Catalysis in Mexico

This document briefly presents the history of the catalysis field in Mexico, from early collaboration to attempts to organize the Mexican Catalysis Academia. Today, we have a great community of more than 200 members working in several universities and research centers nationwide.

Background

The catalyst research efforts in Mexico began in the 1960s, focusing mainly on petroleum and petrochemical applications. The Mexican Institute of Petroleum (IMP), acting on behalf of *Petróleos Mexicanos* (PEMEX), spearheaded these initiatives. During the period from 1967 to 1974, members of the catalysis group at IMP were among the pioneering Mexican researchers who pursued doctoral studies abroad. In the 1970s, academic research groups in catalysis began to emerge. The first appeared in 1970 at the Chemistry department of the National Autonomous University of Mexico (UNAM), followed by establishing similar groups at the Metropolitan Autonomous University (UAM) in 1974. The National Polytechnic Institute (IPN) recorded its first catalysis research activities in 1981. Initially, most of these groups were concentrated in Mexico City. However, today, catalysis research groups with varying degrees of consolidation have proliferated across the country.

The Mexican Catalysis Academy

The Mexican Catalysis Academy (ACAT) was established in 1988 with the aim of advancing and disseminating knowledge on catalysis activities in Mexico, encompassing research, education, and applications. ACAT's research groups are distributed across the country, leading to the organization of regional sections. Each region is represented by a delegate elected through voting. The ACAT regions include Baja, North, West, Central, Bajio, Southeastern, and two recently formed regions: the National Students and Zeolites and Mesoporous Materials regions, as seen in Figure 1. ACAT's membership comprises professors, researchers, and students, some of whom serve on the Executive Committee and as Representatives for their respective geographical regions. The ACAT members work in several universities and research centers across the country. Table 1 contains some academic units with members working in the catalysis field.

ACADEMIA DE CATÁLISIS A.C. MÉXICO

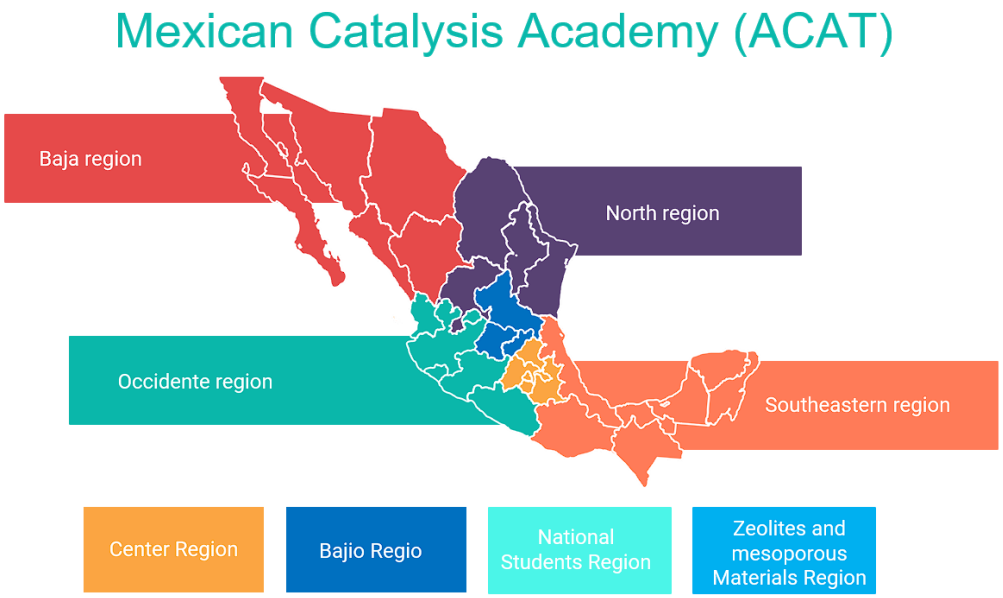

Figure 1 Regional Organization of Mexican Catalysis Academy

Table 1 Academic Units with members working in the catalysis field.

