

Role of Chemistry in Raising India

DR. LAXMI TANTUVAY
ASSISTANT PROFESSOR
GOVT.HOLKAR SCIENCE COLLEGE INDORE M.P.

Development of Chemistry in India

The development of chemistry in India has deep roots, tracing back to ancient times with significant contributions in the fields of metallurgy, medicine, and alchemy. Early Indian chemists made remarkable advancements in the production of glass, dyes, and soaps. The Ayurvedic texts contain references to various chemical processes and medicinal formulations. During the medieval period, India saw the rise of alchemy (Rasayana), aimed at transmuting base metals into noble ones and discovering the elixir of life. With the advent of the colonial era, modern chemistry was introduced through European education systems, leading to the establishment of research institutions and universities. Post-independence, India has made significant strides in chemical research, with contributions to pharmaceuticals, materials science, and industrial chemistry.

Key Points on the Development of Chemistry in India

1. **Ancient Contributions:** Early advancements in metallurgy and medicinal formulations.
2. **Ayurvedic Chemistry:** References to chemical processes in traditional texts.
3. **Medieval Alchemy:** Development of Rasayana, focused on metal transmutation and life elixirs.
4. **Colonial Influence:** Introduction of modern chemistry through European education.
5. **Establishment of Institutions:** Founding of research institutions and universities.
6. **Post-Independence Growth:** Significant advancements in various branches of chemistry.
7. **Global Impact:** Contributions to pharmaceuticals, materials science, and industrial chemistry.
- 8.

Ancient India's contribution to Science and Technology included principles of chemistry

India's chemical sector is emerging as a key driver of industrial growth and has the potential to generate around 10 million jobs by 2040, according to Department of Chemicals and Petrochemicals (DCPC) Secretary Ms. Nivedita Shukla Verma. Speaking at an industry event, she highlighted the sector's growing contribution to manufacturing, exports and economic development, supported by rising domestic demand and increasing global interest in India as an alternative manufacturing destination. The Secretary noted that the chemical industry plays a critical role in several downstream sectors, including pharmaceuticals, textiles, agriculture, automotive, infrastructure and consumer goods. India is currently among the world's largest producers and consumers of chemicals, and the sector is expected to benefit from supply-chain diversification, policy support and investments in sustainable manufacturing. She emphasised that innovation, research and development, and adoption of advanced technologies will be crucial in enhancing competitiveness and supporting long-term growth.

The Secretary further stated that India's chemical industry has the potential to become a major contributor to the country's ambition of becoming a developed economy by 2047. The sector is witnessing increasing investments across speciality chemicals, petrochemicals and green chemistry solutions, supported by improving infrastructure and ease of doing business. Growing global demand, coupled with India's skilled workforce and expanding manufacturing base, is creating opportunities for export growth and employment generation. She also highlighted the importance of sustainability, resource efficiency and circular economy practices in ensuring balanced sectoral development. With continued policy support, technology adoption and capacity expansion, the chemical sector is

expected to strengthen India's industrial ecosystem, enhance value addition across supply chains and create substantial employment opportunities over the next two decades.

These chemists made fundamental contributions to their field, and had an impact on India.

The beginnings of chemistry in India are often traced to P.C. Ray in West Bengal. Ray established a school of chemistry in Presidency College in Calcutta, and his work on nitrites brought him international recognition. Ray was also India's first scientist-entrepreneur. The next milestone was the establishment of the Indian Institute of Science, where chemistry was among the first departments to be set up. Compared to the state of chemistry in Europe, these were small steps. The true pioneers of modern chemistry in the country were T.R. Seshadri and K. Venkataraman, both of whom studied at Presidency College in Madras initially, and were professional rivals. They also did their PhD research under the same scientist, Nobel Laureate Robert Robinson.

