



Lean NO_x Removal by a Bifunctional (EtOH + NH₃) Mixture Dedicated to (Ag/Al₂O₃ + NH₃-SCR) Dual-Bed Catalytic System: Comparison Between WO₃/CeZrO₂ and Cu-FER as NH₃-SCR Catalyst

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Lean NO_x removal by a bifunctional (EtOH+NH₃) mixture dedicated to (Ag/Al₂O₃+NH₃-SCR) dual-bed catalytic system. Comparison between WO₃/CeZrO₂ and Cu-FER as NH₃-SCR catalyst.

M. Barreau¹, M. Delporte¹, E. Iojoiu², X. Courtois^{1*}, F. Can^{1*}

¹IC2MP (UMR 7285), Université de Poitiers 4 rue Michel Brunet, 86073 Poitiers Cedex 9, France.

²Renault Trucks - Volvo Group Trucks Technology, 99 route de Lyon – 69806 Saint-Priest Cedex, France

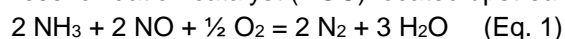
*xavier.courtois@univ-poitiers.fr *fabien.can@univ-poitiers.fr

Abstract: In a previous study, a drastic enhancement of the NO_x conversion in EtOH-SCR process was achieved by means of ammonia and ethanol co-feeding over Ag/Al₂O₃ catalyst to avoid the NO₂/NO_x ratio dependency of conventional implemented urea-SCR technology. The ammonia activation was mainly attributed to the availability of hydrogen H* species resulting from EtOH dehydrogenation, which promoted the H₂ assisted NH₃-SCR over Ag/Al₂O₃. Additional conversion gain was reached with a dual-bed configuration in which a NH₃-SCR catalyst (WO₃/Ce_xZr_{1-x}O₂) was added downstream to the silver-based sample (Ag/Al₂O₃ + NH₃-SCR catalyst). This study deals with the influence of the SCR catalyst formulation on the catalytic performances of the dual-bed system. Oxide-based sample (WO₃/Ce_xZr_{1-x}O₂) and exchanged copper zeolite (Cu_{2.5}-FER) were selected as model NH₃-SCR catalysts. Results shows that WO₃/Ce_xZr_{1-x}O₂ is more appropriate in dual-bed configuration for (EtOH+NH₃)-SCR process because ammonia and ethanol (or its by-products) strongly interacted together on Cu_{2.5}-FER.

Keywords: SCR, DeNO_x, Ag/Al₂O₃, ethanol, NH₃.

1. Introduction

NO_x reduction from Diesel and lean burn engines remains a major challenge at low temperature. Currently, NO_x conversion is achieved by the urea/NH₃ selective catalytic reduction (SCR) process, which is strongly dependent on the NO₂/NO_x ratio (Eq. 1: standard-SCR; Eq. 2: Fast-SCR), itself imposed by the Diesel oxidation catalyst (DOC) located upstream the SCR converter.



Unfortunately, the DOC activity also undergoes kinetic limitation at low temperature (175-250°C) and then penalizes the deNO_x efficiency of the SCR converter downstream.

EtOH-SCR process was also described as an attractive way to reduce NO_x over silver-based catalyst [1]. The NO conversion is assumed to be dependent on the nitromethane route formation, based on the ethanol oxidation to acetaldehyde *via* a large variety of adsorbed intermediates. N-containing compounds such as HNCO and NH₃ are also involved in the NO_x reduction mechanism [2]. Unfortunately, this system also suffers from limited activity at low temperature, although partial oxidation of ethanol leads to significant NO₂ emission in the 175-300°C temperature range [3].

In a recent work [4], it was reported that co-feeding of ethanol and ammonia over Ag/Al₂O₃ catalyst is a promising way to enhance the deNO_x efficiency at low temperature (175-250°C), while avoiding the NO₂ dependency. The (EtOH+NH₃)-SCR process avoids the rate-limiting step of nitromethane route formation encountered in the conventional EtOH-SCR mechanism, by three different pathways: the original EtOH-SCR, the NH₃-SCR process (poorly active, even if NO₂ is formed during EtOH-SCR) and more remarkably, by the H₂-assisted NH₃-SCR (H* species were provided by ethanol dehydrogenation into acetaldehyde) *via* the formation of HNO_x intermediate.