Academic Unit	Academic Unit
Nacional Autonomous University of México (UNAM)	San Nicolas de Hidalgo University (UMSNH)
Center for Nanosciences and Nanotechnology-UNAM	University of Veracruz (UV)
Technological Institute of Tijuana (ITT),	Juarez Autonomous University of Tabasco (UJAT)
Autonomous University of Baja California (UABC)	Yucatan Scientific Research Centre (CICY)
Center of Scientific Research of Ensenada (CICESE)	Politecnical National Institute (IPN)
Autonomous University of Nuevo León (UANL),	Mexican Petroleum Institute (IMP)
Technological Institute of Ciudad Madero (ITCM)	National Institute of Nuclear Research (ININ)
Applied Chemistry Research Center (CIQA)	Autonomous University of the State of Hidalgo
Autonomous University of Guanajuato (UGTO)	Autonomous University of the State of México
Autonomous University of Queretaro (UAQ)	Interdisciplinary Center for Research and Studies on Environment and Development
Autonomous University of San Luis Potosí (UASLP)	Center for Research in Advanced Materials S.C.
Technological Institute of Celaya (ITC)	Center for Research and Advanced Studies of the National Polytechnic Institute
Potosino Institute of Scientific and Technological Research (IPICYT)	

Research activities

Our research is concentrated in the fields of Environmental Catalysis, Catalysis for Energy, Photocatalysis, Electrocatalysis, Hydrotreatment, Biomass transformation, CO_2 capture and transformation, Asymmetric catalysis, Homogeneous catalysis, catalysts regeneration of spent catalysts, Reactor design, and Catalysis by Gold, among others. Computational Catalysis and Modeling are also undertaken in many institutions.

Examples of the catalysts under investigation are: supported metals and oxides, nanostructured mixed oxides, TM sulfides, nanostructured catalysts and supports, mesoporous oxides, thin films, MOFs, zeolites, 2D materials, organometallic compounds, composites, clays, and layered materials.

Photocatalysis is a growing field in the catalytic community. In the last five years, almost 300 papers have been published by Mexican researchers, according to Web of Science.

Publications of the Mexican catalysis community are found, for example, in the following journals: Journal of Catalysis, Applied Catalysis B: Environmental, Applied Catalysis A: General, Catalysis Today, ACS Catalysis, Catalysis Letters, Catalysis Communications, Topics in Catalysis, Fuel, International Journal of Hydrogen Energy, Catalysis Science and Technology, RSC Advances, Applied Surface Science, Journal of Photochemistry and Photobiology. In two Mexican journals such as “Revista Mexicana de Ingeniería Química” and “The Journal of the Mexican Chemical Society”. Papers are also published in journals devoted to Materials Science and Physical Chemistry.

On the other hand, IMP is the leader in patent requests, with about 50 in the last five years. IPN has 12, followed by UNAM and UAM.

Research funding mainly comes from the National Council for Science and Technology (CONAHCYT) in the form of Basic and Applied Research projects or related to the actualization of infrastructure. Also, funds come from calls from some universities, such as UNAM. PEMEX, the Mexican Department of Energy, and some other government offices also provide funding through CONAHCYT for specific research projects, for example, catalysts for ultra-low sulfur fuels, rejuvenation of spent HDT catalysts, catalysts for FCC, and catalysts for sulfur recovery plants. Other funds come from industry, although to a lesser extent.

ACAT is associated with the Iberoamerican Federation of Catalysis Societies (FISOCAT), and since 1992, with The North American Catalysis Society (NACS). Since the year 2000, ACAT

has been part of the Iberoamerican Countries Group (Cuba, Colombia, Chile, Peru, Uruguay, Mexico) of IACS.

Summary of Catalysis Research

The following is an example of the catalysis research done in Mexico at the present time:

1D structured catalytic materials: carbon nanotubes (CNT), $H_2Ti_3O_7$ and $Na_2Ti_3O_7$ nanotubes (TiNT), 1D-ceria; metals supported on TiNT for cross-coupling reactions; decorated TiNT as support of gold for oxidation reactions; doped TiNT for photocatalytic reactions; oxides/TiNT, for SCR of NO by NH_3; nickel supported on doped 1D-Ceria for WGS and PROX reactions, surface acidity of protonated TNT decorated with metals, In the last years, researchers are obtaining Metal-organic frameworks (MOFS) and materials as HKUST-1 framework, which is built up of dimeric metal units, which are connected by benzene-1,3,5-tricarboxylate linker molecules. Hydrotreatment catalyst: nanostructured catalysts, deep HDS, hydrodeoxygenation,. Photocatalysis for water splitting, degradation of emergent water pollutants, herbicides and CO_2 conversion: visible light-activated semiconductors, metal-semiconductor-perovskites composites; heterojunctions, titania modified by gold–metal catalysts, metal-graphene oxide nanocomposites, ZnO-TiO2/delaminated montmorillonite Ag-coated heterostructures, graphite and graphene oxide, CdS nanofibers modified with graphene oxide and nickel nanoparticles. Fine chemicals: selective hydrogenation of aldehydes, ketones and nitro compounds over supported metals, liquid-phase oxidation of alcohols in green chemistry. Biofuels: Mo-based catalysts for hydrodeoxygenation, Co/Fe-Mixed Oxides for Biodiesel production, supported bimetallic catalysts for transformation of HMF and molecules derived from, thiol and sulfonic functionalized alumina support for HMF production, biodiesel from shrub plants using basic solid catalyst, glycerol-based processes for added value industrial products, valorization of products from biomass reactions. Electrocatalysts: Nitrogen-Doped Reduced GO as a Support for ORR, bi and trimetallic catalysts for ORR, shape effects of core-shell nanostructures,

In the last years, researchers are obtaining Metal-organic frameworks (MOFS) and materials as HKUST-1 framework, which is built up of dimeric metal units that are connected by benzene-1,3,5-tricarboxylate linker molecules. Double Layered Hydroxides and Hydrotalcites: CO_2 capture, green synthesis of benzaldehydes. Aasymmetric catalysis:

Bisphosphine-diamine metal complexes for asymmetric hydrogenation reactions, C_2-symmetric sulfonamides as homogeneous and heterogeneous organocatalysts. Spectroscopic in-situ studies: DRIFT, Raman and UV-Vis Spectroscopies, NEXAFS. Computational studies on the structure and electronic properties of supported and non-supported metal clusters. Reactor design: Catalytic Hydrotreatment of Vegetable Oils. Environmental catalysis and Catalysis for Energy: Selective catalytic reduction SCR, VOC oxidation, metal-supported catalysts for wet air oxidation of organic compounds, Pd-only TWC and supported Pd model catalysts, hydrogen production and purification over supported metals; PGM, Ag, Cu, Ni, ceria, WGS, PROX, Methanol decomposition, steam reforming of alcohols over metals supported on nanostructured ceria, dry reforming over Ni-based supported catalysts.

Organization and participation in catalysis meetings

ACAT has played a central role in the organization of workshops, meetings, conferences, round tables, and courses since its creation in 1988. The first ten years of activities included international workshops and national seminars, which in time evolved into the Mexican Catalysis Congress/International Congress, with a biannual periodicity from year 2001. However, the catalysis community participates actively in international events, such as the Iberoamerican Congress in Catalysis (CICAT), the International Congress in Catalysis (ICC), the North American Catalysis Society Meeting (NAM), the European Congress on Catalysis (Europacat) and other international topical meetings.

Up to date, ACAT has organized:

- Five international workshops. The first one took place in 1988 in Hacienda Vista Hermosa, Morelos, called “First International Workshop on Heterogeneous Catalysis”, to start the activities of the society; Professors M. Boudart, G. Somorjai, R. Chianelli, L. Schmidt, K. Klier, M. Breysse, P. Grange, F. Figueras, F. Fajula and M.J. Yacaman were invited and attended this workshop.
- Four national seminars, the first in 1989 in Tequisquiapan, Queretaro;
- Nine Mexican Catalysis Congress (CMCs), including the XVII Mexican Catalysis Congress/VIII International Congress, in November 2021 in San Luis Potosí, which was done in a virtual format due to the COVID-19. Pandemic forced us to update this meeting and organize it online in late November 2021. However, we had the

participation of professors Avelino Corma, Enrique Iglesia, Susannah L. Scottt, Antonia Infantes Molina, and Sergio Fuentes Moyado as plenary lecturers and more than 130 oral presentations broadcast live.

