecule, the molecule is eliminated (`-j 5`) from processing. If options are passed to `ligparse` using the `ligprep -W` option, the `-any` and `-j 5` options are no longer passed by

default, so that other filtering strategies can be used, such as retaining only the molecules that match the criteria specified. The output files from `ligparse` are renamed by LigPrep. The `_cull.mae` file is renamed `_lpout.mae` and the `.out` file is renamed `_lp.out`.

4.10 stereoizer

The `stereoizer` has two modes: label mode and stereoisomer mode. In label mode, various stereochemical features in the input structures are labeled, such as atom chiralities (R/S) or double-bonded atom conformations (E/Z for groups of atoms connected by an odd number of bonds or P/M for groups of atoms connected by an even number of bonds). In stereoisomer mode, the `stereoizer` generates multiple output structures for each input structure, based upon the chiral properties of the chiral atoms in the structure. The coordinates of the atoms are not modified in the copies; only the chiral properties included in the structure for the chiral atoms are distinct. The structures produced in stereoisomer mode should be processed by a LigPrep-licensed version of MacroModel to adjust the atomic coordinates to match those required for the various stereoisomers and to eliminate combinations of chiralities that are very unfavorable. To use stereoisomer mode, set the `-n` option described under Options on page 55. To use the label mode, omit the `-n` option.

In stereoisomer mode, the chiralities of the atoms specified in the input structure or that can be determined from the geometry are retained. Only the chiralities of the other atoms are varied. If the `-a` option is specified, the input chiralities are ignored and the chiralities of all chiral atoms are varied as follows. Stereoisomers are generated by varying chiralities systematically starting from those that can be determined from the input geometry. Each internally generated structure is examined to see if it passes geometric or natural product restrictions on chiralities. Structures passing this stereoisomer filter are recorded in the output structure file. This process of generating stereoisomers is repeated until either all possibilities are sampled or until the maximum number of stereoisomers per input structure is reached.

Stereoisomer filtering is based upon geometric and natural product considerations. In functionalized norbornane both bridging atoms can be chiral. The geometry of these attachments is tightly coupled by geometric considerations so of the four combinations of chiralities, only two are possible. The `stereoizer` has geometric restrictions on a good number of simple fused ring systems, including norbornane, adamantane, and 2,2,2-bicyclooctane. Natural products (such as steroids and peptides) and their derivatives are often present in databases of drug-like molecules. These compounds often have multiple chiral centers many of which are customarily unspecified. Consequently it is possible to generate many uninteresting stereoisomers and not generate some of the important ones within the maximum number that the `stereoizer` is to generate. To reduce this problem the `stereoizer` is able to enforce the geometries of chiral atoms in L alpha amino acids and steroids.

Geometric restrictions on stereoisomers are more generally and strictly enforced. However, depending on the type of natural product and the project at hand, natural product restrictions should or should not be enforced. To deal with these distinctions, each type of stereoisomer filtering is placed in an enforcement class and may also permit violations for chiralities specified in the input structure. To deal with these nuances the `stereoizer` has two options, `-pat` and `-pat_keep_orig_off`. The former controls the general class of enforcement while the latter can be used to turn off retention of input structures that violate the restrictions on stereoisomers for those patterns that would otherwise permit them. Geometric restrictions are in class 1 while steroids are in class 2 and peptides are in class 3. Steroids and peptides permit violations of the restrictions for chiralities explicitly listed in the input structure.

When LigPrep calls the `stereoizer`, it uses `-n 32`. If you are running LigPrep with more than 5 chiral centers in any structure and want to generate all combinations, use the `-s` option of the `ligprep` command to specify the number of stereoisomers, or the `-n` option of the `stereoizer` command. The syntax is as follows; the options are given in [Table 4.2](#).

```
$SCHRODINGER/utilities/stereoizer [options] input-file.mae
output-file.mae
```

You must have a LigPrep license to run the `stereoizer`:

Table 4.2. Options for the `stereoizer` command

Option	Description
<code>-a</code>	Overwrite existing chirality properties.
<code>-g</code>	Overwrite existing chirality properties. Assign chiralities using geometry where possible. This option is only active when used with the <code>-n</code> option.
<code>-h</code>	Show usage summary.
<code>-n number</code>	Generate up to this many stereoisomers (stereoisomer mode). If omitted, existing stereoisomers are labeled and no new stereoisomers are generated (label mode).
<code>-pat class</code>	Set the type of enforcement for combinations of chiral atoms. <ul style="list-style-type: none"> 0 No enforcement 1 Enforce combinations that should always be met (e.g. for bridging atoms in norbornane) 2 Class 1 plus patterns that are expected to be followed (e.g. conserved patterns of chiralities in steroids) 3 Class 2 plus any additional patterns in the database The default is class 2.
<code>-pat_keep_orig_off</code>	Turn off retention of original templates that fail for specified patterns of chiral atoms.

Table 4.2. Options for the `stereoizer` command

Option	Description
<code>-retain</code>	Ensure that the input chiral properties are present in at least one output structure. Used with <code>-a</code> option.
<code>-verb level</code>	Controls MMERR level of reporting. 0 MMERR_FATAL—only report errors. 1 MMERR_WARNING—only report errors and warnings. 2 MMERR_INFO—report errors, warnings, and processing information. 3 MMERR_DEBUG—report errors, warnings, processing information, and debugging information.
<code>-v</code>	Show version number.

4.10.1 Stereochemical Properties

Stereochemical properties created and recognized by the `stereoizer` include those related to atom chiralities and to the conformations of doubly bonded series of C and N atoms. Another type of stereochemical information, atom numbering chiralities, is used to help track higher-order stereochemical features like syn and anti 1,4, attachments to cyclohexane.

Chiral atom properties have the form:

$$A_N-C-N_1-N_2-N_3-N_4$$

where:

- A_N is the atom number for the chiral atom.
- C specifies the chirality of atom A_N and is either 'R' or 'S'.
- N_1 through N_4 give the atom numbers of the atoms attached to atom A_N in decreasing order of their Cahn-Ingold-Prelog (CIP) priorities. If only 3 atoms are bonded to atom A_N , then $_N4$ is missing.

For example, the property `7_S_15_1_8_62` indicates that atom 7 has a 'S' chirality and that the four atoms attached to it in order of decreasing CIP priority are: 15, 1, 8, and 62.

Atom numbering chiralities are analogous to chiralities except that the atoms themselves need not be chiral. These specifications are used to describe higher-order stereochemical features like the relative attachment geometries of groups symmetrically attached to rings. These only originate from bond direction specifications in SD files. The syntax for atom numbering chiralities is the same as for chiralities just described except that the ANR and ANS are used instead of R or S and the bonded atoms are ranked solely based upon their atom numbers.

The isomers of doubly bonded series of C or N atoms with distinct attachments at each end are designated with properties of the form:



where:

- N_2 through N_{i-1} are the atom numbers of the doubly bonded series of atoms in the order in which they are bonded together.
- N_1 and N_i are the highest priority atoms bonded to N_2 and N_{i-1} respectively, according to the CIP rules.
- G is a character used to designate the overall geometry. If there is an even number of atoms specified then all the atoms are coplanar with N_1 and N_i lying on either the same, $G='Z'$, or opposite, $G='E'$, sides of the doubly bonded atoms. If there is an odd number of atoms then N_1 and N_i lie roughly perpendicular to each other. If on moving from one end of the series of doubly bonded atoms to the other the highest priority atom lies counter clockwise then $G='P'$. If they lie clockwise then $G='M'$.

In problematic cases, C or G appear as “???” if the structure was distorted enough to prevent unambiguous designation of the stereochemistry.

4.10.2 Known Limitations

The `stereoizer` is a fairly strict implementation of the standard CIP rules for chiralities and double-bond geometries as described in Prelog, V.; Helmchen, G. Basic Principles of the CIP-System and Proposals for a Revision. *Angew. Chem., Int. Ed. Engl.* **1982**, *21*, 567-583, except that prioritization of atoms by chiralities is not implemented. For instance, for prioritizing groups attached to the terminal atom of double bonded systems of atoms, if the groups are otherwise equivalent the CIP rules indicate that they may be prioritized if they differ in the chiralities of atoms within them. The `stereoizer` does not do this.

In stereoisomer mode, the `stereoizer` avoids some combinations of chiralities that are not achievable for geometric reasons or are atypical for some types of natural products (e.g. peptides and steroids). The coverage is not exhaustive, and for functionalities outside those covered the `stereoizer` does not attempt to distinguish realistic from unrealistic chiral atoms combinations. The unrealistic combinations can be largely eliminated in the `bmin` stage of LigPrep processing.

4.11 ring_conf

It can be difficult, or at least computationally demanding, to find low-energy conformations for the flexible ring systems within a structure. The `ring_conf` tool attempts to do so by identifying ring systems in the structure, then seeking suitable ring templates from its collection, and using these templates to generate good ring conformations.

Briefly, `ring_conf` examines the molecule to identify groupings of flexible rings, referred to as ring systems, that require a template. Many aromatic ring systems are recognized as such and no template will be sought for them and the input geometry will be used. However, aromatic rings within ring systems containing flexible rings need special attention. If they share 2 or more atoms with a flexible ring then they influence the conformation of the flexible ring and thus must be considered part of the ring system for template matching. However, if they do not share 2 or more atoms with a flexible ring they are not included in ring system that must be matched by a template. In this way, ring systems in which flexible rings are connected by non-flexible rings that do not overlap with flexible rings may be split into separate ring systems for templating purposes. Once the process of identifying portions of the molecule that require ring system templates are found, templates are sought separately for each such portion. Ring systems for which templates cannot be found retain the input geometry for the ring system. Template matching has some flexibility in that enantiomers may be matched and protonation states of sp^2 or sp^3 nitrogen atoms need not match. The template library has more than 770 templates, many of which have multiple conformations. Templates in the library include inversions of non-quaternary sp^3 nitrogen atoms in their collections of conformations.

After the template identification for the ring systems is complete, the conformational energies that depend on the ring conformation are estimated in a crude manner. The energy of each ring system is estimated separately based upon the ring conformation energies recorded in the template database, the axial-equatorial energies of the attachments and a pair-wise short range repulsion between base atoms for each attachment (the atoms directly bonded to atoms in the rings). The total ring system energy for a particular selection of conformations for all ring systems in a structure is obtained by adding together the energies for these conformations in each ring system.

By default, only the structure with the lowest estimated energy for each input structure is written to the output structure file. However, multiple structures with different ring conformations can be saved (see options `-e`, `-n`, and `-N`) using different selection criteria (see option `-c`).

While `ring_conf` is focused on providing conformations for the flexible ring systems in the structure provided, it can also attempt to adjust the conformations of portions of the structures outside such systems, depending on the linear generation method (see the `-l` option below). We generally recommend using `-l 3`, which instructs `ring_conf` to adjust the linear portions of the molecules so that they adopt extended conformations.