However, in this case, the outlet exhaust gas still contained some NH₃ and NO_x (including NO₂) in this low temperature range. Consequently, the DeNO_x efficiency at low temperature (175-300°C) was

supplementary improved by means of the addition of a dedicated NH_3 -SCR catalyst ($\text{WO}_3/\text{CeZrO}_2$) downstream the $\text{Ag}/\text{Al}_2\text{O}_3$ sample. This dual-bed configuration achieved NO_x conversions similar to that obtained in the most favorable fast SCR stoichiometry over $\text{WO}_3/\text{CeZrO}_2$ catalyst, while only NO was initially introduced, avoiding the DOC dependency. The choice of $\text{WO}_3/\text{CeZrO}_2$ as NH_3 -SCR catalyst was justified by the need to develop new generations of vanadium free NH_3 -SCR catalysts to avoid vanadia sublimation of usual $\text{V}_2\text{O}_5\text{-WO}_3\text{-TiO}_2$ materials [5,6]. Supported transition metal or ceria based oxides such as $\text{Fe}_2\text{O}_3/\text{WO}_3/\text{ZrO}_2$ [7], $\text{MnO}_x\text{-CeO}_2$ [8] also including $\text{WO}_3/\text{Ce}_x\text{Zr}_{1-x}\text{O}_2$ [9] were likewise proposed. However, iron or copper exchanged zeolite with small pore size to assure a suitable thermal stability, are usually implemented as SCR catalyst for automotive application [10], even if the deNO_x activity of these materials is also strongly dependant on the NO_2/NO_x .

This work aims to examine the influence of the NH_3 -SCR catalyst formulation on the deNO_x efficiency of the dual-bed system devoted to $(\text{EtOH}+\text{NH}_3)\text{-SCR}$ process. A copper exchanged ferrierite zeolite ($\text{Cu}_{2.5}\text{-FER}$) was associated to $\text{Ag}/\text{Al}_2\text{O}_3$ and results were compared with those previously obtained with $\text{WO}_3/\text{Ce}_x\text{Zr}_{1-x}\text{O}_2$ as SCR catalyst. Specific attention was paid to the reactivity of carbon and nitrogen compounds on the downstream $\text{WO}_3/\text{Ce}_x\text{Zr}_{1-x}\text{O}_2$ or Cu-FER sample.

2. Experimental part

2.1 Materials

$\text{Ag}/\text{Al}_2\text{O}_3$ (noted Ag/Al ; specific surface area: $160\text{ m}^2\text{ g}^{-1}$) and $\text{WO}_3/\text{Ce}_x\text{Zr}_{1-x}\text{O}_2$ (noted $\text{WO}_3/\text{Ce-Zr}$; specific surface area: $52\text{ m}^2\text{ g}^{-1}$) were the same than those used and detailed in [4]. For Ag/Al sample, silver (2.0 wt-%) was added on alumina (Axens) by impregnation of AgNO_3 dissolved in ethanol. After drying, the resulting powder was calcined under synthetic air with 10 % H_2O at 700°C for 4 h. XRD analyses collected using an Empyrean (PANalytical) diffractometer showed no visible reflection assigned to silver species (Ag^0 , Ag_2O , AgO , $\text{Ag}_2\text{Al}_2\text{O}_4\ldots$). H_2 -TPR experiment, performed on a Micromeritics Autochem 2920 after *in-situ* calcination at 450°C , showed a broad H_2 consumption peak, with a maximum at around 260°C . Hydrogen consumption indicated that 67 % of the deposited silver was in metallic state, according to results previously reported by Flura *et al* [11].

For $\text{WO}_3/\text{Ce-Zr}$ sample, tungsten (6.0 wt-% WO_3) was added on a ceria-zirconia support (40 wt-% of CeO_2 , provided by Solvay) by impregnation at 60°C using an aqueous solution of ammonium metatungstate. After drying, the same hydro-treatment that applied to Ag/Al was carried out (700°C , 4 h). No modification of the XRD pattern of the CeZr support was recorded after WO_3 impregnation, and no diffraction peaks attributable to WO_3 was observed, suggesting a good dispersion of tungsten trioxide on $\text{WO}_3/\text{Ce-Zr}$.