When they returned to India, Venkataraman joined the fledgling University Department of Chemical Technology (UDCT) and Seshadri went to Andhra University. They nurtured their fields in both these institutions before moving on to the National Chemical Laboratory (NCL) and Delhi University, respectively. After India became independent, Delhi University, NCL and UDCT became major centres of research in chemistry. Seshadri and Venkataraman could be regarded as the first generation of chemists in independent India, with a focus on synthetic organic chemistry.

Two more major chemistry hubs came up in the next generation, with T.R. Govindachari at Presidency College in Madras, and Asima Chatterjee in Calcutta. Meanwhile, chemistry was changing as a discipline, with quantum mechanics driving the creation of new theoretical and experimental methods. C.N.R. Rao at IIT Kanpur became the leader in this line of research, focusing largely on materials. The Chemistry Department at IIT Kanpur in the 1960s had other stars as well — P.T. Narasimhan and M.V. George, to mention two — to whom students were drawn like magnets from all over India.

Over the next 50 years, a large number of chemists from these departments left academia to create chemical and pharmaceutical industries. Until the mid-1990s, import restrictions made life difficult for academic chemists. Liberalisation lifted some of these restrictions, but only a small number of scientists have been able to make a mark on the global scene. We pick some of them here, looking at either their fundamental contributions to their field or their impact on India. In rare cases, in both ways.

The Indian chemical sector, valued at over \$220 billion, is poised to be a massive economic engine. It benefits greatly from the "China Plus One" global supply chain diversification and a booming domestic market. However, the industry faces structural hurdles like heavy feedstock import reliance and high logistics costs. [\[1, 2, 3, 4, 5\]](#)

Key Opportunities

- **Supply Chain Diversification:** Global multinational corporations (MNCs) are shifting procurement away from China due to trade restrictions and environmental regulations. This opens the door for Indian firms to capture significant global market share. [\[1\]](#)

- **Surging Domestic Consumption:** Nearly 70% of production is consumed locally. With domestic demand projected to surge to up to \$1 trillion by 2040, the market is expanding across agrochemicals, pharma, and automotive end-use segments. [1, 2]
- **Specialty Chemicals Focus:** India is uniquely positioned to scale production of high-value specialty and knowledge chemicals. The availability of affordable engineering talent (like chemists and chemical engineers) provides a solid foundation for growth. [1, 2, 3, 4]
- **Green Energy Transition:** The shift toward carbon neutrality and green hydrogen provides an opportunity to build sustainable, cost-effective infrastructure that aligns with long-term global sustainability goals. [1, 2]

Major challenges in India regarding the actual discipline, practice, and application of **chemistry** (covering academic research, laboratory synthesis, and translational chemical sciences) involve structural and technical hurdles that limit groundbreaking innovation: [1, 2]

1. The Transition from Lab Bench to Scale-Up (Chemical Engineering Gap)

- **Process Scale-up Failures:** Academic chemists successfully synthesize complex molecules at the milligram scale in round-bottom flasks. However, transitioning these to multi-kilogram industrial yields regularly fails. [1]
- **Thermodynamic Control Issues:** Indian labs struggle to manage heat dissipation, mass transfer, and altered reaction kinetics during scaling. This results in low yields and unpredictable impurity profiles. [1]
- **Disjointed Ecosystems:** Pure chemistry departments (focused on discovery) rarely collaborate effectively with chemical engineering departments (focused on scaling). This bottlenecks molecular commercialisation. [1]

2. Severe Shortage of Sophisticated Analytical Infrastructure

- **Access to Equipment:** High-end analytical instrumentation—such as 600+ MHz Nuclear Magnetic Resonance (NMR) spectrometers, High-Resolution Mass Spectrometers (HRMS), and Single-Crystal X-ray Diffractometers (SC-XRD)—is concentrated in a few premier institutes (like IISc and IITs).
- **Bureaucratic Bottlenecks:** Researchers at tier-2 and tier-3 universities face months of delays simply waiting for sample testing results from centralized national facilities. [1]
- **Maintenance and Downtime:** Because India relies heavily on foreign manufacturers (e.g., Bruker, Agilent, Shimadzu) for these instruments, sourcing spare parts, specialized software drivers, and expert technicians takes months, stalling critical research timelines. [1]

