

over five half-lives. To account for mixing and temperature equilibration, spectra recorded in the first 2 min were discarded.

### C. Preparation of *Syn* 2-Methylcyclohexanone Imines (**9**, **11** and **13/15**) and the Following Lithiation by LDA/THF.

**Method (1).**<sup>ref 2</sup> An oven-dried 10 mL Kimble vial was equipped with a magnetic stir bar and a rubber septum cap. Following evacuation under full vacuum and flushing with argon, the vial was charged with 2.0 mL solution of LDA (60 mg, 0.55 mmol) in THF and cooled to -78 °C. Cyclohexanone imine **2**, **3** or **4** (0.50 mmol) was added drop wise by a syringe. The reaction mixture was taken to desired lithiation temperature (0 °C for **2**, -78 °C for **3** and -65 °C for **4**) for 15 min and warmed to 0 °C and stirred for 10 min to complete the lithiation. The clear solution turned into bright yellow, indicating the formation of lithioimine. The solution was cooled to -78 °C for 10 min and 0.10 mL solution of iodomethane (0.60 mmol) in THF was added over a period of 10 min. The mixture was allowed to stir at -78 °C for 10 min. 0.20 mL solution of the resulting *syn* isomer (**9**, **11** or **13/15**, 0.25 M) was taken quickly into a gas-tight syringe and injected into the flask on an in situ IR for lithiation (final concentration 0.005 M).

**Method (2).** An in situ IR experiment was set up and started in a regular way as described above in **B** and cyclohexanone imine **2**, **3** or **4** (0.060 mmol, 0.006M) was added for lithiation. Disappearance of the C=N peak (1663-1667 cm<sup>-1</sup>) was monitored. After the lithiation was completed, iodomethane (0.050 mmol) was added to the reaction. A new C=N peak (1652-1655 cm<sup>-1</sup>) which belonged to the *syn* isomer (**9**, **11** or **13/15**) appeared and was monitored as the lithiation went on.

The lithiation of the *syn* imine by methods (1) and (2) showed no difference (± 10%) in terms of reaction rate and regioselectivity (see below). The kinetics data of imines **9**, **11** and **13** (section XXXI – XXXIV, XXXVII and XXXVIII) were obtained with Method (2).

### D. Regioselectivity of Imine Lithiations and Determination of Absolute Stereochemistry of 13-16.

Imine lithiations (0.005 M imine, 0.13 M LDA, 10 mL THF) were performed in a flask attached to an in situ IR instrument as described in **B**. When the lithiation was completed (>98% conversion shown by IR profile of the imine substrate), the flask was cooled to -78 °C by dry ice/acetone. When the profile perturbed by the temperature change became stable, 0.1 mL solution of iodomethane (0.060 mmol) in THF was added. A new peak belonging to the C=N stretch (1652-1655 cm<sup>-1</sup>) appeared instantly, accompanied by the drop of the peak belonging to the lithioimine (1590 cm<sup>-1</sup>). When the profile became stable again (within 5 min), 10 mL buffer solution (made by dissolving 4.6 g sodium acetate and 15 mL acetic acid in 100 mL water) was added to quench the reaction and the flask was warmed to room temperature and kept stirring for 3 hours.<sup>ref 2</sup> The mixture of organic and aqueous layers was washed with 5% HCl (5 mL) then extracted with Hexane (15 mL x 3). The combined organic layer was sequentially washed with water (10 mL), 5% sodium carbonate (10 mL), water (10 mL), and saturated sodium chloride (10 mL) and dried with sodium sulfate. Removal of the solvent by evaporation gave a light yellow residue which contained 2,2- and/or 2,6-dimethylcyclohexanones in 80-90% yield as well as 2-methylcyclohexanone.<sup>ref 3</sup> The residue was dissolved in 3 mL fresh hexane and was subjected to GC analysis. The ratio of the dimethyl ketones were calculated by the integration areas. Authentic samples of 2-methylcyclohexanone, 2,2-dimethylcyclohexanone and 2,6-dimethylcyclohexanone (*cis:trans* = 11:1) were obtained from Aldrich.

When a 1:10:1:10 mixture of imines **13**, **14**, **15** and **16** was lithiated to 50% conversion at -20 °C with a following alkylation as described above, the final product contained about 50% 2-methylcyclohexanone which results from unreacted imine **16** and was determined as 80% in enantiomeric excess by GC analysis using a chiral column (astec, Chiraldex G-PN). The absolute configuration of **16** was determined as 2-(*R*) by comparison of [ $\alpha$ ]<sub>D</sub> value of the optically active 2-methylcyclohexanone with published data.<sup>ref 2</sup> By inference and NMR experiment (sections **XI-XIII**), the absolute configurations of **13-15** were determined.

#### **E. General Procedures of NMR spectroscopy experiment**

NMR experiments were carried out on Varian 300, VXR 400 or Varian 500 spectrometers.

**(1). Preparation of Samples for NMR Spectroscopy of Imine Lithiations.** A typical sample was prepared as follows: An NMR tube capped with a septum stopper was evacuated under full vacuum with heating and flushed with argon. Under argon, the NMR tube was charged with 0.66 mL solution of LDA (0.33 M) in THF- $d_8$  and cooled to  $-78\text{ }^\circ\text{C}$  by placing the sample in dry ice/acetone for 5 min. The imine substrate (neat oil, 0.04 mL, 0.21 mmol) was added slowly to the top and let flow down along the inside of the NMR tube, thus frozen. The tube was then sealed under partial vacuum. The tube was placed in a  $-92\text{ }^\circ\text{C}$  freezer for 10 minutes. The final mixing was achieved in the freezer to minimize undesired lithiation. The sample was then kept at  $-78\text{ }^\circ\text{C}$  until ready for spectroscopic experiment. The resulting solution contained 0.33 M LDA, 0.30 M imine. NMR samples of section **XXI**, **XXII** and **XXIII** were prepared by this method. For low temperature experiment, the NMR probe was precooled to desired temperature, e.g.  $-90\text{ }^\circ\text{C}$ .

**(2). Preparation of Samples of *Syn* Imine Isomers for NMR Spectroscopy.** Cyclohexanone imines (**2**, **3** or **4**) were allowed to be metalated by LDA/ THF- $d_8$  and alkylated by  $\text{CH}_3\text{I}$  in a Kimble vial as described above in **C(1)**. The final solution contained *syn*-imine (0.25 M), 1.1 eq di-*iso*-propylamine, 1.1 eq lithium iodide and trace amount of iodomethane. Under argon, the solution (0.7 mL) was charged quickly via syringe to a NMR tube pre-dried as described above in **E(1)** and precooled to  $-78\text{ }^\circ\text{C}$ . The NMR tube was sealed under partial vacuum and kept at  $-78\text{ }^\circ\text{C}$  until taken into spectrometer. Samples to characterize **9** (section **VIII**), **13/15** (section **XI**) and samples for *syn/anti* isomerization experiments ( for section **XIV** – **XVI**,  $^{13}\text{C}$ -iodomethane was used) were prepared by this method.

**References for LXXII:**

1. Ref 25 of text.
2. Ref 13 of text.
3. Ref 34 of text.