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Catalytic Oxidative Deamination by Water with H_2 Liberation

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Cite This: J. Am. Chem. Soc. 2020, 142, 20875−20882

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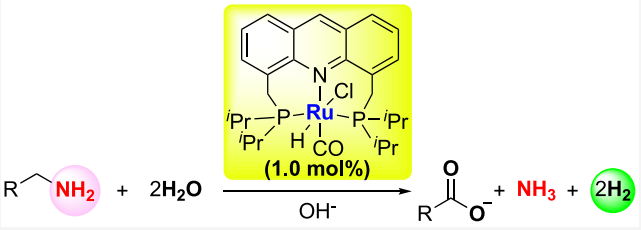
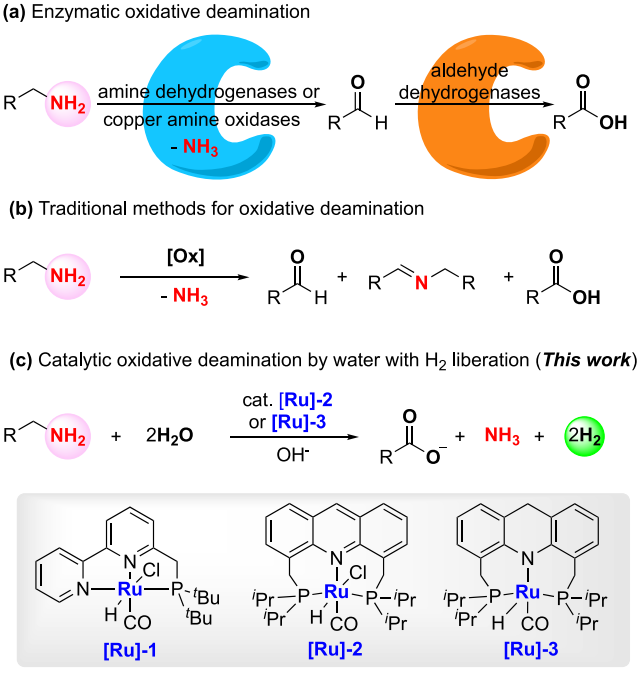
ABSTRACT: Selective oxidative deamination has long been considered to be an important but challenging transformation, although it is a common critical process in the metabolism of bioactive amino compounds. Most of the synthetic methods developed so far rely on the use of stoichiometric amounts of strong and toxic oxidants. Here we present a green and efficient method for oxidative deamination, using water as the oxidant, catalyzed by a ruthenium pincer complex. This unprecedented reaction protocol liberates hydrogen gas and avoids the use of sacrificial oxidants. A wide variety of primary amines are selectively transformed to carboxylates or ketones in good to high yields. It is noteworthy that mechanistic experiments and DFT calculations indicate that in addition to serving as the oxidant, water also plays an important role in assisting the hydrogen liberation steps involved in amine dehydrogenation.



INTRODUCTION

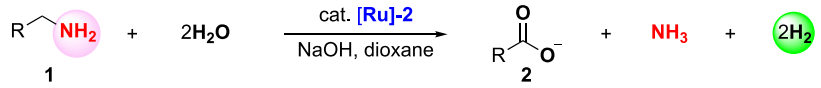
Amine functional groups are fundamental structural motifs in an abundance of biomolecules and pharmaceuticals.[1] Over the past few decades, great attention has been devoted to the synthesis of amines by the amination of alcohols or ketones.[2−12] However, the reverse reactions, consisting of the deamination of primary amines, have long been considered to be important but synthetically challenging transformations.[13−15] In contrast, the enzymatic oxidative deamination of primary amines is a very common metabolic process in living cells.[16−19] Generally, this process is catalyzed by amine dehydrogenases or copper amine oxidases, affording either aldehydes or ketones.[20−25] In the case of linear primary amines, the generated aldehydes are further oxidized to carboxylates in subsequent metabolic steps catalyzed by aldehyde dehydrogenases (Scheme 1a). Because of the importance of accessing new categories of carbonyl compounds from bioactive amino compounds, oxidative deamination has also received considerable attention by synthetic organic chemists. A notable example is the use of oxidative deamination in the synthesis of prostaglandin E1 by Corey and coworkers.[26] However, similar to other biocatalytic methods, a narrow substrate scope hinders the application of enzymatic oxidative deamination in organic synthesis.[27,28] At the same time, traditional synthetic methods for oxidative deamination usually require the use of strong, toxic chemical oxidants, such as permanganate or dichromate, to afford ketones or aldehydes.[29−32] Corey and co-workers described another reaction strategy, utilizing mesitylglyoxals as sacrificial reagents to promote the transformation of primary amines to ketones or aldehydes via the formation of Schiff bases.[33] More recently, a biomimetic oxidative deamination of benzylic amines was