The syntax is as follows; the options are described in [Table 4.3](#).

```
$SCHRODINGER/utilities/ring_conf [options] input-file.mae
output-file.mae
```

You must have a LigPrep license to run `ring_conf`.

Table 4.3. Options for the ring_conf command.

Option	Description
<code>-c conf_method</code>	<ol style="list-style-type: none"> 1 Produce conformations in order of increasing energy (default). 2 Always provide the lowest energy conformation. 3 Select conformations at random. 4 Provide conformations with a probability proportional to their Boltzmann weight. 5 Systematically provide ring conformations.
<code>-e energy_limit</code>	Set the maximum energy (kJ/mol) relative to the lowest energy ring conformation for output conformers (default 50.0 kJ/mol). This option sets <code>num_conf</code> to 8 unless the <code>-n</code> option is used to specify another value.
<code>-h</code>	Show usage summary.
<code>-l lin_method</code>	Non-flexible ring generation method to use. <ol style="list-style-type: none"> 1 Leave as it was in the input structure (default). 2 Reconstruct all portions of the molecule (can lead to distorted rigid rings). 3 Generate only linear parts of the molecule. and use original geometry for the rigid rings. Note: <code>ligprep</code> passes a value of 3 to <code>ring_conf</code> for this option.
<code>-retain_amide_conf</code>	Retain the conformation around amide bonds in side chains. Use this option if you have an unusual conformation in the input.
<code>-N num_conf</code>	Produce exactly <code>num_conf</code> (see <code>-n</code>) conformers. Conformations will be repeated if necessary.
<code>-n num_conf</code>	Produce up to this many conformations for each input conformation Default: 1.
<code>-t temperature</code>	The temperature to use in Boltzmann weighting.
<code>-v</code>	Show version number.
<code>-verb number</code>	Controls MMERR level of reporting. <ol style="list-style-type: none"> 0 MMERR_FATAL—only report errors 1 MMERR_WARNING—only report errors and warnings 2 MMERR_INFO—report errors, warnings, and processing information. 3 MMERR_DEBUG—report errors, warnings, processing information, and debugging information

Additional output files:

<i>jobname_rcout_tmpl_att_prob.mae</i>	Structures for which either templates were missing or the relative energies of axial vs. equatorial geometries for attachments were missing.
<i>jobname_rcout_misc_prob.mae</i>	Structures for which <code>ring_conf</code> had other types of problems.

Limitations:

Missing Templates: The collection of templates for flexible ring systems is incomplete. In our trials, typically `ring_conf` did not find templates for all ring systems present for 8–25% of the valid input structures. However, we expect that the rate of misses will vary dramatically. Flexible ring systems for which templates are not found are simply treated by `ring_conf` as though they were rigid. At present, `ring_conf` does not support the ability to add templates.

Attachment Geometries for Missing Templates: Under some circumstances, attachments to flexible ring systems for which templates were not found are placed on top of each other if a value of 2 or 3 is given for the `-l` option. However, these geometries usually do not cause problems in subsequent processing by `premin` and `bmin` within LigPrep protocol.

Misidentification of Smallest Set of Smallest Rings: In very rare instances, the software that identifies the rings within ring systems, particularly fused ring systems, omits some rings. In such cases, it may not be possible to find a suitable template even if one is present.

Overlapping Atoms: `ring_conf` generates low-energy ring conformations using criteria that depend on features which are local to individual ring systems. The relative positions of portions of a molecule that are not directly associated with a single ring system are not taken into account, and in some instances may lie too close to each other. Within the LigPrep context the follow-up minimization and optional conformational search using MacroModel are expected to eliminate nearly all such problems.

4.12 premin

`premin` is used in filter mode in LigPrep to eliminate structures that could cause severe problems when processed by Schrödinger applications. Ligands that are processed successfully are written to the output structure file, which by default is called *jobname-min.mae*, while problematic structures are stored in *jobname-bad.mae*. In the LigPrep process, these files are named *jobname_prouit.mae* and *jobname_prouit_bad.mae*.

When `premin` is run using a LigPrep license, one MacroModel command file is created, named `filter.com`. Limited customization of the filtering process is possible with a modified `filter.com` file if `premin` is run directly from the command line and the `-custom` option is specified. When `premin` is run using a LigPrep license, only a restricted subset of the internal MacroModel commands (*opcodes*) is supported. The following section lists these opcodes.

The syntax is as follows; the options are described in [Table 4.4](#).

```
$SCHRODINGER/utilities/premin [options] input.mae
```

Here, `input.mae` is the input file containing ligand structures.

Table 4.4. Options for the premin command.

Option	Description
<code>-custom</code>	Use custom <code>.com</code> files.
<code>-doc</code>	Show a brief guide to using <code>premin</code> .
<code>-f 11</code>	Use OPLS_2001 instead of the default force field (MMFFs).
<code>-f 14</code>	Use OPLS_2005 instead of the default force field (MMFFs).
<code>-filter</code> <code>-m filter</code>	Filtering only (skip minimization).
<code>-h</code>	Show usage summary.
<code>-lic ligprep</code>	Use LigPrep license instead of MacroModel license.
<code>-s output</code>	Output file of successfully minimized structures. Default: <code>input-min.mae</code> .
<code>-nc</code>	Do not remove the working subdirectory.
<code>-u bad</code>	Output file of structures that could not be minimized. Default: <code>input-bad.mae</code> .
<code>-v</code>	Show version number.

4.13 MacroModel (bmin)

LigPrep uses MacroModel to enforce the chiral properties listed in each structure while producing an energy-minimized structure. When run under a LigPrep license, MacroModel has a very limited set of commands enabled. These commands, or *opcodes*, are targeted specifically for LigPrep use.

The CHIP opcode (see below) is used to instruct MacroModel that this calculation is being performed to assist LigPrep. The overall process is formally a serial MCM search. Each

structure is processed separately and sequentially from the input structure file. The positions of hydrogen atoms attached to chiral atoms are adjusted if they are not originally in an appropriate position.

First, the structure is read in and a small random displacement is made to separately to each atom present. Up to 4 improper torsions are placed on each atom indicated as chiral by a chiral property in the structure to strongly encourage the atom to adopt the chirality specified. This structure is then energy minimized. Then the improper torsional potentials are removed and a second minimization conducted. If the resulting structure has bonds close to their equilibrium length the conformational search is skipped. Otherwise a short conformational search is conducted and the lowest energy structure from the search retained. The same two stage minimization with and without the additional improper torsions is used for each conformation generated during the search. This optional search is used to attempt to correct distorted structures, such as those with connected atoms passing through the central portions of small rings. The lowest energy structure from either the full or truncated search is then checked to see if the requested chiralities were obtained, all bonds lie within 0.25 Å of their ideal length, and all bond angles are greater than 10 degrees. If the structure passes all of these tests then it is added to the output structure file. If not, by default, it is rejected and no structure is recorded in the output structure file. This strategy is used to eliminate unrealistic combination of chiralities, particularly in fused ring systems, which may be generated by the stereoizer.

See the *MacroModel Reference Manual* for `bmin` syntax.

4.13.1 MacroModel Opcodes Enabled for LigPrep

The following opcodes are enabled under a LigPrep license: `READ`, `MINI`, `FFLD`, `BGIN`, `END`, `CONV`, `EXNB`, `MCOP`, `DEBG`, `NANT`, `MCMM`, `MCSS`, `MCNV`, `SOLV`, `BDCO`, `MSYM`, `SPAT`, and `AUTO`. See the *MacroModel Reference Manual* for details. In addition, the `CHIP` and `CHOP` opcodes, described below, are available only with a LigPrep license.

CHIP — CHirality Protocol

CHIP instructs MacroModel to adjust its behavior appropriately for enforcing chiralities and avoiding common pitfalls encountered for structures that were originally 2D. CHIP is intended to be used within a `.com` file that would otherwise be a fairly typical MCMM serial search.

CHIP modifies the behavior of the `READ`, `MCMM` and `MINI` opcodes. When CHIP has been specified, structures read in with the `READ` opcode are examined for chiral atom properties. For each chiral atom specified up to 4 improper torsional potentials are added to encourage the atom to adopt the chirality requested. In addition, each atom in the structure is displaced by a small random displacement to encourage the system to leave saddle points during minimizations. Sometimes hydrogen atoms are placed in positions inconsistent with the chirality of atoms that

they are bonded to. When this problem is detected the hydrogen is repositioned to facilitate minimization to the correct geometry.

The behavior of the MCMM opcode is tightly coupled with the MINI opcode. In a serial search, when CHIP has been specified, the search proceeds as follows:

1. The structure is read using READ, whose behavior is modified as described above.
2. An initial minimization is performed on this structure with the additional improper torsional potentials in effect.
3. A second minimization is performed with the additional improper torsional potentials turned off.
4. If the bond lengths deviate from their ideal values by less than a specified value no search is performed and the next step (5) is skipped. Significantly distorted bonds are a good indicator that a portion of the molecule is passing through the center of a small ring.
5. A short MCMM search is performed. Each structure generated is minimized using the same two-stage procedure described in steps 2 and 3.
6. The structure is checked to see if it has adopted the requested chiralities. If so it is saved to the output structure file. If not, by default the structure is not recorded in the output structure file.

arg1 Chirality enforcement

- 1 Turn on the requirement for LigPrep licensing, but do not turn on chirality enforcement behavior.
- 0 Turn on the requirement for LigPrep licensing, and turn on chirality enforcement behavior.

arg2 Recording structures with incorrect chiralities

- 1 Write structures whose chiralities do not match those requested in the output structure file along with structures whose chiralities do match. These structures have the property `b_mmod_Chiralities_Consistent-Force_field_name` set to 0 (for FALSE).
- 0,1 Do not write structures whose chiralities do not match those requested in the output structure file.

arg3 Search control for strained structures

Strained structures are defined as those structures with bond lengths differing from the equilibrium bond length by more than the value specified by arg7.

- 1 Never perform searches on strained structures.
- 0,1 Perform an MCMM search on strained structures.

arg4 Random displacement control

Displacing atoms by small random amounts is useful in shifting minimizations away from saddle points, a problem that often arises in structures that were originally 2D. The maximum displacement is controlled by arg6.

- 1 Do not randomly displace each atom after a new structure has been read in.
- 0,1 Randomly displace each atom after a new structure has been read in.

arg5 Chirality enforcement force constant in kJ/mol

Must be non-negative. The size of the force constant for the improper torsions. Equivalent to arg5 of FXTA. Default value: 1000.0 kJ/mol

arg6 Maximum size of random displacement in Å

Must be non-negative. The maximum size of the random change in angstroms. introduced into each of the X,Y, and Z coordinates of each atom in the structure. The random change is chosen with a uniform probability on the range indicated. Default value: 0.05 Å.

arg7 Extent of bond distortion in Å that triggers a search

Must be 0 or greater than 0.05. If any bond is distorted away from the equilibrium bond length by more than this amount after the initial minimization then a full conformational search is to be performed provided that arg3 is not -1. Default value: 0.25 Å.

arg8 CHIP verbosity

- 0 Normal level of reporting to the .log file.
- 1 Turn on verbose reporting of CHIP processing to the .log file.

