

# The Great Technology Convergence

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## Opening Scenario: When technology boundaries disappear

A biotechnology company is developing a targeted therapy and needs a nanoscale excipient that can protect a fragile active molecule until it reaches the right biological environment. A semiconductor company is searching for a bio-derived cleaning chemistry that can reduce environmental burden without compromising wafer yield. A nutraceutical company wants a fermentation-derived specialty lipid that supports cellular health, stability, and consumer trust. On paper, these are three different customers from three different industries. In reality, they are beginning to knock on the door of the same specialty chemical supplier.

This is the new world of specialty chemicals. The future will not be organized neatly into old industrial boxes. Chemistry will merge with electronics, biology, nanotechnology, artificial intelligence, data science, sustainability engineering, advanced manufacturing, medicine, agriculture, and energy transition. The boundaries that once separated sectors are dissolving, and the most valuable molecules will be those that can travel across boundaries.

A modern semiconductor fabrication plant already depends on precision chemistry, surface science, nanomaterials, ultra-clean packaging, advanced analytics, and algorithmic process control. A pharmaceutical company developing ribonucleic acid medicines depends on lipid chemistry, polymer science, particle engineering, biological understanding, sterile manufacturing, and advanced characterization. A battery manufacturer depends on electrochemistry, mining chemistry, solvent systems, separators, binders, nanostructured materials, recycling technologies, and predictive performance modelling.

The important lesson for the future chemical marketer is simple: the value of a molecule will no longer depend only on its chemical identity. It will depend on how effectively that molecule performs inside a larger technology system. The marketer who understands only the product will struggle. The marketer who understands the system will lead.

## Why convergence is becoming the new industrial reality

The twentieth century rewarded specialization. A company could succeed by becoming excellent in dyes, solvents, polymers, intermediates, surfactants, coatings, agrochemicals, or pharmaceutical ingredients. Specialization will still matter, but specialization alone will not be enough. Customers increasingly expect suppliers to understand how one technology interacts with another.

The reason is that the world's major growth sectors are themselves convergent. Artificial intelligence requires advanced semiconductors, high-performance cooling fluids, power electronics, data-center materials, and large energy systems. Electric vehicles require batteries, adhesives, electronics, thermal management, lightweight composites, coatings, recycling chemistries, and flame-retardant systems. Preventive healthcare requires nutraceutical science, biotechnology, delivery systems, biomarker diagnostics, consumer trust, regulatory discipline, and digital health data. Climate technology requires catalysis, membranes, sorbents, enzymes, electrochemistry, water treatment, circular materials, and lifecycle thinking.

This convergence is changing the structure of competitive advantage. A company that sells a chemical as a stand-alone substance may be pushed toward commoditization. A company that positions the same chemical as part of a customer's technology architecture can create a premium. The premium is earned when the supplier can explain performance, reduce uncertainty, solve application problems, support documentation, anticipate regulation, and participate in innovation.

The new question is therefore not merely, 'What product do we sell?' The new question is, 'At which technology intersection can our molecule create strategic advantage for the customer?'

## Chemistry and electronics: the invisible backbone of digital civilization

Every smartphone, artificial intelligence server, electric vehicle, satellite, medical imaging device, and defence platform depends on semiconductors. Yet semiconductors depend on chemicals so pure and so precisely controlled that ordinary industrial language becomes inadequate. A small contamination event can reduce yield, damage device reliability, or delay customer qualification.

The semiconductor ecosystem requires photoresists, developers, etchants, ultrapure acids and bases, high-purity solvents, deposition precursors, chemical mechanical planarization slurries, specialty gases, low-k and high-k materials, packaging adhesives, underfills, encapsulants, thermal interface materials, and cleaning chemistries. The commercial buyer may issue the purchase order, but the real customer is the process itself.

Extreme ultraviolet lithography demonstrates the intensity of this convergence. ASML describes EUV systems using 13.5 nm light to produce advanced chip patterns, and the entire lithography environment depends on materials, optics, vacuum conditions, photoresist chemistry, contamination control, and process precision. As device dimensions move toward atomic-scale tolerances, chemical purity becomes a strategic enabler of digital progress.

This changes the commercial role of specialty chemical companies. They are no longer simply vendors. They become yield partners, qualification partners, risk-reduction partners, and long-term technology collaborators. Japan and South Korea have built powerful positions in electronic materials because they combine manufacturing discipline, customer intimacy, quality culture, and patient qualification. Future Indian companies that want to enter this space must learn the same lesson: semiconductor customers do not buy cheap chemicals; they buy confidence that chemistry will not disturb a billion-dollar process.