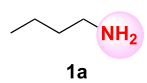
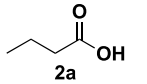
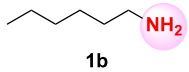
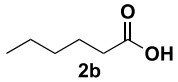
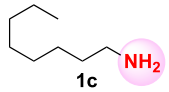
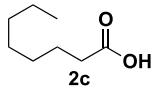
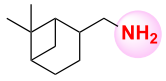
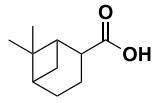
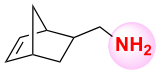
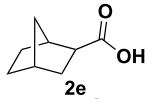
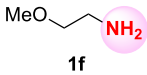
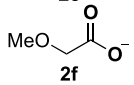
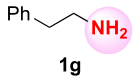
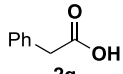
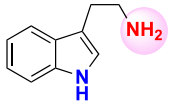
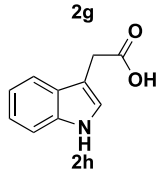
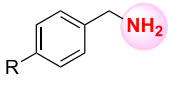
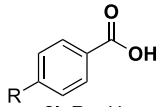
Scheme 1. Oxidative Deamination of Primary Amines

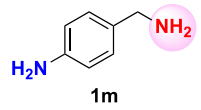
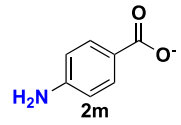
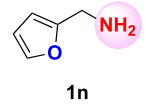
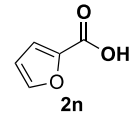
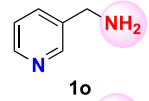
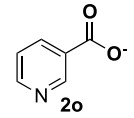
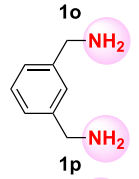
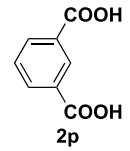
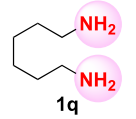
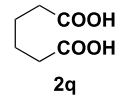
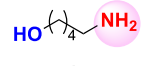
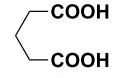
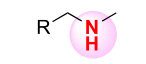
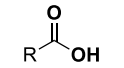
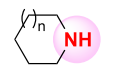
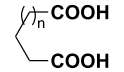


Received: October 13, 2020
Published: November 25, 2020

Table 1. Catalytic Oxidative Deamination of Linear Aliphatic Amines to Carboxylates by Water with H_2 Liberation[a,b,c,d]



entry	amine	product	yield (%)
1	 **1a**	 **2a**	95
2	 **1b**	 **2b**	86
3	 **1c**	 **2c**	98
4	 **1d**	 **2d**	71
5	 **1e**	 **2e**	65
6	 **1f**	 **2f**	>99[b]
7	 **1g**	 **2g**	98
8	 **1h**	 **2h**	75
			
9	**1i**, R = H	**2i**, R = H	98
10	**1j**, R = OMe	**2j**, R = OMe	95
11	**1k**, R = CF_3	**2k**, R = CF_3	87
12	**1l**, R = Cl	**2l**, R = Cl	93

entry	amine	product	yield (%)
13	 **1m**	 **2m**	98
14	 **1n**	 **2n**	81
15	 **1o**	 **2o**	89
16	 **1p**	 **2p**	99[c]
17	 **1q**	 **2q**	65[b,c]
18	 **1r**	 **2r**	52[b,c]
			
19	**1s**, R = ^{n}Pr	**2a**, R = ^{n}Pr	23%[b]
20	**1t**, R = Ph	**2i**, R = Ph	25%[b]
			
21	**1u**, n = 1	**2r**, n = 1	30%[b,d]
22	**1v**, n = 2	**2q**, n = 2	50%[b,d]

[a]General reaction conditions: amine (0.50 mmol), [**Ru**]-**2** (0.0050 mmol), NaOH (1.0 mmol), water (2.0 mL), and dioxane (2.0 mL) were heated in a closed system at 150 °C (silicon oil bath temperature, solvent reflux) for 48 h. Carboxylic acids were isolated after treatment of the carboxylates with dilute hydrochloric acid. Yields of carboxylates **2f**, **2m**, and **2o** were determined by ^{1}H NMR using pyridine as an internal standard. ^{1}H NMR signals of the following groups were used for quantification: methoxyl C−H of **2f**; aryl C−H of **2m** ortho to the carboxylate; aryl C−H of **2o** ortho to the nitrogen and para to the carboxylate. [b][**Ru**]-**2** (0.010 mmol) was used. [c]Amine (0.25 mmol) was used. [d]NaOH (1.5 mmol) was used.