CHOP— CHirality OPtions

The CHOP opcode allows you to change some of the behavior associated with the CHIP opcode in MacroModel calculations.

arg1 Saving problematic structures

Structures that do not have the correct chiralities or are severely distorted are not placed in the output structure file for the bmin stage of ligprep. This option controls whether these such structures are saved to an auxiliary output file, *jobname_bmout-bad.mae*.

0 Do not save problematic structures

!=0 Save problematic structures

arg2 Scaling factor for conformational search steps if ring_conf could not find a template

Scale the number of steps in the conformational search if a template could not be found by ring_conf. The number of steps is set by arg1 of MCMM.

>0 Scale the number of conformational search steps by this value. The default scaling factor is 2.

arg5 Force constant for the torsional constraints that are used to enforce chiralities

< 0 Do not use torsional constraints

0 Use the default value of 500.0 kJ/mol

> 0 Use this value (kJ/mol) for the force constant.

arg6 Maximum average stretch energy for acceptable molecules

Conformations of molecules containing more than 9 bonds with stretch energies greater than this value are eliminated from consideration.

0 use a value of 9 kJ/mol

< 0 turn off elimination of molecules by average stretch energy

> 0 use this value (in units of kJ/mol)

arg7 Maximum deviation of a bond angle involving hydrogen

Conformations in which a bond angle involving at least one hydrogen atom deviates from the ideal bond angle given by the force field by more than this value are eliminated.

- 0 use a value of 25 degrees
- < 0 turn off elimination of conformations by this mechanism
- > 0 use this value (in units of degrees)

4.13.2 The LigPrep Command File for MacroModel

ligprep creates the .com file below for the MacroModel calculations used in the LigPrep process. The overall form of the file is fairly specific for the LigPrep process but follows that for an MCM serial search.

```
jobname_prout.mae
jobname_bmout.mae
DEBG      38      0      0      0      0.0000      0.0000      0.0000      0.0000
DEBG      51      0      0      0      0.0000      0.0000      0.0000      0.0000
FFLD      14      2      0      0      4.0000      0.0000      0.0000      0.0000
BDCC      0      0      0      0      41.5692 99999.0000      0.0000      0.0000
CHIP       1      0      0      0      0.0000      0.0000      0.0000      0.0000
CHOP       1      0      0      0      0.0000      0.0000      0.0000      0.0000
NANT
READ       0      0      0      0      0.0000      0.0000      0.0000      0.0000
MCM        20      0      0      0      0.0000      0.0000      0.0000      0.0000
MCNV       1     10      0      0      0.0000      0.0000      0.0000      0.0000
MCSS       2      0      0      0     1000000.0      0.0000      0.0000      0.0000
MCOP       1      0     20      0      0.0000      1.0000      0.0000      0.0000
MSYM       0      0      0      0      0.0000      0.0000      0.0000      0.0000
AUTO
CONV       2      0      0      0      0.0500      0.0000      0.0000      0.0000
MINI      -9      0     500      0      0.0000      0.0000      0.0000      0.0000
```

4.13.3 MacroModel Limitations and Workarounds

AUTOMATIC setup and ring closure failures

Automatic setup for the conformational searches sometimes fails to identify all of the ring closure bonds in a conformational search. When this occurs in a serial search MacroModel abandons the current search and the structure is not included in the output structure file. Processing then proceeds from the next structure in the input structure file, if present.

When the specified chiralities are not obtained the structures may be distorted

The strong improper torsions applied to chiral atoms aggressively try to force the molecules to attain the specified chiralities. If this process fails to produce the correct chiralities the resulting structures may be quite distorted. Such failures usually are the result of physically inconsistent chiralities. If the option to save those structures that fail to attain the specified chiralities is given (this is not the default behavior) a significant number of distorted structures might be written to the output structure file.

Ligprep stopping during bmin processing

`bmin` processing consumes more than 75% of the CPU time required to process a collection of ligands. If the LigPrep process stops while `bmin` is processing ligands, the output structure file for `ligprep` can be empty or contain only one ligand. However, the file `jobname_bmin.out` should contain essentially all of the ligands successfully processed up to the stage at which `bmin` stopped.

The ionizer Utility

Under physiological conditions, a molecule with acidic or basic groups can exist in a variety of protonation (ionization) states. Ligand structures are usually provided in only one of these states. To ensure that the important ionization states are sampled, LigPrep includes the `ionizer` utility to generate the states that are significantly populated under a prescribed set of conditions.

The Ionizer, or ionization state expander, produces multiple structures for each input structure with different combinations of ionized states based on the ionizable groups present. The `ionizer` makes use of a database of substructure patterns (templates) for ionizable groups, which it matches to the input structure to identify candidates for protonation or deprotonation. If a template for the ionizable group is not found, the group is not ionized.

LigPrep sets only a few of the `ionizer` options. For information on these options, see [Table 2.1 on page 14](#) and [Section 4.7 on page 50](#). You can pass a restricted set of `ionizer` options to the `ionizer` with the `ligprep -w i` option. These options are indicated in the option descriptions below.

This chapter describes the use of the `ionizer` as a stand-alone utility.

5.1 Running the ionizer

To run the `ionizer` from the command line, use the following syntax:

```
$SCHRODINGER/utilities/ionizer [options]
```

The options are described in [Table 5.1](#).

Table 5.1. Options for the ionizer command.

Option	Description
Information options	
-? -h -help	Show usage summary.
-doc	Show full description.
-v -ver -version	Show program version information.

Table 5.1. Options for the ionizer command. (Continued)

Option	Description
File options	
-b -bad -badfile <i>badfile</i>	Specify file name for input structures that ionizer fails to process. Default is <i>jobname-ion-bad.mae</i> .
-i -in -infile <i>infile</i>	Specify input file. Default is <i>jobname.mae</i> .
-j -job -jobname <i>jobname</i>	No default (must be specified unless all essential files are specified).
-l -log -logfile <i>logfile</i>	Specify log file name. Default is <i>jobname.log</i> . To log to screen, replace <i>logfile</i> with <i>-</i> .
-o -out -outfile <i>outfile</i>	Specify output structure file name. Default is <i>jobname-ion.mae</i> .
Log file options	
-ll -loglevel <i>level</i>	Expansion report log level. Use 0 for quietest (default), 1 to log state generations, 2 provides additional details for debugging. Supported with <i>ligprep -W i</i> .
-sf -showfinal	Show final ionization candidate list. Supported with <i>ligprep -W i</i> .
-sm -showmatches	Show substructure pattern matches. Supported with <i>ligprep -W i</i> .
-ss -showskips	Show skipped state generations. Augments log level 1 and higher. Log levels > 1 give skip reasons. Supported with <i>ligprep -W i</i> .
Restriction options	
-mg -maxgroups <i>limit</i>	Maximum number of ionizable groups to be handled. Structures containing more than this number of ionizable groups are recorded in the output structure file with no variation of ionization states. Default 15; <i>ligprep</i> default 10. Set by <i>ligprep -mg</i> . Cannot be set larger than 31.
-mi -maxions <i>count</i>	Maximum number of ionization states. Applies only to pK_a mode. Default 4. Supported with <i>ligprep -W i</i> .
-mo -maxoutcts <i>limit</i>	Maximum number of output structures per input structure. Default 512. Supported with <i>ligprep -W i</i> .
-mq -maxabstotq <i>charge</i>	Maximum absolute total charge. Only applies to pK_a mode. Default 2. Supported with <i>ligprep -W i</i> .

Table 5.1. Options for the ionizer command. (Continued)

Option	Description
-ph <i>value</i>	Effective pH of active site. Default 7.0. Supported with <code>ligprep -W i</code> .
-pht -phtthresh <i>maxdiff</i>	pH threshold for pH-based ion state rejections. Ion states are rejected if the pK_a of the (protonated) ionizable group differs from the pH value by more than this threshold. Default 2.0. Supported with <code>ligprep -W i</code> .
-pkt -pkthresh <i>maxdiff</i>	pK_a threshold for pK_a -based ion state rejections. Overrides pH-based rejection mode. Ion states are rejected if the maximum pK_a of the deprotonated groups is larger than the minimum pK_a of the protonated groups by more than <i>maxdiff</i> . No default. Supported with <code>ligprep -W i</code> .
Other options	
-adjust	Retain only the most favorable structure in the output file.
-kp -keep_props	Keep properties and write to output file. Default is to delete properties. Set by <code>ligprep -kp</code> .
-retain	Retain the input structure in the output.
-retain_lab	Retain the input structure and add a label property to the retained input structure that identifies it as the input structure.
-rw -retitle_with <i>prefix</i>	Add ion state number onto structure titles. The prefix precedes the ion state number. Quote <i>prefix</i> if there are spaces. By default, structures are not retitled. Examples of retitling: If the original structure title is "TITLE," and the output structure is for ion state 3, then <code>-rw _</code> produces the output structure title <code>TITLE_3</code> , <code>-rw " Ion_state_num="</code> produces the output structure title "TITLE Ion_state_num=3."
-s -spec -specfile <i>specfile</i>	Use non-standard patterns specification file. See Section 5.7 on page 77 . Supported with <code>ligprep -W i</code> .
-strict	Force termination of <code>ionizer</code> if it encounters an unacceptable input structure.

5.2 Input Structure Requirements

For the `ionizer` to process all input structures successfully, each structure must satisfy the following requirements:

- Hydrogens must be added.
- Atom types must be correct.
- There must be no formal charge on atoms matched as centers of ionizable groups.

It is not necessary for input structures to be minimized fully, as the Ionizer works in terms of atom types and connectivity. However, bond lengths and bond angles should have reasonable values: unreasonable structures can cause processing failures. Coincident atomic coordinates can cause serious problems, especially if atoms coincide within an ionizable group.

By default, structures that the Ionizer cannot process are passed unchanged to the output file. It also records these structures in the file *jobname-ion-bad.mae* (or the file specified by the `-b` option). If you set the `-strict` option, the ionizer stops if it encounters a structure that it cannot process.

5.3 Restricting Ionization State Generation

The Ionizer has two methods for restricting the generation of ion states to ensure that each state has a significant population under the chosen conditions. The default method is to screen values according to a pH range. This is done by specifying a target pH value with the `-ph` option and a threshold value with the `-pht` option. The default pH is 7, and the default threshold is 2. For any ionizable group whose pK_a lies within the threshold value around the target pH value ($|pK_a - pH| \leq \text{threshold}$), both protonated and deprotonated forms are generated. If the pK_a is smaller than the target pH value by more than the threshold value, only the deprotonated form is generated, and if the pK_a is larger than the target pH value by more than the threshold value, only the protonated form is generated. To generate all possible ionization states, you can set the threshold to a large value.