Copper exchanged zeolite sample was prepared from a ferrierite (FER) zeolite which exhibits a channel system of 10 and 8 member rings ($\text{SiO}_2/\text{Al}_2\text{O}_3 = 20$, provided by Alfa Aesar). Copper addition (2.5 wt-%, measured by ICP elemental analysis after preparation of the sample) was performed by the ion exchange at $\text{pH} = 5$ as reported in [12]. The resulting powder was finally hydro-treated at 600°C for 16 hours. The corresponding stabilized samples (denoted $\text{Cu}_{2.5}\text{-FER}$) exhibited a specific surface area of $252\text{ m}^2\text{ g}^{-1}$. No evolution of the ferrierite zeolite structure was observed by XRD analysis after copper exchange and the stabilization treatment. Moreover, CuO phase ($2\theta = 35.5^\circ$ and 38.7°) was not detected. H_2 -TPR profile of Cu-FER exhibited two main reductions peaks. The first one ($200\text{-}350^\circ\text{C}$) is attributed to the reduction of Cu^{2+} species to Cu^+ and the second one at higher temperature (950°C) corresponds to the reduction of the formed Cu^+ species into Cu^0 [13]. These both peaks must exhibit the same H_2 consumption. If present on the catalyst surface, the reduction of CuO species into metallic copper should be also observed in the $200\text{-}400^\circ\text{C}$ temperature range [13,14], while copper aluminate (CuAl_2O_4) reduction possibly occurs around 500°C [15]. H_2 -TPR profiles were deconvoluted and integrated to assess to the copper distribution: $\text{Cu}_{2.5}\text{-FER}$ exhibited more than 90% of copper as Cu^{2+} in exchanged position. No CuO was evidenced (in accordance with XRD results), only few percent of copper aluminate were deduced from the deconvolution of the TPR profile. This species may be formed because the zeolite sample exhibited traces of extra-framework aluminium (EFAL).

2.2 Catalytic tests

Catalytic test set up was previously described in [4]. Tests were performed in a quartz tubular micro-reactor under various realistic reaction mixtures depending on the implemented reductant(s): ethanol (EtOH), ammonia (NH₃), and a blend of both (EtOH+NH₃) (Table 1). The total flow rate was fixed at 333 mL min⁻¹ for 100 mg of powdered catalyst diluted in 100 mg SiC, both sieved between 100 µm and 250 µm, corresponding to a GHSV of 130 000 h⁻¹ toward the catalyst (200 L.h⁻¹.g_{cata}⁻¹; 100 L.h⁻¹.g_{powder}⁻¹). For the dual-bed configuration, 100 mg of NH₃-SCR sample (WO₃/Ce-Zr or Cu_{2.5}-FER) were placed downstream 100 mg of Ag/Al catalyst (no SiC was used for these experiments).

Gaseous NO/NO₂/NH₃/O₂/N₂ mixtures were adjusted by mass-flow controllers (Bronkhorst). For ethanol addition, an aqueous solution containing 8.02 10⁻¹ mol L⁻¹ ethanol was vaporized and mixed upstream the SCR catalyst *via* a micro-nozzle (The Lee Company, Ø_{nozzle}= 50 µm) connected to a HPLC pump (Jasco, PU-2085, 22 µL min⁻¹, ΔP=10 bar). The composition of the inlet and outlet gases were monitored using online MKS 2030 Multigas infrared analyser for NO, NO₂, N₂O, NH₃, CH₃CH₂OH, CH₃CHO, CH₃OH, CH₂O, C₂H₄, CH₄, CO, CO₂ and In fact, CH₃CHO is the main observed C_xH_yO_z-compounds from ethanol conversion and the records of the other C_xH_yO_z products are not presented in this study.

Table 1. Gas mixtures for the catalytic tests (total rate: 333 mL.min⁻¹).

Catalytic test	NO (ppm)	NO ₂ (ppm)	NH ₃ (ppm)	EtOH (ppm)	O ₂ (%)	CO ₂ (%)	H ₂ O (%)	N ₂
Standard-NH ₃ -SCR	400	-	400	-	10	10	8	balance
Fast-NH ₃ -SCR	200	200	400	-	10	10	8	
EtOH-SCR	400	-	-	1200	10	10	8	
(EtOH+NH ₃)-SCR	400	-	400	1200	10	10	8	
(EtOH+NH ₃)-SCO*		-	400	1200	10	10	8	

*oxidation test, referred as selective catalytic oxidation (SCO) experiment.