reported, which employs an *ortho*-naphthoquinone as the catalyst under aerobic conditions.[34] Compared to the enzymatic processes, traditional synthetic methods for the oxidative deamination of linear primary amines usually suffer from poor selectivity, affording a mixture of aldehydes, imines, and carboxylic acids (Scheme 1b).[35,36] Until now, all reported methods required the use of sacrificial oxidants, which can be problematic in being intolerant toward other oxidizable functionalities and generating waste.[37−47]

Catalytic processes in organic synthesis using water as a formal oxidant, with concomitant H_2 liberation, are very rare and are among the most atom-economical and environmentally friendly approaches for the selective oxidation of organic compounds.[48−56] By utilizing ruthenium pincer complexes as dehydrogenation catalysts, our group has developed several catalytic oxidation reactions by water with the concomitant generation of hydrogen gas.[48−51] In 2016, we reported that a bipyridine-based PNN-Ru complex ([**Ru**]-**1**) catalyzed the oxidation of amino alcohols to amino carboxylates in alkaline water in the absence of any sacrificial oxidant.[49] Notably, the amine moiety of the amino alcohols was left untouched, even though no protecting group was used. In another study, we observed the deamination of primary aliphatic amines to alcohols by using an acridine-based PNP-Ru complex ([**Ru**]-**2**) as a catalyst.[57] To the best of our knowledge, the highly desirable selective oxidative deamination in the absence of added oxidant is unknown. Herein, we report a green and efficient method for catalytic oxidative deamination, employing complex [**Ru**]-**2** or [**Ru**]-**3** as a catalyst and using water as an oxidant with H_2 liberation

https://dx.doi.org/10.1021/jacs.0c10826
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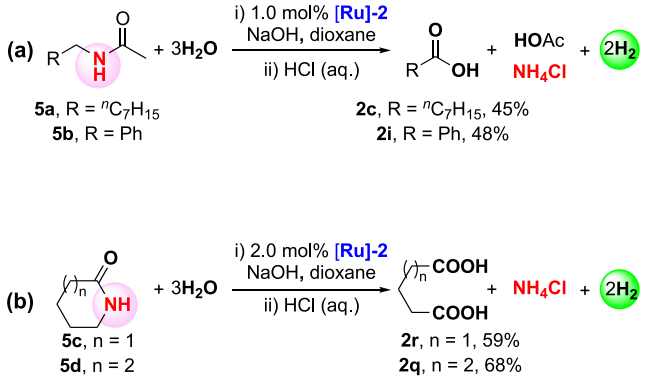
(Scheme 1c). This reaction system is applicable to the oxidative deamination of both aliphatic amines and amides with remarkable selectivity. A wide range of linear primary amines have been directly oxidized by water to carboxylates, providing the first selective method for achieving this transformation.[13,14] Notably, this reaction strategy avoids the use of any sacrificial oxidant. A mechanistic study of the catalytic system suggests that in addition to serving as the oxidant, water also plays an important role in facilitating hydrogen liberation along the reaction pathway.