The alternative method is to use the `-pkt` option to specify a relative threshold for the pK_a values to screen out improbable states. In this method, a structure generated by the ionizer is rejected if the maximum pK_a value of any deprotonated group is greater than the minimum pK_a value of any protonated group by the specified threshold.

For example, if the threshold is 3.0 and the structure has two ionizable groups with pK_a values of 6.0 and 10.0, the structure with the first group protonated and the second group deprotonated is rejected. Likewise, if the threshold is 2.0 and the structure has 4 ionizable groups, with pK_a values of 4.0, 5.5, 7.0, and 8.5, the structure with the first and fourth groups deprotonated and the second and third groups protonated is rejected. In this case the maximum pK_a of the deprotonated groups is 8.5 and the minimum pK_a of the protonated groups is 5.5. The difference is greater than the threshold value of 2.0.

This method treats each structure independently and ensures that the totally protonated form and the totally deprotonated form are always included in the output. There is no default value for the threshold, and as for the pH-based method, it is possible to specify a pK_a threshold large enough so that no ion state is rejected.

If you specify the pK_a threshold, you can also specify a maximum number of groups ionized and a maximum total charge, to limit the number of structures generated. Setting the `-mi` option limits the maximum number of ionized groups to the value specified. The default is 4. If a possible ion state has more individual groups ionized than this value, the state is rejected. This limit applies only to the ionizable groups detected by the *Ionizer*. Setting the `-mq` option limits the absolute value of the total charge to a value less than or equal to the value specified. The default is 2. If the structure already has a formal charge, this charge is taken into account when the restriction is applied.

5.4 Structural Output

If an input structure contains a large number of ionizable groups, the number of output structures will be very large (2^N combinations) and the *ionizer* will take a long time to run. The *ionizer* has a limit on the number of ionizable groups in any structure that can be set, above which the *ionizer* skips its normal analysis and expansion of the structure and passes it unchanged into the output file. To set this limit, use the `-mg` option (see [page 70](#)). The default value is 15 for standalone use, and 10 for use within *LigPrep*. You cannot set the limit higher than 31. An input structure that contains close to 31 ionizable groups could take hours or days to be treated by the *ionizer*. You should therefore set this limit well below 31 if you do not want long run times.

In addition, structures that cannot be processed are passed unchanged into the output file and are recorded in a separate file, named *jobname-ion-bad.mae* by default. The name of this file can be set with the `-b` option.

5.5 Log File Output

As the *Ionizer* expands input structures into ionized output structures, it records various status messages in the log file, which by default is named *jobname.log*. You can specify the log file name with the `-l` option. If you want to direct the log file to your screen, set the log file name to a hyphen: `-l -`. Examining the log file output can be useful if you want to determine how a particular structure was handled.

Substructure matching: If you use the `-sm` option of the *ionizer* command, the substructure pattern matches are logged on each input structure as it is processed. The information logged for each match includes the line number in the pattern file where the substructure pattern is given, the pattern itself, the ion center atom number where the match is anchored, the acid/base character of the ionizable group, and a comment as to whether the match modifies an earlier match at the same atom.

Final ionization candidate list: If you use the `-sf` option of the `ionizer` command, the final list of ion centers identified on each input structure is logged as it is processed. The information logged for each ion center includes the ion center atom number, the acid/base character of the group, and the pK_a value associated with this group.

Log level: The `-ll` option gives general control over the amount of information provided in the log file. Each level adds information to the previous level.

At level 0, the report on each input structure processed includes the structure number (in the input file), structure title, the number of distinct ionizable groups identified, the number of ionization states to consider generating, and the number of states actually generated after imposition of restrictions.

At level 1, the report contains a line on each ion state generated, showing the state's index and a brief description of the state, listing the original atom numbers in the input molecule which become ionized in the output.

At level 2, the report provides more details which may be helpful in debugging in conjunction with Schrödinger Technical Support, and increases the run time slightly.

For production runs, you should use level 0 if possible and level 1 only if you need to see a list of the ion states generated or skipped.

Skipped states: If you use the `-ss` option of the `ionizer` command, a line is written for each ion state skipped—that is, rejected from generation due to imposition of some restriction. This option affects only log levels greater than 0. If this option is specified when running at level 2, the reasons for rejecting an ion state are shown. You might want to see these reasons spelled out, for example, when adjusting the restriction parameters to see which rejections they lead to in practice.

If structures are skipped because the structure itself is faulty, error messages are printed to the log file. In the default fault-tolerant mode, each set of error messages resulting from input structure problems is followed by a message indicating that the otherwise fatal errors have been tolerated, and the structure passed to the output file unchanged.

5.6 Maestro Properties

When the ionization state changes, most if not all of the properties of the structure are no longer valid. By default, the `Ionizer` does not copy the properties of the input structures to the output. In some cases, the properties of the parent structure are useful for later screening or identification—for example, `QikProp` properties. If you want to ensure that properties are inherited by the output structures, you can add the `-kp` option to the command line.

The Ionizer generates some Maestro properties, which are summarized in Table 5.2.

Table 5.2. Maestro properties generated by the ionizer.

Property Name in Project Table	Name in Maestro Output File	Description
Ion state n	i_ionizer_Ion_state_n	Ionization state number. This is an index running from 0 to the number of ionized states, and serves as a unique identifier.
Tot Q	i_ionizer_Tot_Q	Total formal charge. This value includes any formal charges in the input structure that have been retained.
Ion centers	s_ionizer_Ion_centers	String of atom numbers for new charge centers generated by the ionizer. ^a
Ion types	s_ionizer_Ion_types	String of MacroModel atom type symbols for new charge centers generated by the ionizer. ^a
Ion ctrs in	s_ionizer_Ion_ctrs_in	String of atom numbers of the original uncharged atoms in the input structure that correspond to new charge centers in this output structure.
Ion passthru	s_ionizer_Ion_passthru	Brief description of the reason an input structure was passed to the output file unchanged. Generated only if an input structure is not processed.
Ionization penalty	r_ionizer_Ionization_penalty	This ionization state's total energy penalty ^b
Ionization penalty charging	r_ionizer_Ionization_penalty_charging	This ionization state's energy penalty due to charged sites ^b
Ionization penalty neutral	r_ionizer_Ionization_penalty_neutral	This ionization state's energy penalty due to neutral sites ^b

- The strings are empty for the non-ionized state. Neither of these strings is a unique id for the ionization state. It is not uncommon for these strings to match between different ionized variants of the same input.
- The energy penalties are expressed in kcal/mol units. These properties are not written if running in pK-threshold mode. Details of the calculation are presented below.

Calculation of Ionization State Energy Penalties

For each ionizable group involved in a generated state, we define two energy costs:

Y_n : The energy cost of ionizing the group

Z_n : The energy cost of keeping the group neutral

Consistent with the Ionizer's other simplified assumptions, we do not account for cooperative effects between multiple groups.

At the given pH, with the group's specified pK_a , if the group is a base, we calculate:

$$Y_n = RT \ln(10^{pH-pK_a} + 1)$$

$$Z_n = RT \ln(10^{pK_a-pH} + 1)$$

where $R = 0.001987207$ kcal/(mol K), and $T = 298.15$ K.

If the group is an acid, we calculate the alternate pair:

$$Y_n = RT \ln(10^{pK_a-pH} + 1)$$

$$Z_n = RT \ln(10^{pH-pK_a} + 1)$$

Now, for each generated ionization state combination, we sum the Y_n for all groups that are ionized, calling the total Y , and we sum the Z_n for all groups that are not ionized, calling the total Z .

For small values of the pH threshold (controlled by `-pht`), Y is dominated by the energy cost of ionizing weak acids and bases, while Z is dominated by the energy cost of keeping weak acids or bases neutral. For larger values of the pH threshold, these penalties begin to include the corrections for producing stronger acids and bases in atypical forms.

We also compute $P = Y + Z$, which is the total energy cost of the ionization state combination.

The P , Y , and Z values are expressed in the energy penalty properties for the output structure:

`r_ionizer_Ionization_penalty`

`r_ionizer_Ionization_penalty_charging`

`r_ionizer_Ionization_penalty_neutral`

5.7 Creating a Customized Patterns File

The file that contains the substructure patterns used to identify ionizable groups can be customized. This file contains substructure patterns for protonating N atoms, and deprotonating NH, OH, and SH groups. The standard patterns file can be found at

```
$SCHRODINGER/mmshare-vversion/data/ionizer.ini
```

If you want to add your own patterns, you should make a copy of the file and edit it. Documentation on the pattern specification commands can be found in comments in this file. The pattern specification commands require use of Schrödinger's linear substructure notation, which is documented in the *Maestro User Manual*.

Once you have made your changes, you can then use the modified file as input to the `ionizer` in the following ways:

- By providing its name with the `-s` option when you run the `ionizer`, or the `-is` option when you run `ligprep`.
- By copying this file to the directory from which you launch an `ionizer` or `ligprep` job. The file must be named `ionizer.ini`.
- By adding this file to your `$HOME/.schrodinger/mmshare` directory. The file must be named `ionizer.ini`, and becomes your global default patterns file.

Note: Correct use of the syntax is not trivial. You might have to experiment for some time to ensure that you have the correct result, and you may need to contact Schrödinger for assistance.

Warning: Do not change the standard patterns file.

5.8 Ionizer Limitations

The limitations described in this section apply only to the Ionizer operation, if used in the LigPrep process, or if used on a stand-alone basis. Limitations of the LigPrep process as a whole are described in [Section 2.6 on page 27](#).

- Local Focus in Adjustment of Protonation States

The Ionizer adjusts the protonation state of each ionizable group without regard for the protonation state of other ionizable groups found in the molecule. In other words, when deciding which states of one ionizable group to generate, the Ionizer does not take into account changes in the group's effective pK_a due to neighboring protonation states. This can lead to generation of the wrong ionization states for molecules containing more than one ionizable group.

For the specific case of an aliphatic diamine separated by two carbons (for example, piperazines and ethylene diamines) patterns have been introduced in which the pK_a of both nitrogens is given as the average of the two experimental values for the mono and diprotonated species. As a result, when the ionizer is run with the default settings (pH 7.2), four forms are generated: neutral, both monoprotonated forms and the diprotonated species.

Note: Only the monoprotonated forms are favorable near pH 7. Without these patterns, only the diprotonated form would be generated. The ordering of the penalties for this class of system is not accurate. This behavior can be disabled by commenting out the diamine lines in the `ionizer.ini` file.

The erroneously excluded states can be generated by running the Ionizer with non-default pH and/or pH threshold settings, but it can take some trial and error. Of course, running with modified settings to produce previously excluded states of one molecule can generate undesired variants of other input molecules.