3. Results and discussion

3.1 Single NH₃-SCR catalyst behaviors: WO₃/Ce-Zr and Cu_{2.5}-FER

Both studied NH₃-SCR catalysts were firstly evaluated in standard and fast NH₃-SCR conditions. In standard-SCR condition (only NO as inlet NO_x, Figure 1A), the NO_x conversions recorded with WO₃/Ce-Zr (Δ) and Cu_{2.5}-FER (□) were very close, from approximately 10 % at 175°C and near to 90 % in the 300-450°C temperature range. At temperature higher than 450°C, the NO_x conversion decreased, which was attributed to a competition with the ammonia oxidation reaction, in agreement with previous reported work [9,12]. As expected, the NO_x conversion was considerably improved in fast-SCR condition for both catalysts (Figure 1B), pointing out the major interest to gain NO₂ at low temperature, whereas the usual DOC placed upstream the SCR system is then generally poorly active in NO oxidation. Interestingly, in “fast” SCR condition, Cu_{2.5}-FER sample exhibited significantly higher NO_x conversion rate at 175°C, at 88 % versus 53 % for WO₃/Ce-Zr. This is a promising behavior for a higher deNO_x efficiency at low temperature in the dual-bed configuration. For higher temperatures, both catalysts exhibited high NO_x conversions. However, for both fast and standard SCR conditions, WO₃/Ce-Zr catalyst presented higher maximum NO_x conversion rates in the 250-450°C temperature range, while the NH₃ conversions were close to 100 % for both catalysts.

Both single NH₃-SCR catalysts were also evaluated in EtOH-SCR and (EtOH+NH₃)-SCR conditions (Figure 2). In EtOH-SCR condition (Figure 2A), the WO₃/Ce-Zr sample exhibited 12 % ethanol conversion at 175°C and the full conversion was recorded from 350°C. However, the NO_x conversion was very limited, with a maximum of only 7 % at 300°C (Table 2). It results that WO₃/Ce-Zr catalyst is not efficient to reduce NO_x by ethanol. Compared with WO₃/Ce-Zr sample, higher activity in ethanol conversion was recorded for Cu_{2.5}-FER catalyst, with 100 % ethanol conversion since 250°C. The maximum NO_x conversion was also improved, but remained moderate with a maximum of 20 % at

450°C. Concomitantly, acetaldehyde outlet concentration reached a maximum of 160 ppm at 250°C for WO₃/Ce-Zr and 120 ppm at 200°C for Cu_{2.5}-FER sample (Figure 2A).

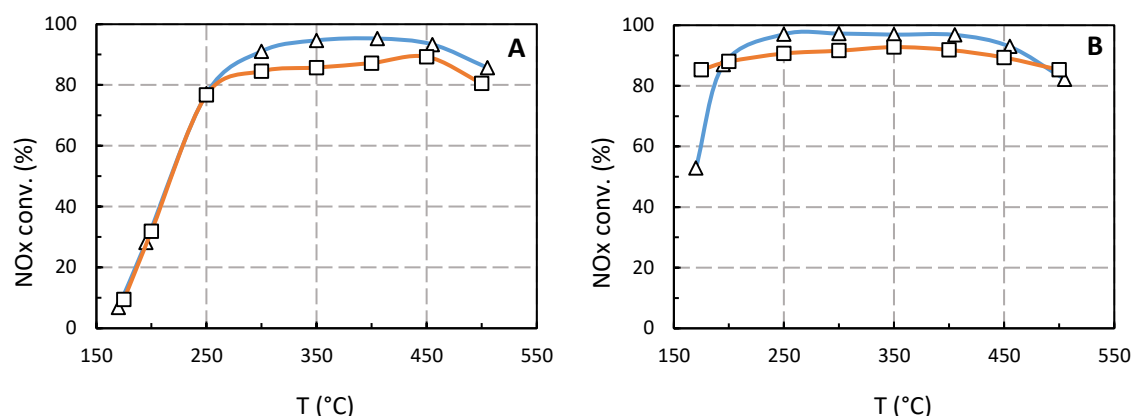


Figure 1. NO_x conversion in NH₃-SCR over WO₃/Ce-Zr (Δ) and Cu_{2.5}-FER (□) catalysts for standard NH₃-SCR (A) and fast NH₃-SCR condition. Reaction mixtures are depicted in Table 1.