RESULTS AND DISCUSSION

Catalytic Oxidative Deamination of Amines and Amides. The oxidative deamination of linear primary amines was first studied using complex [**Ru**]-**2** as the catalyst. An alkaline water/dioxane (1:1 volumetric ratio) solution of these amines, containing 1.0 mol % complex [**Ru**]-**2**, was heated in a sealed tube at 150 °C (oil bath temperature) for 48 h, affording the corresponding carboxylates in good to high yields (Table 1). For the representative *n*-butylamine (0.50 mmol), 24 mL of hydrogen gas was collected after cooling the reaction mixture to room temperature, amounting to a 98% yield (determined by GC; see Supporting Information, Figure S1, for details). Upon treating this reaction mixture with diluted hydrochloric acid, butyric acid was isolated in 95% yield (Table 1, entry 1) and NH_4Cl was detected by ^1H NMR (details in Supporting Information, Figure S2). Linear primary amines with longer chains also demonstrated high reactivity to give the corresponding carboxylic acids (Table 1, entries 2 and 3). Subjecting the bulky *cis*-myrtanylamine to the same reaction conditions afforded the acid in a moderate yield of 71% (Table 1, entry 4). The oxidative deamination of 5-norbornene-2-methylamine was accompanied by the hydrogenation of the carbon−carbon double bond, furnishing 5-norbornane-2-carboxylic acid in 65% yield (Table 1, entry 5). A slightly higher catalyst loading of 2.0 mol % was used for the oxidative deamination of 2-methoxyethylamine, affording 2-methoxyacetate quantitatively (Table 1, entry 6). Our catalytic system also demonstrated high selectivity and efficiency in the oxidative deamination of phenethylamine and tryptamine (Table 1, entries 7 and 8). It should be noted that when bulky primary amines were used as substrates for oxidative deamination (Table 1, entries 4, 5, and 8), the corresponding alcohols were the major byproducts. Activated primary amines also showed high reactivity in our catalytic oxidative deamination system. Notably, benzylamine was transformed to benzoic acid in 98% isolated yield (Table 1, entry 9). The yield of benzoic acid was not affected when a drop of mercury or 1.0 equiv of triethylamine was added to the reaction of benzylamine, excluding the involvement of metal nanoparticles in the catalytic oxidative deamination process. Benzylamines bearing electron-donating, electron-withdrawing, and halogen substituents at the para position all showed high reactivity in this transformation (Table 1, entries 10−13). Even an NH_2 substituent at the para position was well tolerated (Table 1, entry 13). 2-Aminomethylfuran and 3-aminomethylpyridine were also efficiently converted to the corresponding carboxylates (Table 1, entries 14 and 15). Isophthalic acid was obtained in quantitative yield in the oxidative deamination of 1,3-phenylenedimethanamine (Table 1, entry 16). A higher catalyst loading of 4.0 mol % was required to achieve good reaction efficiency in the transformation of an aliphatic diamine to its corresponding dicarboxylic acid (Table 1, entry 17). When 5-amino-1-pentanol was employed as the substrate, both the amino and hydroxyl groups were oxidized, furnishing glutaric acid in 52% yield after treatment with hydrochloric acid (Table 1, entry 18). Compared to primary amines, lower conversions were observed with secondary amines in the catalytic oxidative deamination, which may be due to increased steric hindrance during the amine dehydrogenation step. For example, low yields were observed in the oxidative deamination of *N*-methylbenzylamine and *N*-methylbutylamine, even with an increased catalyst loading (Table 1, entries 19 and 20). Formate was detected in the crude reaction mixture of *N*-methylbenzylamine by ^{13}C NMR analysis, which likely originated from the *N*-methyl group. In the case of cyclic amines, oxidative deamination led to the formation of dicarboxylic acids in slightly increased yields (Table 1, entries 21 and 22). Polyamides were found to be the major side products in the reaction of bifunctional amines or cyclic amines (Table 1, entries 17, 18, 21, and 22). Tertiary amines such as *N*,*N*-dimethylbenzylamine and tri-*n*-butylamine were also examined, but no reaction was observed.

It is well known that amides can undergo hydrolysis under strongly alkaline conditions to generate amines.[58] Since our oxidative deamination reactions were also performed under alkaline conditions, the possibility for the direct oxidative deamination of amides was explored. Under reaction conditions similar to those used with amines, the oxidative deamination of *N*-octylacetamide and *N*-benzylacetamide was indeed observed, affording octanoic and benzoic acid, respectively, in moderate yields (Scheme 2a). ^{13}C NMR analysis of the reaction mixture obtained for *N*-benzylacetamide indicated that the acetyl group was transformed to acetic acid. A control experiment, conducted with the reaction of *N*-benzylacetamide in the absence of the ruthenium catalyst, resulted in only 26% conversion, with a 23% yield of benzylamine. This observation suggests that the oxidative deamination of benzylamine assists in driving the base-promoted hydrolysis of *N*-benzylacetamide. Aside from *N*-alkyl acetamides, lactams also underwent oxidative deamination under similar reaction conditions. Using a higher catalyst loading (2.0 mol %), dicarboxylic acids were isolated in moderate to good yields (Scheme 2b). In all of the above transformations, hydrogen gas was detected by GC, and NH_4Cl was identified by ^1H NMR after treatment with hydrochloric acid.

Scheme 2. Catalytic Oxidative Deamination of Amides to Carboxylic Acids with H_2 Liberation



https://dx.doi.org/10.1021/jacs.0c10826
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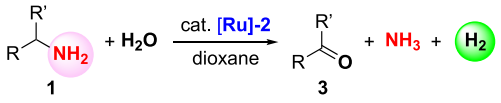
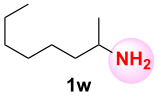
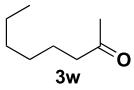
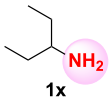
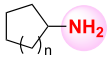
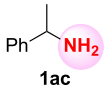
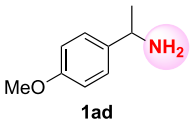
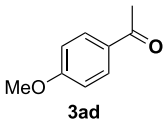
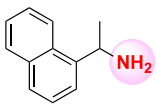
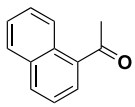
Whereas the oxidative deamination of linear aliphatic amines consistently produced carboxylates, branched primary amines afforded ketones. As shown in Table 2, good selectivity and