- Incompatibility with Certain Force Field Implementations

The Ionizer may generate structures that cannot be used with certain force field implementations. One known case involves the atom type N5 ($N^+ sp^3$) and AMBER* (Modified AMBER), which arises when ionized forms are generated outside of “normal” pK_a ranges, particularly the protonation of anilines and aromatic heterocyclic nitrogens. There could also be problems with atom type N4 ($N^+ sp^2$).

- Rotation of Output Molecules

In some ionized molecules with protonated nitrogens, the output structure will be rotated with respect to the input structure.

- Upper Limit on Number of Ionizable Groups in Input Molecule

The program is capable of handling up to 31 ionizable groups in an input molecule (though it would take a long time, and a lot of disk space, to do so). The value 31 is a hard upper limit. This is the maximum value allowed to be specified with the command-line option `-mg` or `-maxgroups`.

The tautomerizer Utility

Tautomers are an important class of isomers that can interconvert under physiological conditions. Tautomeric forms have different chemical properties and interact differently. For instance, one tautomeric form may interact with the active site of a protein more strongly than the other forms. Therefore, for some types of calculations, such as docking with Glide, considering the appropriate tautomeric forms of ligands can be important.

There does not seem to be a universal definition for tautomers. In LigPrep, tautomers are defined as isomers that meet the following conditions:

- In aqueous solution tautomers interconvert rapidly enough to be present as mixtures.
- One or more hydrogen atoms are bound to different atoms and the orders of one or more of the bonds between non-hydrogen atoms differs between tautomers.
- The non-hydrogen atom topology of the structure does not change during these interconversions.

LigPrep's definition of tautomers therefore excludes the aldose-hemiacetal ring opening and closing equilibrium in sugars that are sometimes regarded as tautomerizations. An example of the well-known keto-enol tautomerization is shown in [Figure 6.1](#).

The `tautomerizer` relies on a database of tautomeric templates to guide it in generating tautomers. For more information on this database, see [Section 6.2 on page 81](#).

The `tautomerizer` is not intended to generate all possible tautomers. The collection of groups of tautomers in the database is not exhaustive. As well, each set of tautomeric forms in the database is limited to those tautomers that are expected to have significant populations in aqueous solution, rather than being a comprehensive list. Tautomers in the database are assigned probabilities to assist in focusing on the most highly populated tautomeric forms.

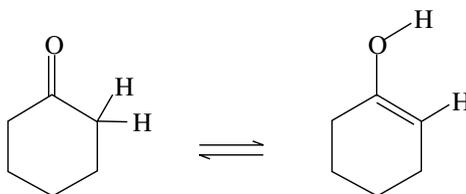


Figure 6.1. Keto-enol tautomerization.

Some types of functional groups such as amino groups strongly perturb tautomeric equilibria. The presence of such groups severely reduces the value of the probabilities recorded in the database which could lead to inappropriate tautomers being generated. To avoid this problem, most patterns exclude the possibility of attachment to such functional groups. In selected cases, new patterns have been added that explicitly include such functionalities in the tautomeric pattern and in the calculation of the probabilities.

The tautomerizer provides control over tautomer generation through the command-line options and by permitting users to modify the database.

6.1 Running the tautomerizer

To run the tautomerizer from the command line, use the syntax below. The tautomerizer is part of the LigPrep collection of programs and requires a LigPrep license.

```
$SCHRODINGER/utilities/tautomerizer [options] input_file.mae
output_file.mae
```

The options are described in [Table 6.1](#).

Table 6.1. Options for the tautomerizer command.

Option	Description
-h	Show usage summary.
-m <i>number</i>	Set the maximum number of tautomers generated internally to <i>number</i> . Output tautomers are selected from this set. Default: 128
-ma <i>number</i>	Set the maximum number of atoms to <i>number</i> . Default: 150
-n <i>number</i>	Set the maximum number of tautomers produced to <i>number</i> . Default: 8
-p <i>number</i>	Set the minimum probability for retaining a tautomer. The most probable tautomeric form for each input structure is always written to the output structure file even if its probability lies below the threshold, to avoid completely eliminating molecules. Default: 0.01
-retain	Retain the input structure.
-retain_lab	Retain the input structure and add a label property to the retained input structure that identifies it as the input structure.
-s <i>filename</i>	Specify a custom tautomer database.

Table 6.1. Options for the tautomerizer command. (Continued)

Option	Description
-v	Show the version number.
-verb <i>level</i>	Controls MMERR level of reporting. 0 MMERR_FATAL—only report errors. 1 MMERR_WARNING—only report errors and warnings. 2 MMERR_INFO—report errors, warnings, and processing information. 3 MMERR_DEBUG—report errors, warnings, processing information, and debugging information.

The tautomerizer can also be run as part of the LigPrep process. When LigPrep is run from the LigPrep panel in Maestro, the default options are used. When it is run from the command line, the defaults can be overridden by options to the `ligprep` command. See [Section 2.2 on page 13](#) and [Section 4.8 on page 51](#) for more information.

6.2 The Tautomer Database

In LigPrep 2.0 the default tautomer database is not accessible to users. However, you can provide your own file to either completely override the default file, or add patterns to it.

Note: The database file format has changed in LigPrep 2.0. The current format will not work with previous versions of the program although earlier versions of the data file may work with LigPrep 2.0, with some modifications.

At the top level of the tautomer database file the following four items can be present: `name`, `clear_standard`, `group_def`, and `tautomer_set`. These items are described in the following sections. Lines beginning with a `#` are comment lines and are ignored when interpreting the contents of the tautomer database file. Blank lines are also ignored.

6.2.1 name Data Item

`name` specifies the name of the solvent. For example:

```
name: water
```

`water` and `DMSO` are standard names for which the tautomerizer already has information. Currently, the `DMSO` tautomer information is just a duplicate of that for `water`.

6.2.2 clear_standard Directive

By default, information in a custom tautomer database file is added to any existing information already available for the solvent specified. Including `clear_standard:` in a tautomer database file clears any values for this solvent accumulated before the current file was read.

6.2.3 group_def Data Structure

The tautomerizer does not support recursive SMARTS. However, a mechanism that supports some of the functionality of recursive SMARTS is provided by the `group_def` data structure. This data structure permits you to define variables that correspond to SMARTS patterns. The variables may be reused in groups and `tautomer_sets` that appear later in the tautomer database file.

Each group contains two items:

`name`: an arbitrary name for the group which is used to reference the group.

`pattern`: The SMARTS pattern for the group. This pattern may refer to previously defined groups using `$groupname`.

Below are some examples of `group_def` data structures:

```
group_def{
    name: Halogens
    pattern: [F,Cl,Br,I]
}

group_def{
    name: Amides
    pattern: [CX3](=[OX1])-[NX3]
}

group_def{
    name: Carbonyls
    pattern: [CX3](=[OX1])
}

group_def{
    name: Carbonyls_only
    pattern: [$Carbonyls;!$Amides]
}
```

6.2.4 tautomer_set Data Structure

tautomer_set data structures define sets of interconvertible tautomers. There are more than 215 tautomer sets available by default for water.

Some examples of tautomer_set data structures are given below, and the syntax for the data structures is described following these examples.

Note: The entry for pattern: values must be a single line. In the examples below, some of the pattern: text wraps to the next line due to formatting constraints within this manual. When creating tautomer data structure files in a text editor, ensure that text-wrapping is turned off, or that margins are set wide enough to accommodate single-line entry for this value.

```
tautomer_set{
  name: single-sided_ket-enol
# From: Handbook of organic chemistry

  tautomer{
    name: enol
    pattern: [CX3](-[#1,$Sub_aC])(-[#1,$Sub_aC])=[CX3](-
[#1,$Sub_carbonyl_C])-[OX2]-[#1]
    probability: 0.00005
  }

  tautomer{
    name: ket
    pattern: [CX4](-[#1])(-[#1,$Sub_aC])(-[#1,$Sub_aC])-[CX3](-
[#1,$Sub_carbonyl_C])=[OX1]
    probability: 0.99995
  }
}

tautomer_set{
  name: double-sided_ket-enol
# From: Handbook of organic chemistry

  tautomer{
    name: 1enol
    pattern: [CX3](-[#1,$Sub_aC])(-[#1,$Sub_aC])=[CX3](-[CX4](-
[#1])(-[#1,$Sub_aC])(-[#1,$Sub_aC]))-[OX2]-[#1]
    probability: 0.00000001
  }
}
```

```
tautomer{
  name: ket
  pattern: [CX4](-[#1,$Sub_aC])(-[#1,$Sub_aC])(-[#1])-[CX3](-
[CX4](-[#1])(-[#1,$Sub_aC])(-[#1,$Sub_aC]))=[OX1]
  probability: .99999998
}

tautomer{
  name: 2enol
  pattern: [CX4](-[#1,$Sub_aC])(-[#1,$Sub_aC])(-[#1])-
[CX3](=[CX3](-[#1,$Sub_aC])(-[#1,$Sub_aC]))-[OX2]-[#1]
  probability: 0.00000001
}
}
tautomer_set{
  name: imidazole

  tautomer{
    name: form1
    pattern: c1(~[#1,$Sub_c])n(-[#1,$Sub_n])-c(-
[#1,$Sub_c])=[nX2]c1(~[#1,$Sub_c])
    probability: 0.50
  }

  tautomer{
    name: form2
    pattern: c1(~[#1,$Sub_c])[nX2]=c(-[#1,$Sub_c])-n(-
[#1,$Sub_n])c1(~[#1,$Sub_c])
    probability: 0.50
  }
}
```

Each tautomer set contains a name: designator and a number of tautomer structures. The name: designator is followed by a space and a contiguous non-blank label to identify the class of tautomers described by the set. The label provided does not affect processing. In the examples below, there are three tautomeric sets: single-sided_enol-ket, double-sided_enol-ket, and imidazole.

The tautomer structure describes the properties of one tautomeric form. There are three designators that may be used within a tautomer structure: name:, probability:, and pattern:.

The name: designator provides a label for the tautomer but does not otherwise affect processing.

The `probability`: designator is used to assign a probability or fractional population of this tautomer within this tautomeric set. In many cases, reliable information on the probability of various tautomeric forms is not available and the values entered in the database are simply educated guesses.