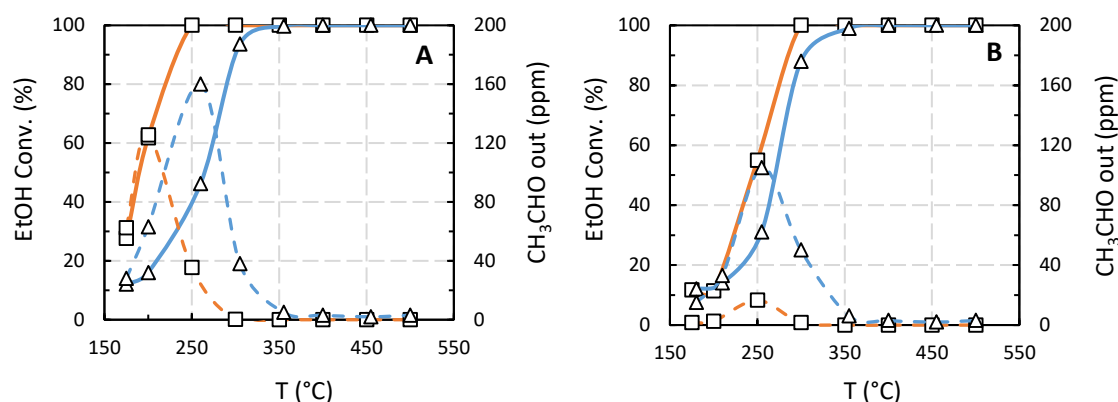


Figure 2. EtOH conversion (full line) and CH₃CHO emissions (dotted line) over WO₃/Ce-Zr (Δ) and Cu_{2.5}-FER (□) catalysts for EtOH-SCR (A) and (EtOH+NH₃)-SCR condition. Reaction mixtures are depicted in Table 1.

Table 2. NO_x conversion and NH₃/NO_x outlet ratio over WO₃/Ce-Zr or Cu_{2.5}-FER catalysts for EtOH-SCR and (EtOH+NH₃)-SCR experiments.

T (°C)	WO ₃ /Ce-Zr			Cu _{2.5} -FER		
	EtOH-SCR NO _x Conv. (%)	(EtOH+NH ₃)-SCR		EtOH-SCR NO _x Conv. (%)	(EtOH+NH ₃)-SCR	
		NO _x Conv. (%)	NH ₃ /NO _x out		NO _x Conv. (%)	NH ₃ /NO _x out
175	1	13	1.0	4	12	0.9
200	0	24	1.0	3	21	0.8
250	3	38	1.0	3	53	0.3
300	7	60	0.8	3	69	0.1
350	4	71	0.2	6	79	0.1
400	2	71	0.1	13	82	0.1
450	0	70	0.1	20	84	0.1
500	1	64	0.1	16	73	0.0

With NH₃ co-injection ((EtOH+NH₃)-SCR experiments, Figure 2B), ethanol conversion decreased for both catalysts together with lower acetaldehyde emissions compared to EtOH-SCR experiments. However, the impact of NH₃ co-feeding was significantly more pronounced over Cu_{2.5}-FER sample. The temperature for 50 % EtOH conversion increased from approximately 263°C to 268°C for WO₃/Ce-Zr, and from 188°C to 245°C for Cu_{2.5}-FER. As expected, the presence of ammonia in the reaction gas mixture also caused an increase of the NO_x conversion (Table 2). Nevertheless, it remained lower than the activity measured in standard NH₃-SCR (Figure 1). For instance at 250°C, the NO_x conversion reached 77 % in standard NH₃-SCR for both catalysts, while only 38 % and 53 % was obtained in (EtOH+NH₃)-SCR condition with WO₃/Ce-Z and Cu_{2.5}-FER, respectively. In addition, the NH₃/NO_x outlet ratio reported in Table 2 clearly illustrates an over ammonia consumption for Cu_{2.5}-FER catalyst even at low temperature (T<300°C).

Globally, these results suggest a competitive adsorption of ethanol (or these by-products) with NH₃ for both catalysts. However, compared with WO₃/Ce-Zr, the exchanged copper-based catalyst presented both stronger interactions between both reductants on the Cu²⁺ active sites and a higher ammonia conversion ability in presence of ethanol.