Table 2. Catalytic Oxidative Deamination of Branched Aliphatic Amines to Ketones by Water with H_2 Liberation[a,b]



entry	amine	product	yield (%)
1	 **1w**	 **3w**	94
2	 **1x**	 **3x**	74
			
3	**1y**, n = 1	**3y**, n = 1	84
4	**1z**, n = 2	**3z**, n = 2	81
5	**1aa**, n = 3	**3aa**, n = 3	90
6	**1ab**, n = 4	**3ab**, n = 4	79
7	 **1ac**	 **3ac**	86
8	 **1ad**	 **3ad**	98
9	 **1ae**	 **3ae**	59[b]

[a]General reaction conditions: amine (0.50 mmol), [**Ru**]-**2** (0.0050 mmol), water (0.50 mL), and dioxane (2.0 mL) were heated in a closed system at 150 °C (silicon oil bath temperature, solvent reflux) for 48 h. Yields were determined by GC using mesitylene as an internal standard. [b]Amine (0.25 mmol) was used.

efficiency were achieved by heating a neutral water/dioxane (1:4 volumetric ratio) solution of branched primary amines in the presence of 1.0 mol % complex [**Ru**]-**2**. An excellent yield of 94% was obtained for the oxidative deamination of 2-aminooctane (Table 2, entry 1), while the reaction of 3-aminopentane afforded 3-pentanone with a slightly decreased yield of 74% (Table 2, entry 2). Oxidative deamination of cycloalkylamines having different ring sizes afforded the corresponding cyclic ketones in good to high yields (Table 2, entries 3−6). Aside from aliphatic primary amines, α-methylbenzylamine and its analogues also demonstrated good to high reactivity toward the formation of their respective ketones (Table 2, entries 7−9). It is noteworthy that no imines were observed, and alcohols were observed as the only organic byproducts of the above-mentioned oxidative deamination reactions. Unfortunately, natural amino acids did not undergo this transformation, possibly because they act as bidentate ligands, thereby suppressing the catalytic activity of the acridine-based ruthenium pincer complex.

Mechanistic Investigation. According to previous studies by our group,[59,60] as well as by Hofmann et al.,[61] complex [**Ru**]-**2** undergoes reduction by alcohols or amines, under basic conditions, to generate catalytically active dearomatized complex [**Ru**]-**3**. As expected, the activity of complex [**Ru**]-**3** was quite similar to that of complex [**Ru**]-**2** in the oxidative deamination of amines to afford carboxylates in the presence of sodium hydroxide. To understand the role of base in this transformation, control experiments were carried out with benzylamine in the *absence* of base. Under these conditions, using complex [**Ru**]-**2** or [**Ru**]-**3** as a catalyst resulted in nonselective reactions, affording a mixture of benzyl alcohol, benzoic acid, and *N*-benzylidenebenzylamine. In both cases, benzyl alcohol was the major product, while dearomatized complex [**Ru**]-**3** gave a slightly higher yield of this alcohol (Scheme 3a). Notably, complex [**Ru**]-**3** also demonstrated excellent catalytic activity in the direct oxidation of benzyl alcohol to benzoate in the presence of sodium hydroxide (Scheme 3b). However, when the reaction was conducted in the absence of base, very low conversion was observed (Scheme 3b). It appears that the acid product suppresses the dehydrogenation of benzyl alcohol. Besides benzyl alcohol, the imine byproduct, *N*-benzylidenebenzylamine, also underwent efficient oxidative deamination catalyzed by complex [**Ru**]-**3** in alkaline water/dioxane (Scheme 3c). Since aldehydes are believed to be generated from the imine intermediates in aqueous solutions, the oxidation of benzaldehyde by water was also investigated (Scheme 3d). In the absence of the ruthenium catalyst, we observed the disproportionation of benzaldehyde to benzyl alcohol and benzoate, but with very low conversion. When complex [**Ru**]-**3** was used as the catalyst, full conversion of benzaldehyde to benzoate was observed, along with the evolution of hydrogen gas.