- The most recent Mexican Congress was held in Morelia, Michoacan whose members belong to the western region of ACAT again in presential mode with more than 200 participants.
- Four major international meetings: in 2003 the 18th North American Catalysis Meeting (NAM) in Cancún and in 1974, 1988, and 2004, the IV, XI and XIX Iberoamerican Congress in Catalysis (CICAT). The IV and XI CICATs took place before the constitution of the catalysis society.

In 2020, ACAT again hosted the CICAT number XXVII, and as part of the 17th International Congress in Catalysis, a satellite conference devoted to biomass transformation to valuable products was also organized. Unfortunately, the COVID-19 pandemic forced us to update this meeting and organize it online in late October, 2020. Nevertheless, we received 523 abstracts, and we had 162 oral presentations, four plenary lectures, and 15 keynotes. All of them were broadcast live, and we had the participation of an average of 250 people connected all day long to the Zoom platform. Also, the posters were presented with a 5-minute recorded explanation of their content.

Finally, we are excited to receive the North American Catalysis meeting (32nd NAM) in 2029.

Participation in the ICCs

Incipient participation of Mexican researchers at the International Congress in Catalysis (ICC) is recorded from the 5th in 1972 in Palm Beach. Some of the actual Mexican Senior researchers attended the 6th ICC in London as students.

Figure 2 shows Mexico's contribution to ICCs from the 10th ICC in Budapest in 1990. At the 11th ICC in Baltimore, a pre-congress symposium on electron microscopy was organized in collaboration with researchers of Oak Ridge National Laboratory.

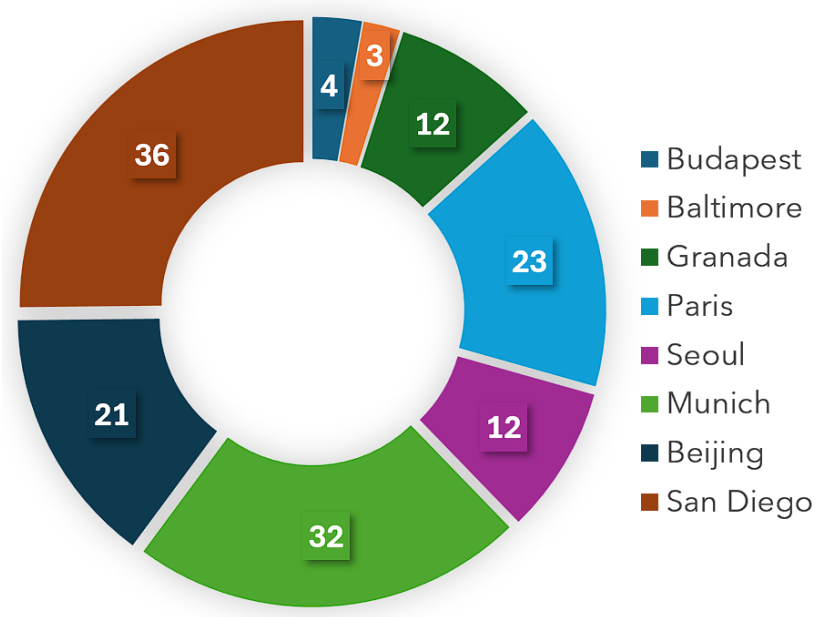

Figure 2 Contribution to each International Congress

Up to now, the 15th ICC in 2012 in Munich has been the congress with the most significant Mexican attendance in the following areas: Hydrocracking, Hydrotreating Catalysts, Carbon-based catalysts, Alcohol reforming reactions, Photocatalysis, Biomass-related reactions, Catalysis by gold, DLH, Fine chemicals, Asymmetric catalysis, SCR catalysts, and In-situ spectroscopic studies. Now, we expect to have around 15 works accepted for participation in this ICC-2024, and more than 60 works were received for the Iberoamerican Congress on Catalysis to be held in Bilbao Spain this year.

Education and other activities.

Education activities are the primary purpose of ACAT. Since its establishment, catalysis has been promoted among undergraduate and graduate students at institutions and through ACAT, supporting their attendance at the Mexican Catalysis Congress (CMC). Also, ACAT awards the best graduate thesis at the Master's and Ph.D levels during the CMC; the one at the Ph.D. level is supported to attend and present a contribution at the upcoming CICAT.