3.2 Dual-bed system: (Ag/Al+ WO₃/Ce-Zr) vs. (Ag/Al+Cu_{2.5}-FER)

Results obtained with Ag/Al (100 mg) and with the two dual-bed configuration depending on the implemented NH₃-SCR catalyst (100 mg of WO₃/Ce-Zr or Cu_{2.5}-FER placed downstream) are compared in Figure 3 for both EtOH-SCR (1) and (EtOH+NH₃)-SCR (2) conditions. Results are compared in terms of ethanol and NO_x conversion (Figure 3 A and B), and NH₃, NO₂ and acetaldehyde outlet concentrations (Figure 3 C, D, E, respectively).

3.2.1 EtOH-SCR condition

In EtOH-SCR condition, whatever the NH₃-SCR catalyst formulation, the ethanol conversion (Figure 3-A1) was enhanced over the dual bed system compared with single Ag/Al catalyst. The combination with Cu_{2.5}-FER (□) clearly led to the largest improvement. For instance, the ethanol conversion at 200°C was increased from 34 % over single Ag/Al (○) to 60 and 72 % for Ag/Al+WO₃/Ce-Zr (△) and Ag/Al+Cu_{2.5}-FER (□), respectively. This result highlighted the higher reactivity of ethanol over the Cu_{2.5}-FER sample. Interestingly, the corresponding CH₃CHO emission (Figure 3-E1) was lower over the dual bed system with WO₃/Ce-Zr than on single Ag/Al sample, suggesting a specific reactivity of acetaldehyde over the SCR catalyst. Note that the higher CH₃CHO emission at 200°C over Cu_{2.5}-FER is correlated to the gain in ethanol conversion.

The addition of a SCR catalyst downstream Ag/Al led to a limited NO_x conversion improvement (Figure 3 B1) despite the full conversion of the emitted NO₂ from the Ag/Al catalyst in the 150-300°C temperature range (Figure 3-D1). The NO₂ consumption was not consistent with the increase of DeNO_x efficiency and, unfortunately, the Cu_{2.5}-FER sample did not present an optimal use of the available NO₂. In fact, higher NO outlet concentration was observed over dual-bed system whatever the NH₃-SCR formulation compared to single Ag/Al sample (results not shown) which suggests a specific reactivity of NO₂ with EtOH by-products to produce NO, in accordance to acetaldehyde yield presented in Figure 3-E1.

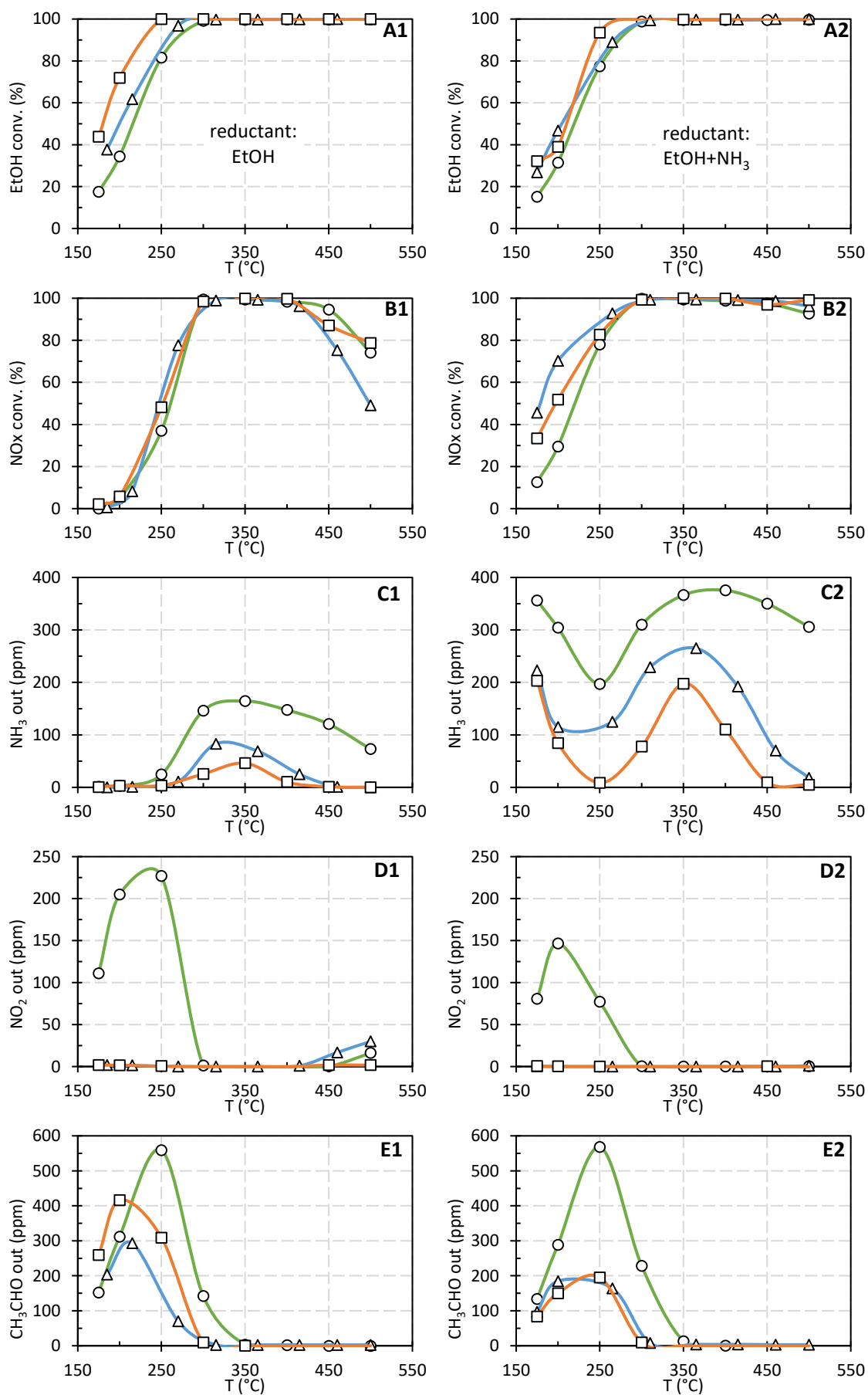
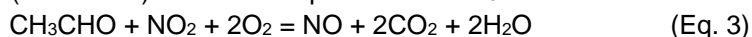


