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ST ANDREWS, SCOTLAND

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INTERNATIONAL CONFERENCE ON SUSTAINABLE CHEMISTRY FOR NET ZERO

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PROGRAMME

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Exhibitors

Advanced Catalytic Strategies for CO_2 Valorization: Bimetallic Nanoparticles and SCILL Systems Enabled by Ionic Liquids

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Background and Objectives

The catalytic conversion of CO_2 into value-added chemicals such as light olefins and methanol is a pivotal step toward net-zero emissions and sustainable fuel cycles. Ionic liquids (ILs), due to their unique chemical and thermal properties, offer versatile functionalities in catalysis—as synthetic media for nanoparticle preparation or as active components in structured systems. This work explores two complementary applications of ILs in CO_2 hydrogenation: **(i)** IL-assisted synthesis of Fe–Ru bimetallic catalysts for olefin production, and **(ii)** Solid Catalyst with Ionic Liquid Layer (SCILL) systems for methanol synthesis.

Fe–Ru Catalysts: Synthesis and Performance

Fe–Ru bimetallic nanoparticles were synthesized using both a conventional colloidal method (COL) and an ionic liquid route (IL), employing [BmIm][BF_4] and [BmIm][PF_6] as solvents. Nanocatalysts with a 3:1 Fe:Ru molar ratio (1 wt.% total metal loading) were supported on γ-Al_2O_3 and characterized via XRD, XRF, SEM, and H_2 chemisorption.

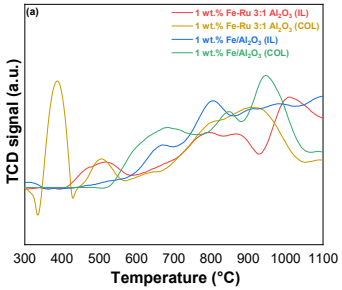

Figure 1. *H_2-TPR profiles of catalysts 1 wt% Fe-Ru 3:1/Al2O3 (COL and (IL)).*

Temperature-programmed reduction (TPR) profiles (**Figure 1**) revealed two main reduction steps: one around 380°C (Fe_2O_3 → Fe_3O_4) and another near 620°C (further reduction to FeO and Fe⁰). In the IL-derived catalyst, a stronger high-temperature peak at ~500°C indicates enhanced Ru–Fe interaction and hydrogen spillover, confirming a more intimate bimetallic phase.

Activity tests (593 K, 6–20 bar) with low CO_2 conversion (<5%) showed that the COL catalyst was more selective toward CO, while the IL catalyst favored CH_4 and C_2–C_5 hydrocarbons (**Figure 2**). This selectivity shift was more pronounced at higher metal loading (4 wt.%), demonstrating the effect of synthesis strategy on product distribution.

SCILL Catalysts for Methanol Synthesis

Separately, SCILL systems were developed by coating a commercial Cu/ZnO/Al_2O_3 (CZA) catalyst with thermally robust ILs ([PPh_4][$C_4F_9SO_3$], [PPh_4][NTf_2]) identified through isothermal and dynamic TGA. Kinetic degradation analysis (Table 1) revealed [PPh_4][NTf_2] had the highest activation energy (182.2 kJ/mol) and minimal mass loss under inert conditions (0.04% at 295°C after 10 h).

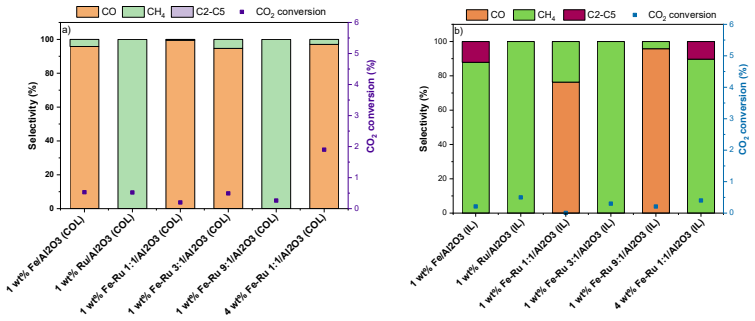

Figure 2. *Hydrocarbon selectivity, CO_2 conversion at 20 bar (3:1 H_2:CO_2, 523 K, 45 mL/min)*[i]

Table 1. *Results from Arrhenius plots and errors calculated through validation of the kinetic model*

IL	Activation Energy [kJ/mol]	Pre-exponential factor [h^{-1}]	R^2	Validation T [°C]	Mass error after 10 h [%]
[PPh_4][$C_4F_9SO_3$]	139.9	$2.38 \cdot 10^{12}$	0.9903	273	0.64
[PPh_4][NTf_2]	182.2	$4.98 \cdot 10^{15}$	0.9922	295	0.04