To gain further insights into the reactivity of complex [**Ru**]-**3**, its interactions with a representative substrate, benzylamine, as well as its respective oxidation products, were probed by stoichiometric experiments (Scheme 3e). Mixing [**Ru**]-**3** with 1.0 equiv of benzylamine in dioxane-d_8 at room temperature resulted in the immediate quantitative formation of the corresponding benzylamine complex, [**Ru**]-**4.** This complex exhibited a singlet at 76.39 ppm in the $^{31}P\{^1H\}$ NMR spectrum, which is shifted only slightly downfield from [**Ru**]-**3** (75.63 ppm). By contrast, the hydride ^1H NMR signal of complex [**Ru**]-**4**, a triplet at −15.02 ppm ($^2J_{PH}$ = 25.0 Hz), exhibits a significant downfield shift compared to that of [**Ru**]-**3** (−20.84 ppm) (details in the Supporting Information). Rapid amine coordination occurred even in the presence of 90 equiv of water in dioxane-d_8, demonstrating the preference of [**Ru**]-**3** for the coordination of the amine substrate over that of water. The three benzylamine oxidation products obtained catalytically in the absence of base (i.e., benzyl alcohol, benzoic acid, and *N*-benzylidenebenzylamine) were also examined stoichiometrically for their interactions with [**Ru**]-**3**. Benzyl alcohol and *N*-benzylidenebenzylamine showed no observable coordination to the metal center in dioxane-d_8, when mixed with the complex in equimolar amounts. Benzoic acid, on the other hand, reacted immediately with [**Ru**]-**3** at room temperature to give three distinct products. Upon heating the reaction mixture to 80 °C, all products converged into one, which was identified as benzoate complex [**Ru**]-**5**. X-ray-quality crystals of this complex were obtained from a saturated

https://dx.doi.org/10.1021/jacs.0c10826
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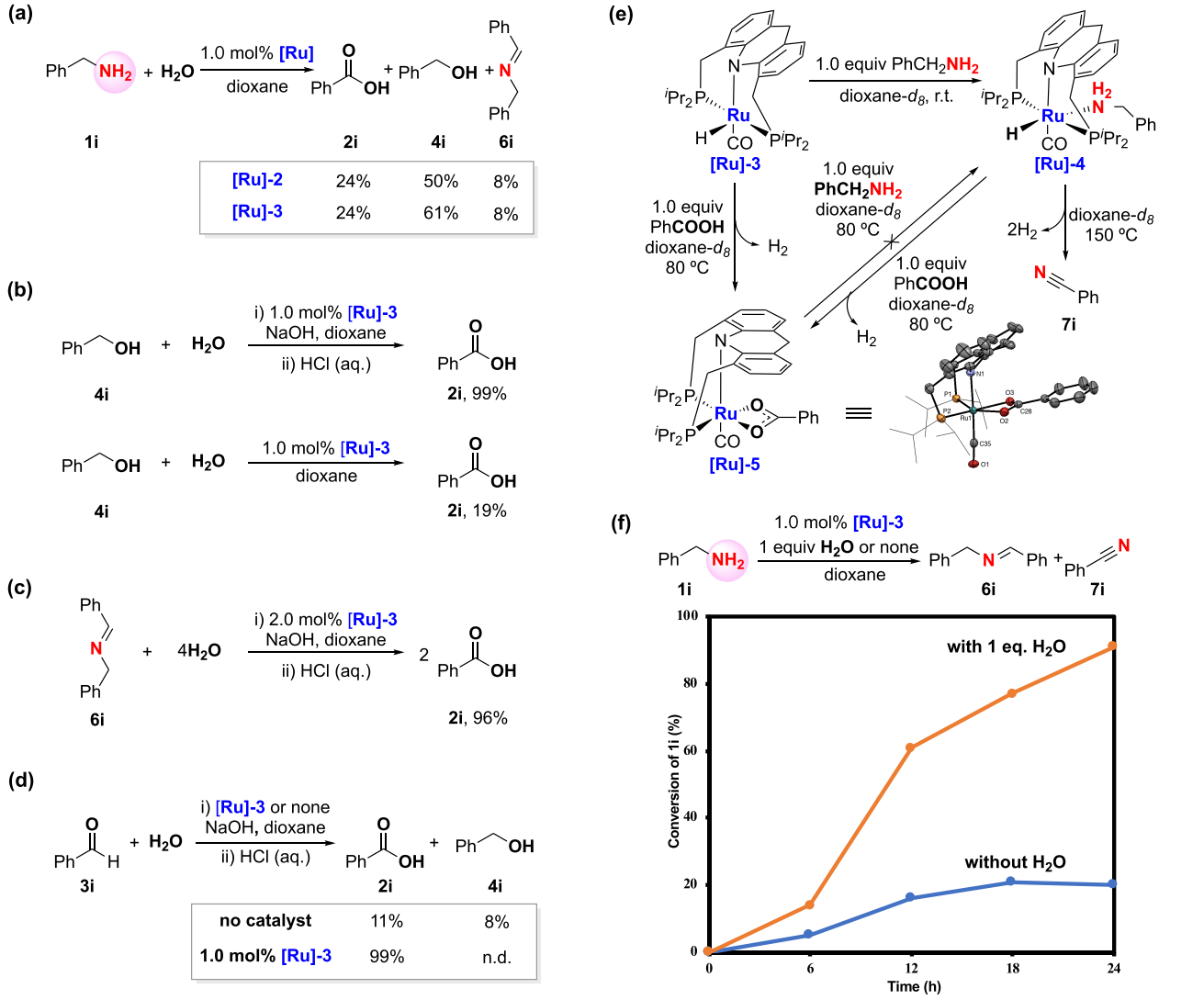
Scheme 3. Mechanistic Experiments