The `pattern`: designator is followed by a contiguous SMARTS-like pattern. A difference between this pattern and a normal SMARTS pattern is that instead of using explicit aromatic bonds, explicit single “-” and double “=” bond designators are used to make the corresponding Lewis structures clear. In addition, these patterns may include references to previously defined groups via the `$group_name` mechanism. Information on SMARTS patterns is provided on the web page: <http://www.daylight.com/learn>⁴. The SMARTS-like pattern is used to detect the corresponding groups of molecules in the input structures and to permit the tautomerizer to understand how the bonding patterns (Lewis structures) differ between tautomers so that they may be interconverted. For heavy atoms that are expected to carry a formal charge it is advisable to include the charge in the SMARTS pattern. To ensure that the SMARTS patterns are properly interpreted by the `tautomerizer`, the following restrictions must be applied:

- The SMARTS patterns for all tautomers within a tautomer set include the same list of non-hydrogen atoms in the same order.
- All SMARTS patterns must explicitly designate the hydrogens that shift positions in any tautomer within a tautomer set with a `-[#1]` pattern.
- All SMARTS patterns within a tautomer set must contain the same number of explicitly designated mobile hydrogen atoms.
- In both non-aromatic and aromatic portions of the SMARTS pattern, bond orders that change between single and double in any tautomer must be explicitly specified in the SMARTS patterns for all tautomers in a tautomer set.
- In portions of molecules that must be represented by aromatic atom types (e.g., `c` and `n`), only changes in the bond orders of bonds involving `n` atoms in the corresponding Lewis structures are supported. If such a bond changes order in any tautomer in a tautomer set, it must be represented as `‘:’` in all the tautomers. See the guanosine tautomer set in the example above.
- Recursive SMARTS are not supported.
- SMARTS patterns within the same tautomer set must all specify the same overall formal charge.

4. Please see the [notice](#) regarding third party programs and third party Web sites on the copyright page at the front of this manual.

The database provided with this release contains templates for keto-enol tautomers and their sulfur analogues, imine-enamine tautomers, histidine-like tautomers, tautomers of DNA and RNA bases, and a large number of common heteroaromatic rings containing C, S, O, and N.

6.3 Tautomer Processing

Each structure in the input structure file is processed separately. The processing of each structure by the `tautomerizer` can be divided into two stages: tautomer pattern matching and structure generation.

6.3.1 Tautomer Pattern Matching

The current structure is examined for all matches of all tautomeric patterns in the `tautomerizer` database. All matches are cross-examined to see if the atoms are completely contained within another match. If so, the match containing the smaller number of atoms is eliminated. If they are the same size, then the match pattern found first is retained. This is the only case where the order of tautomers within a tautomer set or the order of the tautomer sets within the `tautomer_list` file affects processing.

In the example above, there are two related SMARTS patterns for keto-enol tautomerization. The `single-sided_enol-ket` tautomer set handles carbonyl groups that can tautomerize only on one side, such as an aldehyde with at least one H atom bonded to the carbon atom adjacent to the carbonyl carbon, while the `double-sided_enol-ket` tautomer set handles carbonyl groups that can tautomerize on either side, such as ketones with at least one H atom bonded to each carbon atom adjacent to the carbonyl carbon atom. Thus structures that match the `double-sided_enol-ket` pattern also match at least one `single-sided_enol-ket` pattern. However, the single-sided matches for this carbonyl are eliminated because they are completely contained within the double-sided pattern. This is important since the double-sided probabilities are different, and matching an enol form in the double-sided case leads to the consideration of the other enol form during the structure generation stage, which would not happen for a single-sided match.

6.3.2 Structure Generation

For each match, all tautomers in the tautomer set should be considered. Structures in which more than one match has been found have multiple locations in the structure that can be tautomerized, and all combinations of tautomers that are compatible should be considered. Double bonds that can shift to single bonds in any tautomer within a set can shift between E and Z forms, provided that other topological constraints do not prevent this shift.

The `tautomerizer` tries to generate all compatible combinations of all tautomers for each match. For each structure having a high enough probability, all combinations of 180 degree rotations about certain double bonds within each tautomeric pattern are generated. Double bonds are rotated if they involve C or N atoms in which both ends are not attached to two H atoms and in which the two atoms in the bond do not reside in the same ring. No adjustment is made to the probability for the tautomeric form for these double bond rotations. The probability for each structure resulting from this process is estimated as the product of the probabilities for all the tautomer templates used to generate it. The probabilities are normalized amongst all the structures generated for a given input structure.

Tautomers are generated in order of decreasing probability. By default, the maximum number of tautomers generated internally is 128. This limit can be adjusted using the `-m` option of the `tautomerizer` command. Of this collection of tautomers, up to eight tautomers are recorded by default in the output file for each input structure. This limit can be adjusted with the `-n` option of the `tautomerizer` command (`-t` option of the `ligprep` command). The most probable tautomer is always recorded. Except for this tautomer, only tautomers with a probability higher than 0.01 are recorded in the output structure file. This threshold value can be adjusted using the `-p` option of the `tautomerizer` command (`-tp` of the `ligprep` command). If either the `-retain` or the `-retain_lab` option is used to keep a tautomeric form of a molecule that would normally have a probability lower than the threshold probability value, the probability for this form is set to the threshold value.

Note: The probability for forms of a tautomerizable group is not adjusted for other functional groups inside the molecule, but outside the pattern itself. This means that these probabilities, and thus the overall probabilities for molecular forms (particularly when multiple tautomeric sites are being adjusted), are approximate and intended as a guide.

A chiral atom in a tautomer can switch its chirality if one of its tautomeric forms involves a double bond to this atom. The `tautomerizer` does not vary the chiralities of such atoms and does not add chirality properties for such atoms. However, the `stereoizer` can generate these variations. See [Section 4.10 on page 54](#) for more information. In the LigPrep process, the `stereoizer` is run after the `tautomerizer` and the chiralities of such atoms are varied. Some LigPrep options that restrict the generation of stereoisomers may prevent this variation—see [Section 2.2 on page 13](#).

The `ligparse` Utility

The `ligparse` utility is a tool for examining the structural composition of a molecular data set in a Maestro- or MDL SD-formatted file. `ligparse` can use this structural information to select subsets of compounds within the original data set that meet some user-defined criteria.

Note: This utility has been replaced by `ligfilter` in the LigPrep process. It may be removed from the distribution in a future release.

Note: The input files for `ligfilter` and `ligparse` are not compatible.

A.1 Descriptors and Composite Descriptors

The `ligparse` utility analyzes the composition of a molecular structure by counting structural components, which include the usual organic functional groups. These structural components are represented by SMARTS patterns. A single SMARTS pattern for a given structural component is called a *descriptor*. Linear combinations of SMARTS patterns can be generated to represent more sophisticated structural entities, such as a hydrogen bond donor or acceptor, or metal-ligating groups. These sums of descriptors are called *composite descriptors*. A descriptor is defined by the combination of a SMARTS pattern with its label.

`ligparse` checks each molecule in turn against all descriptors. The algorithm is “greedy”—each atom or bond matches all applicable SMARTS patterns rather than only the most sophisticated or the most simple pattern. For instance, a carboxylic acid group in a molecule would match one instance of `[#6;X3]~([O;X1])~[O;X1]`, two instances of `[#6;X3]~[O;X1]`, and two instances of `[#8]`.

The default descriptor list is stored in the file `$$SCHRODINGER/macromodel-vversion/data/str_keys.type`. You can copy and modify the `str_keys.type` file and use it in place of the default with the `-s` command-line option. The `str_keys.type` file is a free-format file with column descriptions as given below.

```
15  H  H  0.00  [n;X2;!H]  nosel  high  -  #  Num heteroaromatic n w.outH
(1) (2) (3) (4)- (5)----- (6)-- (7)- (8) (9)-----
```

Only columns (5), (6), and (9) are relevant to this discussion; however, data in the format given above must exist for all columns. In this example, column (5) gives the SMARTS pattern associated with the title in column (9), `Num heteroaromatic n w.outH`. For more information on SMARTS patterns, see <http://www.daylight.com>. Any string may be used as a descriptor label.

The string `nose1` in column 6 is necessary for atom typing to recognize that this SMARTS pattern is to be used by *ligparse*.

A total of 19 composite descriptors are defined by default in the `composite.types` file in `$SCHRODINGER/macromodel-vversion/data`. They are:

Num rings	Num heteroaromatic rings
Num aromatic rings	Num aliphatic rings
Num rotatable bonds	Num atoms
Molecular weight	Num chiral centers
Num neutral amines	Num amide hydrogens
Num divalent oxygen atoms	Num neutral donor groups
Num charged donor groups	Num neutral acceptor groups
Num charged acceptor groups	Num reactive groups
Num acidic hydrogens	Num donor groups
Num acceptor groups	

Of these composite descriptors, the first eight (Num rings, Num heteroaromatic rings, Num aromatic rings, Num aliphatic rings, Num rotatable bonds, Num atoms, Molecular weight, and Num chiral centers) cannot be adjusted by the user. Other descriptors may be added to the file, and descriptors may be removed from the file. You can specify your own `composite.types` file with the `-c` command-line option. The composite descriptors file is in free format, with a single composite descriptor represented as follows:

```
Num neutral donor groups
+ Num H-N
+ Num H-O
- Charged amines
- Charged imines
- Charged pyridine
- Charged N-C=N on -N
- Charged imidazole
- Charged HN-imidazole
```

Here `Num neutral donor groups` is a linear combination of the eight descriptors represented by their labels. The `+` or `-` is required and indicates whether the descriptor is to be added to or subtracted from the composite descriptor.

A.2 Molecular Database Structural Analysis

The average structural composition of a given database may be examined using job type 3 (`-j 3` command-line option). *ligparse* determines the number of times each SMARTS pattern is recognized in each molecule and maintains a sum of the number of times each SMARTS pattern has been found in all molecules. After reading the last molecule in a data set, the mean of the number of times each SMARTS pattern has been found is written to the output file. Standard deviations are also given for some measure of the width of the distribution.

More detailed structural information per compound is available with the `-pcsv` command-line option. With this option, a comma-separated file is written that contains the counts of descriptors and composite descriptors per molecule, with one molecule per line. The file name for the comma-separated file can be adjusted with the `-pcsv filename` command-line argument. The comma-separated file can be imported into common spreadsheet programs for further processing. In addition, the structures in the input file are copied to a Maestro-formatted output file with the descriptors added as properties.

A.3 Molecular Database Subset Selection: “Culling”

ligparse can use four methods for selecting a subset of molecules, which is called *culling*:

- Culling to reproduce the mean value of composite descriptors within the original data set (`-j 2` command-line option)
- Culling to reproduce user criteria for any descriptors (`-j 1` command-line option)
- Culling to retain only compounds that match user criteria (`-j 4` command-line option)
- Culling to remove only compounds that match user criteria (`-j 5` command-line option)

The first two techniques involve optimization of an error function through random molecule substitution. The third and fourth methods allow the use of *ligparse* as a structural filter, removing or retaining molecules that match the user-defined criteria. For job types 4 and 5, if more compounds match the user criteria than is desired to have in the culled subset, molecules are randomly selected from the subset that matched the user criteria.

For a listing of each descriptor and composite descriptor available with the current `str_keys.type` and `composite.types` files, use the `-d` command-line option.