However, stability decreased under reactive CO_2/H_2/H_2O atmospheres. To counteract this, ILs were doped with Li[NTf_2], improving their resilience and retaining CO_2 absorption capacity under reaction conditions (250°C, 20 bar, CO_2:H_2 = 1:3). Catalytic tests (Table 2) showed that [PPh_4][$C_4F_9SO_3$]/Li[NTf_2] achieved 25% CO_2 conversion, outperforming both the undoped CZA (10%) and [PPh_4][NTf_2]/Li[NTf_2] (3.4%). However, this higher activity correlated with reduced methanol selectivity and increased CO production (up to 99.8%). Post-reaction NMR analysis revealed partial degradation of the phenyl group in [PPh_4][NTf_2], explaining the observed shift in selectivity.

Table 2. Results of catalytic testing at 250°C and 20 bar, CO_2/H_2 1:3.

	X CO_2 (%)	Selectivity (%)				
		CH_4	Acetone	DME	CH_3OH	CO
CZA	10.0	0	1.61	8.86	21.9	67.62
[PPh_4][$C_4F_9SO_3$] doped Li[NTf_2]	25.0	0	0	0.15	0.03	99.83
[PPh_4][NTf_2] doped Li[NTf_2]	3.4	0.05	0	1	2.88	96.06

Conclusion

This study illustrates two distinct IL-enabled strategies for advancing CO_2 hydrogenation. IL-mediated synthesis of Fe–Ru bimetallics enables fine control over metal interactions and phase proximity, improving reducibility and shifting selectivity toward valuable light hydrocarbons. Conversely, SCILL systems enhance CO_2 activation and catalyst stability under harsh conditions, though product selectivity remains sensitive to IL composition and degradation. Together, these findings underscore the dual functional potential of ILs as synthetic tools and active catalytic components for next-generation CO_2 conversion technologies.

References

1 A. Aitbekova, E. D. Goodman, L. Wu, A. Boubnov, A. S. Hoffman, A. Genc, H. Cheng, L. Casalena, S. R. Bare and M. Cargnello, Angew. Chemie - Int. Ed., 2019, 58, 17451–17457.

2 J. Krämer, E. Redel, R. Thomann and C. Janiak, Organometallics, 2008, 27, 1976–1978.

3 P. Gabrielli, M. Gazzani and M. Mazzotti, Ind. Eng. Chem. Res., 2020, 59, 7033–7045.

4 M. Scheuermeyer, M. Kusche, F. Agel, P. Schreiber, F. Maier, H. P. Steinrück, J. H. Davis, F. Heym, A. Jess and P. Wasserscheid, New J. Chem., 2016, 40, 7157–7161.

Thursday, 12th June - Continued

	PARALLEL SESSION A SUSTAINABILITY & CIRCULARITY		PARALLEL SESSION B DEVELOPMENT OF SUSTAINABLE SYNTHETIC PROCESSES	
	Venue: Physics Lecture Theatre A		Venue: Physics Lecture Theatre C	
	Chair: Alan Watson		Chair: Cristina Pozo	
Time	**Presenter**	**Presentation**	**Presenter**	**Presentation**
	SESSION PLENARY (SP9)		**SESSION PLENARY (SP10)**	
1150 - 1220	Haritz Sardon	Self-blowing sustainable foams	Nancy Artoli	Advanced catalytic strategies for CO_2 valorisation: bimetallic nanoparticles and SCILL systems enabled by ionic liquids
1220-1240	Jason Love	Supramolecular capsules for rare-earth separation and recycling	Liam Donnelly	Catalytic methods for selective carbonyl deoxygenation
	SESSION PLENARY (SP11)		**SESSION PLENARY (SP12)**	
1240 - 1310	Chris Slootweg	Smarter chemistry: green, circular and safe by design	Erwin Reisner	Solar chemical technologies

1310 - 1430	**LUNCH**	**Agnes Blackadder Hall**

	Chair: Cathy Dwyer		Chair: Jennifer Garden	
Time	**Presenter**	**Presentation**	**Presenter**	**Presentation**
	SESSION PLENARY (SP13)		**SESSION PLENARY (SP14)**	
1430 - 1500	Thoa Thi Minh Nguyen	Driving towards net-zero: the power of catalysis	Anthony O'Mullane	Catalysing green electrochemical processes using liquid metals
1500 - 1520	Sandy Kilpatrick	Bio-Inspired bimetallics: synthesis, structure and sustainable catalysis	Greg Mutch	Removing carbon dioxide from the air using a humidity-driven membrane
	SESSION PLENARY (SP15)		**SESSION PLENARY (SP16)**	
1520- 1550	Benjamin Kuhne	Industry perspective on net-zero challenges in pharma / specialty chemistry	Ina Vollmer	Mechano-catalytic depolymerisation of polyolefins