## Chemistry and biology: the rise of molecular engineering

Biology is becoming programmable. Cells are increasingly being treated as manufacturing systems capable of producing complex molecules with remarkable selectivity. This does not replace chemistry; it expands chemistry. The future belongs to companies that can understand both synthetic routes and biological routes, both reactor chemistry and fermentation, both purification and biological variability.

Synthetic biology, fermentation technologies, and biocatalysis are transforming pharmaceutical intermediates, nutraceutical ingredients, sustainable polymers, specialty enzymes, bio-based surfactants, agricultural biologicals, functional proteins, cosmetics actives, flavors, fragrances, and alternative food ingredients. The Organisation for Economic Co-operation and Development has highlighted synthetic biology as a rapidly evolving field with major potential across health, food security, emissions reduction, and distributed manufacturing.

Traditional chemistry may require high temperature, high pressure, hazardous solvents, heavy metals, or multiple steps. Biological systems can sometimes achieve difficult transformations under milder conditions with high selectivity. Enzymes can improve chiral purity. Engineered microbes can produce rare molecules that are difficult to extract from nature. Fermentation can convert renewable feedstocks into ingredients that carry powerful sustainability narratives.

The marketing opportunity is significant, but the discipline must be strong. Customers will ask about yield, productivity, strain stability, feedstock source, impurity profile, downstream purification, allergens, regulatory classification, sustainability claims, scalability, and cost. The marketer must not sell biology as magic. The marketer must sell verified performance, credible documentation, and practical economics.

## Chemistry and artificial intelligence: accelerating molecular discovery

Artificial intelligence is changing how molecules are discovered, tested, optimized, manufactured, positioned, and sold. Traditional chemical discovery has often been slow, experimental, and iterative. Researchers design molecules, synthesize candidates, test properties, interpret failures, and repeat. Artificial intelligence does not eliminate this process, but it can make the process faster, better directed, and more data-rich.

Machine learning and computational chemistry can support molecular property prediction, toxicity screening, catalyst design, formulation optimization, process control, route selection, predictive maintenance, supply-chain forecasting, demand prediction, customer segmentation, and technical content generation. In advanced materials, AI can identify promising molecular structures before expensive laboratory work begins. In pharmaceutical discovery, AI can help screen biological targets and molecular candidates. In formulations, AI can reduce trial-and-error by identifying composition-performance relationships.

The deeper shift is not only technological. It is organizational. Companies with superior data architecture will increasingly outperform companies that rely only on experience stored in individual memories. Laboratory data, production data, customer trial data, complaint data, regulatory data, and market data must be converted into institutional intelligence.

However, artificial intelligence should be understood as augmented intelligence, not a replacement for scientific judgement. A model can identify patterns, but it cannot replace the wisdom of a chemist who understands impurity behaviour, a production manager who understands scale-up risk, or a marketer who understands customer fear. The future belongs to organizations that combine human expertise with computational power.

## Chemistry, nanotechnology, and surface science: small structures, massive impact

At nanoscale dimensions, materials behave differently. Surface area increases dramatically. Optical, electrical, catalytic, mechanical, and biological interactions can change. A substance that is ordinary in bulk form may become highly valuable when structured at nanoscale dimensions or placed at the right interface.

Nanotechnology enables applications in semiconductor devices, drug delivery, diagnostics, advanced coatings, energy storage, catalysis, sensors, water purification, aerospace composites, food packaging, and smart surfaces. The National Nanotechnology Initiative describes nanotechnology as a platform with applications across information technology, medicine, energy, transportation, environmental science, and many other sectors.

The future of specialty chemicals will increasingly depend on control of interfaces rather than only production of bulk substances. A coating may become self-cleaning. A membrane may selectively separate molecules. A nanoparticle may carry a drug to a targeted site. A catalyst may multiply surface activity. A packaging film may sense spoilage. A surface treatment may reduce microbial adhesion or corrosion.

The marketing challenge is that 'nano' can create both excitement and concern. Customers will ask about particle size distribution, dispersion stability, surface modification, toxicology, regulatory status, dusting risk, environmental behaviour, and compatibility with their formulation. The strongest nanomaterial supplier will not be the one with the most dramatic claim. It will be the one that can prove consistent performance in the customer's real system.

## Chemistry and sustainability: from green claims to lifecycle logic

Sustainability is no longer an optional decoration added to a brochure. It is becoming a design principle, a regulatory expectation, an investor concern, and a customer qualification filter. Technology convergence is accelerating because sustainability problems cannot be solved by one discipline alone.

Electric vehicles require battery materials, electronic materials, lightweight composites, adhesives, thermal management systems, flame retardants, recycling technologies, and clean-energy infrastructure. Hydrogen systems require membranes, catalysts, water-treatment chemicals, gas purification, ammonia handling, and storage materials. Circular economy systems require recyclable polymers, green solvents, bio-based feedstocks, enzymatic recycling, advanced separation chemistry, and digital traceability.