For job types 1, 4, and 5, the user criteria are passed to *ligparse* with the `-i` command-line option. The file containing the user criteria is the `cull.info` file. Any descriptor or composite descriptor may be used in a `cull.info` file. The file is in free format with each line listing the label and target value for a single descriptor or composite descriptor. Any line beginning with “###” is treated as a comment and ignored. Tabs are not recognized and should not be used. For

job type 1, all descriptor and composite descriptor target values must be either integer or real positive values.

For filtering with job type 4, only molecules that match all criteria listed in the `cull.info` file are *retained*. For filtering with job type 5, only molecules that match all criteria listed in the `cull.info` file are *removed*. These behaviors may be modified with the `-any` option, which changes the selection behavior from removing or retaining only compounds that match *all* criteria to removing or retaining only compounds that match *any* of the criteria.

To further enhance the filtering of molecules with job types 4 and 5, you can retain compounds with descriptor values greater than a given value ($>X$), less than a given value ($<X$), or within some range ($X-Y$). Ranges are defined by $X < \text{value} < Y$, thus a molecular weight range of 300.0-400.0 retains only molecules with molecular weights greater than 300 and less than 400. These conditions are valid only when running `-j 4` or `-j 5` jobs.

Two example `cull.info` files are presented below.

```
## Distribution A for job type 1
Num rings                2.600
Num charged donor groups 0.000
Num charged acceptor groups 0.000
Num reactive groups      0.000
Molecular weight         352.247
Num atoms                41.800
```

```
## Filtering for job types 4 or 5
Num rings                0.99-3.01
Neutral Carbonyls       <1.0
```

A.4 The *ligparse* Command

ligparse can only be run from the command line.

Syntax:

```
ligparse {-mae input-file | -sdf input-file} [options]
```

You must specify an input file with either the `-mae` or the `-sdf` flag. The output file will be of the same type as the input file. Examples of the *ligparse* command are given below. The order of the specification of the options and the input file is irrelevant.

Options:

- all Select molecules that match all descriptors in the `cull.info` file. Only applies to job types 4 and 5, for which it is the default.
- any Select molecules that match any descriptor in the `cull.info` file. Only applies to job types 4 and 5.
- bofix Correct bond orders and formal charges in structures prior to SMARTS pattern matching.
- c *string* Input file name for a user-defined composite descriptor file.
- csv *string* Name of comma-separated value file.
- d Display a list of all descriptors and composite descriptors, then exit.
- h Display usage summary.
- i *string* Input file name for the culling information file to be used.
- j *int* Job type to be run.
- 1 Select a subset of structures that approximately reproduce user criteria.
 - 2 Select a subset of structures to retain original property distributions.
 - 3 Analyze structural components.
 - 4 Select a subset of structures that match user criteria.
 - 5 Remove structures that match user criteria.
 - 6 Randomly select user-defined number/percent of structures from a larger dataset (used with `-seed integer`, see below).
- k *double* Percentage of compounds in original data set to keep after culling (0 to 100).
- l *string* Label for output with the culled structures.
- mae *string* Input file name for Maestro-formatted input files.
- n *int* Number of compounds in original data set to keep after culling (0 to number of compounds in dataset).
- noprops Do not include calculated properties in the output structure file.
- o *string* Text file to which data from running `ligparse` is sent.
- pcsv Write a comma-separated value file (spreadsheet), listing values for each molecule of all descriptors. If a file name is not specified with the `-csv` option, the file is written to `jobname.csv` in the working directory.
- s *string* Input file name for a user-defined descriptor file to be used.
- sdf *string* Input file name for MDL SD-formatted input files.

- seed *integer* Select the initial random seed which then directs the selection of compounds when using the -j 6 option (see above).
- sort Sort the output into descriptors that were present in the data set and those that were not.
- v Display program version.

For information on how *ligparse* is called by *ligprep*, see [Section 4.9 on page 51](#).

Examples:

To analyze structural components in a data set:

```
ligparse -j 3 {-mae|-sdf} input-file [ -s str-keys -c composite-types
-o output-file -pcsv -csv csv-file -sort -bofix]
```

To select a subset of structures that approximately reproduce user criteria:

```
ligparse -j 1 {-mae|-sdf} input-file -i criteria-file {-k|-n} what-to-keep
[-s str-keys -c composite-types -o output-file -pcsv -csv csv-file -sort
-bofix -l label]
```

To select a subset of structures to retain original property distributions in the data set:

```
ligparse -j 2 {-mae|-sdf} input-file {-k|-n} what-to-keep [-s str-keys
-c composite-types -o output-file -pcsv -csv csv-file -sort -bofix -l label]
```

To select a subset of structures that match user criteria:

```
ligparse -j 4 {-mae|-sdf} input-file -i criteria-file {-k|-n} what-to-keep
[-s str-keys -c composite-types -o output-file -pcsv -csv csv-file -sort
-l label -any -all -bofix]
```

To remove structures that match user criteria:

```
ligparse -j 5 {-mae|-sdf} input-file -i criteria-file {-k|-n} what-to-keep
[-s str-keys -c composite-types -o output-file -pcsv -csv csv-file -sort
-l label -any -all -bofix]
```

To select a random subset of structures:

```
ligparse -j 6 {-mae|-sdf} input-file {-k|-n} what-to-keep [ -o output-file
-pcsv -csv csv-file -l label -any -all -bofix -seed random-seed]
```

A.5 Input and Output Files

Valid input file names for *ligparse* are *jobname.mae* for Maestro files, and *jobname.sdf* or *jobname.sd* for SD files. The stem of the input file name, *jobname*, is used to construct the default output file name. The averages of descriptor values in the input file are written to *jobname.out*. The name of this file can be set with the `-o` option.

For job type 3, *ligparse* copies the structures from the input file to a Maestro output file, and adds the descriptors as properties to this file. The file is named *jobname-out.mae*.

For job types 1, 2, 4, and 5, *ligparse* writes a structure file named *jobname-label.mae* or *jobname-label.sdf*. Here, *label* has the default value of `cull` and can be set with the `-l` option. The input format dictates the file format of the culled structure file. For example, if the input file is a Maestro file, the output contains a subset of molecules in Maestro format. The properties calculated by *ligparse* are added to the output structure files for job types 4 and 5.

If the `-pcsv` option is given, an additional file is written, *jobname.csv*. This comma-separated file contains the value of each descriptor per molecule. The file name can be set with the `-csv` option.

Examples of *ligparse* commands and the files generated are given below.

Example 1:

```
ligparse -sdf database.sdf -j 1 -k 10 -i cull.info -l set1
```

Keeps 10 percent of *database.sdf* structures selected to maintain average values of descriptors defined in *cull.info*. Output includes 2 files:

<i>database.out</i>	File listing the results of culling and structural information for the starting set of molecules and the culled set of molecules for the descriptors of interest.
<i>database-set1.sdf</i>	MDL file of 10 percent of retained structures.

Example 2:

```
ligparse -mae database.mae -j 1 -k 20 -i ../cull.info -o db1.stat -pcsv
```

Keeps 20 percent of *database.mae* structures selected to maintain average values of the descriptors listed in the file, *../cull.info*. Output includes 3 files:

<code>database-cull.mae</code>	Maestro file of 20 percent of retained structures.
<code>db1.stat</code>	File listing the results of culling and structural information for the starting set of molecules and the culled set of molecules for the descriptors of interest.
<code>database.prop</code>	File listing the number of times each descriptor was identified per molecule.

Example 3:

```
ligparse -mae database.mae -j 2 -n 500 -l small
```

Keeps 500 `database.mae` structures selected to maintain average values of descriptors found in the original dataset. Output includes 2 files:

<code>database.out</code>	File listing the results of culling and structural information for the starting set of molecules and the culled set of molecules for the descriptors of interest.
<code>database-small.mae</code>	Maestro file of 50 percent of the retained structures.

Example 4:

```
ligparse -sdf database.sdf -j 3 -c my_composite.types  
-s my_str_keys.types
```

Determines the average values of a number of descriptors for structure in the SD format file, `database.sdf`. The descriptors are read from the `my_str_keys.types` file, with composite descriptor read from the `my_composite.types` file. Output includes 1 file:

<code>database.out</code>	File listing average number of various structural keys for compounds in <code>database.sdf</code> .
---------------------------	---

Getting Help

Schrödinger software is distributed with documentation in PDF format. If the documentation is not installed in `$(SCHRODINGER)/docs` on a computer that you have access to, you should install it or ask your system administrator to install it.

For help installing and setting up licenses for Schrödinger software and installing documentation, see the *Installation Guide*. For information on running jobs, see the *Job Control Guide*.

Maestro has automatic, context-sensitive help (Auto-Help and Balloon Help, or tooltips), and an online help system. To get help, follow the steps below.

- Check the Auto-Help text box, which is located at the foot of the main window. If help is available for the task you are performing, it is automatically displayed there. Auto-Help contains a single line of information. For more detailed information, use the online help.
- If you want information about a GUI element, such as a button or option, there may be Balloon Help for the item. Pause the cursor over the element. If the Balloon Help does not appear, check that Show Balloon Help is selected in the Maestro menu of the main window. If there is Balloon Help for the element, it appears within a few seconds.
- For information about a panel or the tab that is displayed in a panel, click the Help button in the panel, or press F1. The help topic is displayed in your browser.
- For other information in the online help, open the default help topic by choosing Online Help from the Help menu on the main menu bar or by pressing CTRL+H. This topic is displayed in your browser. You can navigate to topics in the navigation bar.

The Help menu also provides access to the manuals (including a full text search), the FAQ pages, the New Features pages, and several other topics.

If you do not find the information you need in the Maestro help system, check the following sources:

- *Maestro User Manual*, for detailed information on using Maestro
- *Maestro Command Reference Manual*, for information on Maestro commands
- *Maestro Overview*, for an overview of the main features of Maestro
- *Maestro Tutorial*, for a tutorial introduction to basic Maestro features
- LigPrep Frequently Asked Questions pages, at https://www.schrodinger.com/LigPrep_FAQ.html
- Known Issues pages, available on the [Support Center](#).

The manuals are also available in PDF format from the Schrödinger [Support Center](#). Local copies of the FAQs and Known Issues pages can be viewed by opening the file `Suite_2009_Index.html`, which is in the `docs` directory of the software installation, and following the links to the relevant index pages.

Information on available scripts can be found on the [Script Center](#). Information on available software updates can be obtained by choosing Check for Updates from the Maestro menu.

If you have questions that are not answered from any of the above sources, contact Schrödinger using the information below.