3. Reagent Logistics and Supply Chain Friction

- **Delayed Reagent Sourcing:** Sourcing specialty catalysts, chiral ligands, or high-purity solvents from international vendors (like Sigma-Aldrich/Merck) frequently takes **4 to 12 weeks** due to custom clearances and hazardous material transport regulations. In Western nations, these same chemicals arrive overnight. [1, 2]
- **Cold-Chain Deficiencies:** Temperature-sensitive and highly volatile reagents often degrade during transit due to unreliable domestic cold-chain logistics. This leads to compromised reproducibility in sensitive synthetic pathways. [1, 2]

4. Safety Deficits and Waste Management Protocols

- **Ineffective Lab Safety Culture:** Compared to global standards, academic laboratories across India exhibit sub-par adherence to basic process safety standards (e.g., proper fume hood face velocities, continuous gas monitoring, and appropriate PPE). [1, 2]
- **Effluent Treatment and Zero Liquid Discharge (ZLD):** Implementing green chemical protocols that minimise toxic organic solvent waste is lagging. Labs often struggle with cost-effective, environmentally compliant disposal of highly toxic heavy metal catalysts and chlorinated waste. [1, 2, 3]

5. Academic Focus on "Incremental" Chemistry vs. Deep Innovation

- **Quantity Over Impact:** The evaluation matrix in Indian academia heavily incentivizes the *volume* of research papers published rather than the patentability or translational impact of the chemistry.
- **Derivative Research:** A disproportionate amount of research focuses on minor, incremental modifications of existing synthetic methodologies (e.g., exploring variations of known cross-coupling reactions or metal-organic frameworks) rather than discovering entirely new chemical reactions, novel catalysts, or structural paradigms.

Strategic Imperatives for the Future

- **Dismantle the Scale-Up Barrier:** India must create dedicated translational hubs where synthetic chemists work alongside chemical engineers from day one. This integration is vital to solve complex heat and mass transfer issues before molecules ever leave the bench.
- **Democratise Analytical Infrastructure:** Upgrading tier-2 and tier-3 universities with regional, rapidly maintained instrument clusters is critical. Reducing sample analysis wait times from months to days will accelerate research velocity nationwide.
- **Build Autonomy in Core Chemistry:** The scientific community must aggressively develop domestic catalysts, high-purity solvents, and advanced intermediates. This is the only way to eliminate vulnerable 12-week import timelines.
- **Enforce Green and Safe Practices:** Transitioning to green chemistry is no longer optional. Adopting atom-economical pathways, safer continuous-flow chemistry, and strict laboratory safety protocols will make Indian chemical research both globally compliant and environmentally sustainable. By matching its deep pool of chemistry talent with modern infrastructure and a mandate for commercial utility, India can transition from an exporter of raw talent and generic chemistry to a global powerhouse of proprietary molecular innovation.

How would you like to build upon this "Rising India" vision?

Draft a **Government Policy Memo** to accelerate chemical R&DDesign a **Strategic Roadmap** for building sustainable chemical clustersOutline an **Industrial Blueprint** for replacing critical chemical imports

To accelerate India's growth through the chemical sciences, the nation must shift from being a low-margin chemical *processor* to a high-value molecular *innovator*.

Here is the strategic execution roadmap to leverage chemistry as a core engine for a \$5+ trillion economy.

1. Build "Atmanirbhar" (Self-Reliant) Core Value Chains

India's economic growth is vulnerable to supply shocks because it imports critical chemical building blocks.