pentane solution at −30 °C (Scheme 3e; details in the Supporting Information, Figure S3). Significantly, treatment of benzylamine complex [**Ru**]-**4** with 1.0 equiv of benzoic acid in dioxane-d_8 quantitatively generated complex [**Ru**]-**5**, together with free benzylamine, after heating to 80 °C (Scheme 3e). This result indicates that amine coordination to complex [**Ru**]-**3** is reversible. By contrast, no reaction was observed when an equimolar mixture of complex [**Ru**]-**5** and benzylamine was subjected to the same reaction conditions (Scheme 3e). The formation of carboxylate complex [**Ru**]-**5** is likely to be an off-cycle process in the catalytic dehydrogenation of benzylamine. In addition, we examined direct coordination of benzoate to [**Ru**]-**3** by mixing this complex with 1.0 equiv of tetrabutylammonium benzoate in dioxane-d_8/D_2O (9:1), but no significant coordination was observed by ^1H and ^{31}P NMR spectroscopy. Furthermore, it was found that addition of strong bases like NaOH is essential for obtaining high yields of carboxylic acids in the catalytic oxidative deamination reactions (see Supporting Information, Table S1, for the effect of different bases on the conversion of benzylamine). It therefore appears that the role of base in our system is to neutralize the carboxylic acids as they are generated, thereby averting product inhibition as well as driving the reaction forward. In order to examine whether amine complex [**Ru**]-**4** is an active intermediate in the amine dehydrogenation process, we heated a dioxane solution of this complex in a closed system at 150 °C for 16 h. Interestingly, benzylamine was selectively converted to benzonitrile (Scheme 3e).

The effect of water on the catalytic dehydrogenation of benzylamine was then explored by using 1.0 mol % [**Ru**]-**3** in the absence and presence of water. When the reaction was performed in dry dioxane, only a 20% conversion of benzylamine was observed after 24 h at 150 °C, giving *N*-benzylidenebenzylamine and benzonitrile in 16 and 2% yields, respectively. By contrast, adding 1.0 equiv of water to the reaction mixture led to a much higher conversion of benzylamine, affording 83% *N*-benzylidenebenzylamine and 8% benzonitrile. As shown in Scheme 3f, the rate of amine dehydrogenation in the presence of 1.0 equiv of water was much faster than without water. These findings clearly demonstrate that without a large excess of water, the predominant reactions are amine dehydrogenation and its subsequent coupling, generating the corresponding imine and nitrile. Furthermore, water significantly enhances the rate of amine dehydrogenation, leading to high conversion.

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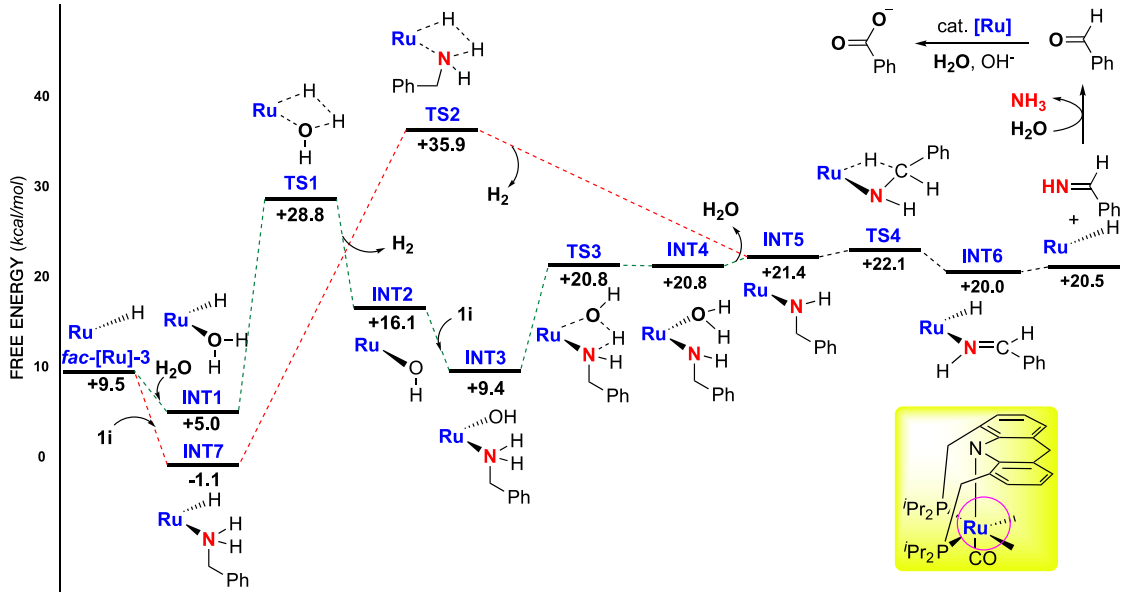