E-mail: help@schrodinger.com
USPS: Schrödinger, 101 SW Main Street, Suite 1300, Portland, OR 97204
Phone: (503) 299-1150
Fax: (503) 299-4532
WWW: <http://www.schrodinger.com>
FTP: <ftp://ftp.schrodinger.com>

Generally, e-mail correspondence is best because you can send machine output, if necessary. When sending e-mail messages, please include the following information:

- All relevant user input and machine output
- LigPrep purchaser (company, research institution, or individual)
- Primary LigPrep user
- Computer platform type
- Operating system with version number
- LigPrep version number
- Maestro version number
- mmshare version number

On UNIX you can obtain the machine and system information listed above by entering the following command at a shell prompt:

```
$SCHRODINGER/utilities/postmortem
```

This command generates a file named `username-host-schrodinger.tar.gz`, which you should send to help@schrodinger.com. If you have a job that failed, enter the following command:

```
$SCHRODINGER/utilities/postmortem jobid
```

where *jobid* is the job ID of the failed job, which you can find in the Monitor panel. This command archives job information as well as the machine and system information, and includes input and output files (but not structure files). If you have sensitive data in the job

launch directory, you should move those files to another location first. The archive is named `jobid-archive.tar.gz`, and should be sent to help@schrodinger.com instead.

If Maestro fails, an error report that contains the relevant information is written to the current working directory. The report is named `maestro_error.txt`, and should be sent to help@schrodinger.com. A message giving the location of this file is written to the terminal window.

More information on the `postmortem` command can be found in [Appendix A](#) of the *Job Control Guide*.

On Windows, machine and system information is stored on your desktop in the file `schrodinger_machid.txt`. If you have installed software versions for more than one release, there will be multiple copies of this file, named `schrodinger_machid-N.txt`, where *N* is a number. In this case you should check that you send the correct version of the file (which will usually be the latest version).

If Maestro fails to start, send email to help@schrodinger.com describing the circumstances, and attach the file `maestro_error.txt`. If Maestro fails after startup, attach this file and the file `maestro.EXE.dmp`. These files can be found in the following directory:

```
%USERPROFILE%\Local Settings\Application Data\Schrodinger\apcrash
```


A

applyhtreat	
brief description.....	2
full description.....	47
atom numbering chiralities	56
atoms	
chiral.....	56
overlapping.....	60

B

batch queues.....	43
bmin (MacroModel)	
brief description of LigPrep use	3
full description of LigPrep use	61
options for.....	17–18

C

charged groups, neutralization of.....	49
chiralities	
atom numbering.....	56
atom property format.....	56
change during tautomerization	87
command options.....	16
enforcement in bmin (MacroModel)...	62–64, 67
enforcements in stereoizer.....	55
GUI options.....	11
retention of.....	11, 54
unrealistic combinations.....	57
chirality information, adjustment with hydrogen treatment	48
composite descriptors.....	89
custom, ligprep option for.....	17
conformational search.....	62
conformations	
approximate energies.....	58
double bond.....	54, 57, 87
non-ring portions of structures	58
ring.....	58
ring_conf options.....	59
conventions	
file names.....	25
conventions, document.....	vii
counter ions, removal of.....	49
command option	15
GUI option.....	12

culling of structures.....	91
examples	42, 92
information files for.....	92

D

deprotonation	49, 69
desalter	
brief description.....	2
full description.....	49
ligprep option for.....	15
options	49
descriptors	89
custom, ligprep option for.....	17
using conditions with.....	92
directory	
installation	4
job submission	13
Maestro working.....	4
tutorial.....	30
distributed processing	20
double-bond conformations	54, 57, 87

E

enantiomers, matching by ring_conf	58
energies	
estimates of conformational	58
minimization of	61
environment variable, SCHRODINGER.....	4, 31
Epik	
passing options to	15
states for metal binding	12
use for ionization and tautomerization	12, 15, 16
error messages.....	74
examples	
3D structure improvement.....	38
adjusting chemistry.....	39
applyhtreat.....	48
default settings.....	37
default variations	31
filtering structures	42
generating QikProp input files.....	42
generating variations.....	39
ligparse commands	95
one-to-one conversion	38
ring conformation variation.....	35

- expansion, of structures 7
- F**
- files
- composite descriptors 90
 - composite.types 90
 - culling information 92
 - descriptor 89
 - naming conventions 26
 - removal of 14, 25
 - size limits 28
 - splitting input 20
 - str_keys.type 89
 - temporary 25
- See also* input files, output files
- filtering structures 91
- command options 17
 - creating file for 8
- force field
- dependence of hydrogen treatment on 47
 - for bmin (MacroModel) 11, 17
- format conversion utilities 4
- H**
- hosts file 18
- hydrogen atoms, adding or deleting 47
- hydrogen bond acceptors, donors 89
- I**
- input files
- ligparse 89, 91
 - removal of 14, 25
 - size limits 29
 - splitting large 20
 - suffixes 26
 - valid structure formats 13
- ionizable groups
- candidate list 74
 - customized patterns for 77
 - limit in ionizer 51, 70, 73
 - maximum total charge 73
 - option for maximum number 16
- ionization states
- command options 16
 - GUI options 11
 - restriction by pH or pK_a 72
 - using Epik for 12
- ionizer
- brief description 3
 - full description 69
 - input restrictions 71
 - LigPrep use of 50
 - options 69
 - output files 73
 - passing options to 15, 69
 - thresholds 71
- J**
- job control
- facility 19, 29
 - hosts file 18
 - ligprep options 18
 - submission to remote hosts 42
- job submission directory 13
- L**
- license, LigPrep 4
- premin use of 61
 - tools requiring 49, 50, 51, 53, 55, 59
 - using with bmin (MacroModel) 61
 - using with premin (MacroModel) 61
- ligfilter
- brief description 3
 - full description 51
 - ligprep options for 17
 - LigPrep use of 51
 - passing options to 15
- ligparse
- composite descriptors file 90
 - descriptor file 89
 - examples 95
 - full description 89
 - ligprep options for 17
 - output files 95
 - passing options to 15
- ligprep
- input file size limit 29
 - options 14
- LigPrep - Start dialog box 13
- LigPrep panel 8
- limitations
- LigPrep 27

-
- MacroModel (bmin)..... 66
 - neutralizer 50
 - ring_conf..... 60
 - stereoizer..... 57
 - limits
 - input structure file..... 29
 - ionizable groups in ionizer..... 51, 70, 73
 - number of atoms 14
 - output structures in ionizer 70
 - ring conformations..... 12, 59
 - stereoisomers 11, 54
 - tautomers 12, 80
 - log file
 - bmin (MacroModel)..... 64
 - ionizer..... 70, 73
 - location of..... 13
 - M**
 - MacroModel
 - brief description of LigPrep use 3
 - chirality enforcement..... 67
 - full description of LigPrep use 61
 - ring closure failures 66
 - Maestro, starting 4
 - Maestro-formatted files, input..... 13
 - maesubset
 - LigPrep use of..... 2
 - options 47
 - metal-binding states 12, 15
 - metal-ligating groups 89
 - meta-options..... 14
 - N**
 - neutralizer
 - brief description..... 2
 - full description..... 49
 - limitations 50
 - options 50
 - O**
 - opcodes 61–64
 - options
 - desalter..... 49
 - ionizer..... 69
 - ligprep..... 14
 - maesubset..... 47
 - meta 14
 - neutralizer 50
 - para_ligprep 20
 - passing from ligprep to tools..... 15
 - premin 61
 - QikProp input files..... 19
 - ring conformations..... 17
 - ring_conf..... 59
 - sdconvert..... 45, 47
 - stage selection..... 15
 - stereoisomers 16
 - stereoizer..... 55
 - tautomerizer 80
 - tautomers 16
 - output files
 - ionizer..... 73
 - ligparse..... 95
 - options 14
 - premin 60
 - ring_conf..... 60
 - suffixes..... 26
 - P**
 - para_ligprep
 - files 21
 - options 20
 - parities..... 37
 - peptides, chirality enforcement in..... 54
 - pH, restriction of ionization states by 11, 72
 - pK_a , restriction of ionization states by 72
 - premin
 - brief description..... 3
 - full description..... 60
 - options 61
 - output files 60
 - problematic structures
 - premin files containing 60
 - removal of..... 14
 - retention of..... 27
 - ring_conf files containing 60
 - product installation..... 97
 - protonation 49, 69
 - Q**
 - QikProp input files
 - example for 42

- option for 19
- qikprop, passing options to 15

- R**
- recursive SMARTS 82
- remote hosts, submitting jobs to 42
- restrictions, ionizer input structures 71
- ring closure failures, bmin (MacroModel) 66
- ring conformations, generating 58
 - GUI option 12
 - ligprep option 17
 - ring_conf option 59
- ring_conf
 - brief description 3
 - full description 58
 - limitations 60
 - options 59
 - output files 60
 - passing options to 15
- rings, flexible
 - identification of 58
 - missing templates 60
 - templates 58
- rings, fused
 - chirality enforcement 54
 - misidentification 60
- rings, rigid
 - identification of 58
 - ligprep option for handling 17
 - ring_conf option for handling 59

- S**
- Schrödinger contact information 98
- schrodinger.hosts file 18
- sdconvert
 - LigPrep use of 2, 3
 - options 45, 47
- SD-formatted files
 - converting to Maestro format 45
 - input, output of 13
- SMARTS patterns
 - ligparse use 89
 - recursive 82
 - tautomerizer use 85
- SMILES files, converting to Maestro format 46
- SMILES format, for input 7, 13

- solvation model, for bmin (MacroModel) 17
- stage of LigPrep process, option for selecting .. 15
- stereoisomers
 - command options 16
 - generation of 37, 54
 - geometric restrictions on 55
 - GUI options 11
 - maximum number 38
 - peptides 54
 - steroids 54
- stereoisomer
 - brief description 3
 - full description 54
 - limitations 57
 - options 55
 - passing options to 15
- steroids, chirality enforcement in 54
- structures
 - culling 91
 - deprotonated form 72
 - format conversion 45–47
 - input, retaining 50, 80
 - ionizer input restrictions 71
 - ionizer output limit 70
 - maximum total charge 73
 - protonated form 72
 - selecting for conversion 14
 - subset selection utilities 5
 - with many ionizable groups 51, 73

- T**
- tautomer database
 - ligprep option for 16
 - tautomerizer option for 80
- tautomerizer
 - brief description 3
 - full description 79
 - LigPrep use of 51
 - options 80
 - pattern matching 86
- tautomers
 - command options 16
 - definition 79
 - GUI option 12
 - screening by probability 16, 87
 - specifying custom database 80
 - types recognized 86

temporary files 25
thresholds, `ionizer` 71
throughput 1
 enhancing with `para_ligprep` 20

torsional constraints, for `bmin` (MacroModel) . 18

U

utilities, additional 4

120 West 45th Street, 29th Floor
New York, NY 10036

Zeppelinstraße 13
81669 München, Germany

101 SW Main Street, Suite 1300
Portland, OR 97204

Dynamostraße 13
68165 Mannheim, Germany

8910 University Center Lane, Suite 270
San Diego, CA 92122

Quatro House, Frimley Road
Camberley GU16 7ER, United Kingdom

SCHRÖDINGER.