- **Develop Indigenous Catalysts:** Catalysts control over 90% of industrial chemical processes. India must design and manufacture its own proprietary catalysts rather than importing them from the West or China.
- **Electronic-Grade Chemicals:** As India builds its domestic semiconductor and electronics manufacturing industries, chemistry labs must produce ultra-high-purity acids, solvents, and photoresists locally.
- **Coal Gasification to Chemicals:** India has massive coal reserves but lacks crude oil. Converting domestic coal into syngas, methanol, and olefins will secure the foundational feedstock for thousands of downstream products.

2. Commercialise through "Flow Chemistry" and Automation

The traditional way of making chemicals in large, inefficient batch tanks is slow and creates heavy waste.

- **Mandate Continuous Flow Microreactors:** Flow chemistry allows chemical reactions to happen continuously in small pipes. This increases safety, cuts energy footprints by up to 40%, and allows rapid scaling from laboratory scale to industrial scale.
- **AI and Robotics in Molecular Discovery:** Deploy machine learning models in Indian labs to predict molecular properties and optimize reaction conditions. This reduces the time required to develop a new molecule from years to months.

3. Capitalise on the Global Green Transition

As international markets penalize high-carbon products, India can capture global market share by pioneering clean chemistry.

- **Biomass to Chemical Feedstocks:** Utilize India's massive agricultural waste to produce bio-plastics, bio-solvents, and bio-based surfactants, completely bypassing petroleum.
- **Green Hydrogen and Carbon Capture Utilization (CCU):** Harness cheap solar energy to produce green hydrogen. Capture carbon dioxide emissions from heavy industries and chemically convert them into useful polymers and methanol.
- **Atom-Economical Agrochemicals:** Develop next-generation, biodegradable pesticides and nano-fertilizers that target pests precisely, preventing toxic runoff into soil and groundwater.

4. Create "Translational Innovation Hubs"

The wall dividing academic chemistry (the discovery) and chemical engineering (the manufacturing) must be dismantled.

- **Co-Location of Labs and Pilot Plants:** Establish national hubs where synthetic chemists work alongside chemical engineers and software developers under one roof.
- **Industry-Sponsored Ph.D. Programs:** Shift academic research metrics away from the total number of papers published. Instead, incentivize universities based on patents filed, technology transferred, and successful industrial scale-ups.
- **Shared Infrastructure Clusters:** Build regional, state-of-the-art testing and characterization facilities accessible to MSMEs and startups within 24 hours, eliminating expensive equipment procurement delays.
- **NITI Aayog Official Study:** The comprehensive report titled [Powering India's Participation in Global Value Chains](#) outlines how the chemical sector (valued at **\$220 billion**) acts as an essential pillar for India's target of becoming a \$5-trillion economy, with projections to scale up to **\$1,000 billion by 2040**. [1]
- **Invest India Sector Insights:** The national investment promotion agency's blueprint, [Chemical Industry Growth Drivers and Investment Opportunities in India](#), details how domestic consumption and the localization of downstream supply chains can capture 20% of the world's incremental chemical demand. [1]
- **Ministry of Chemicals & Petrochemicals Annual Review:** The detailed data on output capacity, specifically relating to import substitution across alkali, organic, and pesticide sectors, can be reviewed via the [Department of Chemicals and Petrochemicals Annual Report](#). [1]
- **McKinsey & Indian Chemical Council (ICC) Briefs:** The core dynamics of managing global margin pressures and fixing the \$31 billion trade deficit via localized backward integration are explicitly broken down in the strategic industry whitepaper, [Leading India's Chemical Industry Through Global Headwinds](#). [1]
- **Private R&D Capital Influx:** Analysis highlighting how private domestic players (such as Aarti Industries, SRF, and Navin Fluorine) are expanding specialized research budgets to capture high-margin global markets is detailed via [Distil Market's Specialty Chemicals R&D Focus](#). [1]

Copyright & License:

© Authors retain the copyright of this article. This work is published under the Creative Commons Attribution 4.0 International License (CC BY 4.0), permitting unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.