Figure 1. Free-energy pathways for benzylamine dehydrogenation to imine catalyzed by complex [**Ru**]-**3**. Green dashed line: Amine dehydrogenation with water participation. Red dashed line: Amine dehydrogenation without water participation. Free energies (kcal/mol) were calculated at 423.15K relative to *mer*-[**Ru**]-**3**, water, and benzylamine and are calculated in a 1:1 water/dioxane continuum (all solutes are 1 M except for H_2 and H_2O, which are at 1 atm and 27.75 M, respectively). Mass balance is ensured throughout. The CO and acridine-based ligands are omitted for clarity.

DFT calculations were carried out to elucidate the role of water in amine dehydrogenation catalyzed by complex [**Ru**]-**3**. In a previous mechanistic study, we reported the formation of lactams from cyclic amines and water utilizing the same catalyst, in which dehydrogenation to imine was proposed to occur via a Ru−OH intermediate generated from [**Ru**]-**3** and water rather than by the direct reaction of [**Ru**]-**3** with the amine.[59] Utilizing benzylamine as a model substrate, we sought to answer the same question to determine the source of the initial hydrogen elimination in the current system (Figure 1). As suggested in our former study,[59] the fac isomer of [**Ru**]-**3** (*fac*-[**Ru**]-**3**) is the active form of the dearomatized catalyst and is accessible from the more stable mer isomer (*mer*-[**Ru**]-**3**, treated as the reference energy point) under the catalytic conditions (water/dioxane at 150 °C). The computation indicates that amine coordination to the cis vacant site of *fac*-[**Ru**]-**3** (**INT7**) is more favorable than water coordination (**INT1**), which is in agreement with the experimentally observed trend above (Scheme 3e). However, the subsequent amine dehydrogenation via **TS2** has a higher energy barrier than a multistep process involving water, namely, dehydrogenation via **TS1**, followed by amine coordination and then dehydration via **TS3** to afford the ruthenium amido complex (**INT5**). These findings are in accordance with the higher acidity of water compared to that of amines. Thus, we propose that the source of H_2 in the reaction is the deprotonation of water rather than amine, which underscores another fundamental role of water in our catalytic process, namely, assistance with H_2 liberation. This is in line with our aforementioned experimental results depicted in Scheme 3f showing that the rate of benzylamine conversion increases dramatically in the presence of water. Our calculations also suggest that the activation energy for β-hydride elimination from the ruthenium amido complex (**TS4**) is lower than that of the hydrogen liberation steps, indicating that H_2 elimination is likely to be the rate-determining step in the amine dehydrogenation process. In the subsequent reaction steps, the generated imine undergoes facile hydrolysis to produce benzaldehyde and ammonia. Further reaction of benzaldehyde with water and base, catalyzed by the ruthenium catalyst, affords the benzoate.[56,62]

CONCLUSIONS

We have developed a new reaction, namely, the oxidative deamination of primary amines using water as the oxidant with concomitant hydrogen evolution. The reaction is catalyzed by an acridine-based ruthenium pincer complex. In contrast to the existing oxidative deamination methods, this reaction does not require added oxidants and does not generate waste. A wide variety of linear primary amines were selectively and efficiently transformed to carboxylates, and branched primary amines were transformed to ketones. Notably, this catalytic reaction is also applicable to the oxidative deamination of amides to produce carboxylates. Our mechanistic studies indicate that water, in addition to serving as the oxidant, also facilitates the hydrogen liberation steps.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/jacs.0c10826.

Experimental details of the synthesis procedures, NMR spectra, X-ray data, and computational details (PDF)

Crystallographic data for [**Ru**]-**5** (CIF)

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https://dx.doi.org/10.1021/jacs.0c10826
J. Am. Chem. Soc. 2020, 142, 20875−20882

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Author Contributions

[§]Michael Rauch and Michael Montag contributed equally.

Notes

The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS

This research was supported by the European Research Council (ERC AdG 692775). D.M. holds the Israel Matz Professorial Chair of Organic Chemistry. S.T. is thankful to the Israel Planning and Budgeting Committee (PBC) for a postdoctoral fellowship. M.R. acknowledges the Zuckerman STEM Leadership Program for a research fellowship.

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https://dx.doi.org/10.1021/jacs.0c10826
J. Am. Chem. Soc. 2020, 142, 20875−20882