Figure 3. Comparison of Ag/Al (○) and dual-bed Ag/Al+WO₃/Ce-Zr (△) or Ag/Al+Cu_{2.5}-FER (□) system for EtOH-SCR (1) and (EtOH+NH₃)-SCR (2) condition.

Complementary tests were performed using acetaldehyde instead of ethanol as reductant. The activities in fast-SCR conditions ($\text{NO}_2/\text{NO}_x = 0.5$) and in CH_3CHO oxidation by O_2 (without NO_x) were investigated. Results (not shown) would correspond to the CH_3CHO - NO_2 stoichiometry of Eq. 3:



Note that ammonia emitted from Ag/Al was also partially converted after addition of a SCR catalyst, with a higher activity over $\text{Cu}_{2.5}$ -FER. However, this conversion mostly occurred in a temperature range for which the NO_x conversion was already completed over Ag/Al.

3.2.2 (EtOH+ NH_3)-SCR condition

When NH_3 was additionally injected with ethanol in the inlet gas mixture, similar ethanol conversions were observed over Ag/Al+ WO_3 /Ce-Zr, combination, compared to the EtOH-SCR condition (Figure 3-A2 vs. Figure 3-A1). To the opposite, the association of Ag/Al+ $\text{Cu}_{2.5}$ -FER led to a decrease in EtOH conversion in the 175-300°C temperature range, probably associated to a strong competition between ethanol and ammonia since NH_3 is highly converted on $\text{Cu}_{2.5}$ -FER in this temperature range (Figure 3-C2). This assumption is consistent with results obtained when the catalytic tests were performed over the single $\text{Cu}_{2.5}$ -FER sample (Table 2). Co-injection of (EtOH+ NH_3) also led to a lower CH_3CHO outlet concentration (Figure 3-E2) than that observed in EtOH-SCR condition, suggesting again a competitive reactivity of acetaldehyde with co-fed ammonia over NH_3 -SCR sample. Acetaldehyde may be either consumed to reduce NO_x or oxidized over WO_3 /Ce-Zr and $\text{Cu}_{2.5}$ -FER. Nevertheless, the single WO_3 /Ce-Zr and $\text{Cu}_{2.5}$ -FER catalysts presented a poor activity for NO_x reduction in EtOH-SCR experiments (maximum NO_x conversion lower than 20 %, Table 2), that tends to validate the oxidation route of CH_3CHO by NO_2 , as previously proposed (Eq. 3).