Green chemistry also changes the language of marketing. A product cannot simply be described as eco-friendly. The claim must be connected to evidence: lower hazard, lower emissions, safer solvent profile, renewable feedstock, better biodegradability, lower energy consumption, reduced waste, improved recyclability, or verified lifecycle advantage. Customers increasingly ask not only whether a product works, but whether it will remain acceptable under future regulation and ESG scrutiny.

For specialty chemical companies, sustainability should be treated as a commercial capability. A supplier that understands lifecycle assessment, regulatory trends, safer alternatives, circular design, and downstream customer pressure can help customers avoid future risk. This is how sustainability becomes strategy rather than slogan.

## Chemistry and advanced manufacturing: precision as a market

Advanced manufacturing is creating new demand for chemical systems that enable precision. Additive manufacturing needs photopolymers, powders, binders, support materials, post-processing chemicals, surface treatments, and quality-control additives. Atomic layer deposition and chemical vapor deposition need volatile precursors, reaction control, high-purity delivery systems, and surface chemistry. Precision coating needs rheology modifiers, adhesion promoters, curing systems, solvents, dispersants, and nano-additives.

In traditional manufacturing, the chemical supplier often sold inputs. In advanced manufacturing, the supplier increasingly sells process capability. The value is not merely in the chemical composition but in how the chemistry behaves under temperature, pressure, light, plasma, deposition, printing, curing, or layer-by-layer construction.

This creates opportunities for companies that understand application engineering. A resin for 3D printing is not merely a resin; it is a balance of viscosity, curing speed, mechanical strength, shrinkage, thermal stability, colour, toxicity, and post-cure performance. A deposition precursor is not merely a molecule; it is a combination of volatility, decomposition behaviour, purity, film quality, and tool compatibility.

The chemical marketer must therefore move closer to the customer's process window. The winning company will not only supply material but help the customer reduce defects, improve throughput, increase reproducibility, and accelerate qualification.

## Chemistry and digital health: molecules inside the healthcare data revolution

Digital health is often presented as a software revolution, but its physical foundation is chemical. Wearable biosensors depend on conductive inks, adhesives, hydrogels, enzyme systems, membranes, electrodes, polymers, biocompatible coatings, and diagnostic reagents. Point-of-care diagnostics depend on antibodies, enzymes, nucleic-acid reagents, stabilizers, buffers, microfluidic materials, and packaging chemistry. Advanced therapeutics depend on excipients, lipids, polymers, delivery systems, and analytical standards.

The convergence of chemistry and digital health creates a new class of products where molecules generate data. A skin patch may measure glucose, lactate, hydration, temperature, inflammatory markers, or drug levels. A diagnostic cartridge may translate a biological signal into a digital result. A personalized nutrition platform may connect biomarker testing to supplement recommendations. In each case, chemistry is the bridge between the body and the digital system.

For chemical suppliers, this creates opportunities in high-value niches: biosensor materials, diagnostic reagents, stabilization systems, biologically compatible adhesives, controlled-release ingredients, microencapsulation

systems, and precision excipients. It also increases documentation expectations because healthcare-linked products face higher scrutiny.

The marketer must speak both the language of performance and the language of trust. Stability, sensitivity, specificity, biocompatibility, shelf life, sterility, regulatory classification, and traceability become part of the value proposition.

## How convergence creates new product categories

Technology convergence creates markets that do not fit neatly into old categories. Is a bio-based semiconductor cleaning agent an electronic chemical, a green chemical, or a biotechnology product? Is a lipid nanoparticle a pharmaceutical excipient, a drug-delivery technology, or a platform material? Is a nanocellulose film a packaging material, a sustainability product, a food-contact material, or a functional coating? The answer is often: all of these.

This category ambiguity is commercially important. When a product sits between categories, customers may not know how to evaluate it. Procurement may not know which budget it belongs to. Regulatory teams may need clarification. Technical buyers may compare it against the wrong benchmark. Sales teams may describe it too narrowly or too broadly.

The marketer must therefore create the category language. The company must define the problem, the application, the proof required, the qualification pathway, the regulatory logic, and the customer benefit. New product categories are not created only in laboratories. They are created through disciplined explanation.

This is where thought leadership becomes a commercial asset. White papers, technical notes, application guides, webinars, e-articles, case studies, and regulatory briefs can help customers understand how to buy what they have never bought before.

## The convergence opportunity matrix

A practical way to identify new opportunities is to map intersections rather than products. Each intersection creates a potential white space where a company can develop a new solution, new application, or new customer conversation.