ACAT has published three books in Spanish dealing with environmental catalysis and catalyst characterization, and selected applications intended for undergraduate and

graduate levels. Recently, a catalog of research activities was published as an effort to gather the history, infrastructure, and current research topics of catalysis groups in several institutions.

ACAT Members have also edited special issues in prestigious journals devoted to showing the research of our catalysis community.

- *Applied Catalysis: A*, 142, 179 Fuentes S. (1996)..
- *Catalysis Today*, (1-2), 107-108 . Domínguez J. M. and Ramírez J. (2005).
- *Petroquimex* (2005). www.petroquimex.com/simp-ibero.htm. Domínguez J.M.,
- *Revista Mexicana de Ingeniería Química* (RMIQ), Vol. 5 (3). Viveros T. (2006).
- *Top. Catal*. Vol. 54 (8-9), 459. Olivas A., Alonso-Nuñez, Zepeda T.A. and Petranovskii V., (2011).
- Special Issue Dedicated to Heterogeneous Catalysis Research done by Mexican Groups, J.C. Fierro-Gonzalez, J.N. Díaz de León, Journal of the Mexican Chemical Society 65 (1) 2021, 1, https://www.jmcs.org.mx/index.php/jmcs/article/view/1492.
- Special issue "Selected contributions of the XXVII Iberoamerican Congress on Catalysis," J.N. Díaz de León, G.Alonso-Nuñez, S. Fuentes-Moyado, T.A. Zepeda, 394-396, (2022) 1, https://doi.org/10.1016/j.cattod.2022.04.029.
- Special Issue of the VII edition of the International Congress and XVII Mexican Congress of Catalysis, Topics in Catalysis 65 (2022) 1181, J.N. Díaz de León, J. G. Pacheco-Sosa and C. Solis-Maldonado, https://doi.org/10.1007/s11244-022-01702-6

In addition, some books have been prepared historically by ACAT members:

1. Aboites, J., Domínguez J.M., and Beltran T. "*La tríada Innovadora*", Ed. IMP/Siglo XXI Ed. (2004). ISBN: 968-23-2537-4.
2. Domínguez J.M., "*El amanecer de la catálisis en Iberoamérica*" Ed.IMP/CYTED ED. (2004). ISBN: 968-489-017-6.
3. Cedeño C. L. and Hernández M.L. Editores, Vol 1: "*Aplicaciones selectas de catálisis*", Ed. Académica Española, (2013). ISBN: 978-3-659-06802-7.
4. Cedeño C. L. and Hernández M.L., Editores, Vol. 2: "*Caracterización de catalizadores*", Ed. Create Space Independent Publishing Plattform, EUA (2014). ISBN: 978-1-500-28933-1.
5. Aguilar P. J., Cedeño C. L. and Hernández M.L., Editores, Vol. 3: "*Catálisis y Medio Ambiente*", Ed. Create Space Independent Publishing Plattform, EUA (2015). ISBN-13: 978154154731.

Finally, on the Web page of the ACAT (www.acat.org.mx), an Electronic Bulletin is published dealing with topics of general interest in catalysis, including editorials, research notes,

technology notes, and commercialization in Mexico. In addition, the offer of national graduate programs in Mexico is also displayed.

In conclusion, the Catalysis journey in Mexico has been one of incredible growth and collaboration since its early beginnings. Through the Mexican Academy of Catalysis (ACAT), we have worked to promote research, education, and applications in catalysis and have made significant contributions in fields as diverse as environmental catalysis, energy, biomass conversion, and fine chemistry.

Our participation in international events and conferences, including the International Catalysis Conference (ICC), demonstrates our commitment to global collaboration and knowledge sharing. We have organized many workshops, seminars, and conferences in Mexico, creating a vibrant community of catalysis researchers.

ACAT also places education at the forefront of our mission, actively supporting undergraduate and graduate students through awards and publications. Our commitment to disseminating knowledge extends beyond academia, as evidenced by electronic bulletin boards and online resources available to all.

We are excited about future opportunities for further collaboration as we continue to broaden our horizons and delve deeper into the catalysis field. We are committed to promoting positive change and innovation in Mexico and globally.

Thank you all for your kind attention and support.

Dr. Jorge Noé Díaz de León Hernández

President

Dr. Juan C. Fierro-Gonzalez

Vice-President