Figure 3-B2 recalls that a remarkable de NO_x activity was reached at low temperature with the co-injection of ethanol and NH_3 using the (Ag/Al+ WO_3 /Ce-Zr) dual bed configuration (Δ symbols). The NO_x conversion was then ranked between 46 and 95 % in the 175-250°C temperature range, close to the activity observed in the most favourable fast-SCR stoichiometry, while only NO was initially injected. Unfortunately, addition of $\text{Cu}_{2.5}$ -FER downstream Ag/Al sample did not allow the expected improvement in the de NO_x efficiency, which remained lower than that observed with WO_3 /Ce-Zr. The obtained NO_x conversion reached only 33 % and 52 % at 175°C and 200°C, respectively. The gain in NO_x conversion appeared then not directly correlated with the NH_3 consumption. Finally, it appears that $\text{Cu}_{2.5}$ -FER zeolite-based catalyst (i) was highly reactive towards oxygenated hydrocarbon compounds (ethanol and its by-products) and (ii) exhibited interaction between ethanol (and its by-products) and NH_3 , which inhibited the expected NO- NO_2 - NH_3 reactivity to improve the de NO_x efficiency. To highlight this interactions, supplementary tests were performed over $\text{Cu}_{2.5}$ /FER without NO_x in the feed stream

3.2.3 EtOH(+ NH_3)-SCO condition

The ammonia and ethanol conversions recorded in oxidation conditions (referred as SCO tests in Table 1) are plotted in Figure 4. Firstly, with a blend of EtOH+ NH_3 (full line), the ammonia conversion exhibited a maximum near 300°C, then decreased before rose again when ethanol conversion reached 100 %. This behavior clearly indicates that both reductants competed on similar active sites. This assumption is also supported by the fact that the ethanol conversion was dramatically affected at low temperature when ethanol was mixed with ammonia. On the contrary, the ammonia conversion was strongly favored on $\text{Cu}_{2.5}$ -FER when NH_3 was mixed with ethanol, in accordance with results previously reported in Figure 3-C2. A direct reaction between ammonia and ethanol (or its by-products) is then suspected. This point have to be investigated to potentially observe amination/imination reactions such as $\text{C}_2\text{H}_5\text{OH} + \text{NH}_3 = \text{CH}_3\text{CH}_2\text{NH}_2 + \text{H}_2\text{O}$ or $\text{CH}_3\text{CHO} + \text{NH}_3 = \text{CH}_3\text{CHNH} + \text{H}_2\text{O}$.

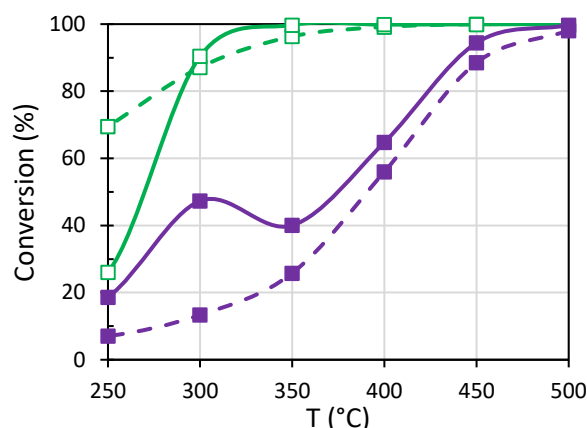


Figure 4. Oxidation tests (400 ppm NO and/or 1200 ppm EtOH, 10 % O₂, 10 % CO₂, 8 % H₂O) over Cu_{2.5}-FER sample. Ethanol (□) and ammonia (■) conversion depending on the considered mixture: single reductant mixture (dotted lines) or with a mix of them (full lines).

4. Conclusion

This aim of this work was to compare two SCR catalysts formulation in the dual-bed system devoted to the (EtOH+NH₃)-SCR process working with only NO as introduced NO_x. Compared with WO₃/CeZrO₂, the studied Cu_{2.5}-FER catalyst exhibited similar standard-SCR behaviour but promising higher fast-SCR activity at low temperature. Unfortunately, in the dual-bed system, the Cu_{2.5}-FER sample led to a lower deNO_x efficiency than WO₃/CeZrO₂, despite a significantly higher ammonia conversion rate. Results showed that ammonia and ethanol strongly interacted together on Cu_{2.5}-FER. Possible products formation from amination/imination reactions have to be investigated.

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