This paper (*Organometallics* **2016**, *35*, 943) outlines the catalytic activity of a ruthenium compound in transfer hydrogenation reactions. A variety of organic substrates were studied in this reaction, and the ruthenium compounds were generally quite effective catalysts.

1. In general terms, what is a transfer hydrogenation reaction and why is it worth studying?
2. Compounds 2 and 3 in Chart 1 are the primary compounds of interest in this study. They are both 18 electron species. Based on this information, classify compound 3 paying particular attention to how the IPr ligand is classified, determine the ligand bond number, the valence on ruthenium and the dn count for ruthenium.
3. Provide a structure of the N-heterocyclic carbene (NHC) ligand IPr. Describe the orbital interactions between the IPr ligand the ruthenium keeping in mind the way you classified the ligand in question 2. Similar NHC ligands are present in Crabtree’s catalyst and Albrecht’s catalyst shown in Chart 1. Those representations should help formulate your discussion.
4. Before discussing the various catalytic reactions performed in this paper, it makes sense to discuss the general mechanism proposed by the authors beginning on page 946 and seen in Figure 2. Is compound 3 the active catalyst in this system?
5. Consider the compound, [CpRu(IPr)(H)3], which is formed under the reaction conditions. Classify this compound, determine the electron count, the ligand bond number, the valence on ruthenium and the dn count for ruthenium.
6. The compound [CpRu(IPr)(H)3] undergoes a reaction before entering the catalytic cycle. This generates the 16 electron species [CpRu(IPr)H] where the box shown in figure 2 represents a vacant coordination site. This reaction allows us to say that [CpRu(IPr)(H)3] is the catalyst resting state (not actively involved in the catalytic cycle) and [CpRu(IPr)(H)] is the active catalyst (since it directly participates in the cycle). Classify [CpRu(IPr)H], determine the ligand bond number, the valence on ruthenium and the dn count for ruthenium. Using this information, identify the reaction taking place that results in the formation of [CpRu(IPr)H].
7. Identify the reactions labeled 1-5 in Figure 2. Step 3 is the most challenging and can best be thought of as two different reactions.
8. The catalytic reactions in this study often require the presence of a base, typically KOtBu. What role does the base serve in these reactions?
9. Figure 1 shows a plot of effective rate vs. the amount of iso-propanol present in the reaction mixture. The authors describe this as saturation behavior. What do they mean by this term?
10. Going back to the specific reactions in this study, the authors mention that some catalytic turnover is observed for the reactions in tables 1 and 2 at room temperature. What do the authors mean by this and what is the significance of this observation?
11. Write a mechanism similar to what is presented in Figure 2 for the transfer hydrogenation of acetophenone shown in Table 1.
12. The product for the reaction in Table 2 may seem a little odd when you first look at it. The nitrile does undergo transfer hydrogenation to yield a primary amine. Draw the structure of that primary amine. The primary amine is then converted to the imine by reacting with an organic molecule that is formed during the course of this reaction. Write this reaction for the conversion of the primary amine to the imine.
13. Suggest a reason why the transfer hydrogenation reaction of tBuCN (entry 8 in Table 3) is significantly less efficient than nBuCN (entry 11 in Table 3).
14. In Table 4, why is there such a difference in the yields and reaction times for the substrates in entries 1 and 4?
15. The products of the reactions in Table 4 are all amines, why do these reactions not form imines as seen in Table 2?
16. In Table 6, account for the differences in reactivity of the substrates in entries 1, 6 and 7.
17. In Table 6, the alkyne substrates (entries 9 and 10) do not undergo transfer hydrogentation. This is somewhat surprising as similar nitriles (Tables 2 and 3) do. Suggest a possible reason for this observation. Are there any substrates that you could suggest the authors examine to determine if alkynes can undergo transfer hydrogenation using this catalyst system?
18. Table 8 presents the transfer hydrogenation reaction of methyl acetate under a variety of conditions. Two different products can be observed, the Michael addition product in which the OMe group is replaced by a OiPr group from the iso-propanol and the hydrogenation product in which the same replacement happens but the alkene is also hydrogenated. For each entry in this table describe the conditions being used, the products and the overall significance of the particular entry with respect to the rest of the table.