Convergence point	Examples of chemical opportunities	Customer value created
Chemistry + Electronics	Photoresists, wet chemicals, CMP slurries, deposition precursors, packaging materials	Yield protection, miniaturization, device reliability, supply security
Chemistry + Biology	Enzymes, fermentation products, biocatalysts, bio-based ingredients, cell-culture inputs	Cleaner routes, rare molecules, traceability, milder processing
Chemistry + AI	Data-driven formulation, molecular prediction, process optimization, customer intelligence	Faster discovery, lower trial cost, improved decision-making
Chemistry + Nanotechnology	Nanoparticles, nanoemulsions, functional coatings, quantum dots, nanostructured catalysts	Higher performance, targeted delivery, stronger surfaces, better efficiency
Chemistry + Sustainability	Green solvents, recyclable polymers, sorbents, membranes, bio-based feedstocks	Regulatory resilience, ESG credibility, lower lifecycle impact
Chemistry + Advanced Manufacturing	3D-printing resins, ALD/CVD precursors, precision coatings, binders	Process precision, defect reduction, faster qualification
Chemistry + Digital Health	Biosensor materials, diagnostic reagents,	Data generation, preventive healthcare,

	excipients, delivery systems	personalized medicine
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## Building cross-disciplinary teams

Convergence cannot be managed by departmental silos. A chemical company seeking future relevance must build teams that can connect science, application, regulation, manufacturing, data, and customer strategy. The chemist understands molecular behaviour. The application engineer understands the customer's process. The biologist understands living systems. The data scientist understands patterns and prediction. The regulatory specialist understands acceptability. The marketer understands customer decision psychology and value communication.

The company that integrates these skills will see opportunities earlier than competitors. It will identify why a nutraceutical molecule may also become a cosmetic active, why a polymer technology may support battery separators, why a fermentation capability may create personal-care ingredients, why a purification technology may support semiconductor-grade supply, and why a documentation system built for pharma may become a credential in other high-trust markets.

This does not mean every company must become expert in every technology. It means every company must learn to collaborate across disciplines. Partnerships with universities, research institutes, application laboratories, startups, distributors, equipment manufacturers, and end users will become central to commercial strategy.

## How convergence changes competition

The future competitor may not look like a traditional competitor. A biotechnology startup may enter a chemical ingredient market. A software company may influence material discovery. A battery company may backward-integrate into electrolyte chemistry. A large end user may develop proprietary formulations. A university spin-off may create a disruptive material platform. A distributor with strong application intelligence may become more influential than a manufacturer with weak customer understanding.

This means chemical companies must watch adjacent sectors, not only direct competitors. The company that sells coatings should watch nanotechnology, green solvents, surface sensors, and circular materials. The company that sells pharmaceutical intermediates should watch biocatalysis, continuous manufacturing, synthetic biology, and artificial-intelligence route design. The company that sells electronic chemicals should watch advanced packaging, 2D materials, photoresist innovation, and geopolitical semiconductor policy.

Strategic blindness often comes from defining the market too narrowly. Convergence punishes narrow definitions. It rewards companies that scan the horizon, interpret weak signals, and reposition before customers are forced to demand change.

## Positioning strategy at convergence points

A company cannot position itself at a convergence point by using generic claims. Statements such as 'high quality,' 'innovative,' 'sustainable,' or 'customer focused' are not enough. Convergence positioning must be specific.

A semiconductor chemical supplier should position around purity, defect reduction, analytical capability, packaging discipline, and change control. A fermentation-derived ingredient supplier should position around traceability, bio-based production, consistent active content, purity, sustainability evidence, and regulatory clarity. A nanomaterial supplier should position around dispersion, particle control, application performance, toxicology, and formulation compatibility. An AI-enabled chemical company should position around faster development, better prediction, stronger data architecture, and expert validation.

The strongest positioning statement answers four questions: What technology intersection do we serve? What customer problem becomes easier because of our molecule? What proof do we have? Why are we difficult to replace?

## What this means for Indian specialty chemical companies

India has a powerful opportunity in the convergence era. The country already has strengths in pharmaceutical intermediates, active pharmaceutical ingredients, process chemistry, engineering talent, entrepreneurship, and cost-effective manufacturing. The next step is to move from supply capability to application intelligence.

For Indian companies, the opportunity is not only to manufacture molecules at competitive prices. The opportunity is to become trusted global partners in future-facing sectors: semiconductor chemicals, nutraceutical ingredients, fermentation-derived actives, green solvents, water-treatment technologies, battery materials, advanced intermediates, specialty coatings, and technical service-led exports.

To capture this opportunity, companies must invest in documentation, analytical capability, application testing, regulatory awareness, technical content, international customer intimacy, and patient qualification. Markets such as Japan, Korea, Europe, and the United States will not be won by price alone. They will be won through consistency, responsiveness, proof, and humility before the customer's process.

India can become a major global specialty chemical platform if it develops the confidence to think beyond contract manufacturing and the discipline to meet the world's most demanding qualification standards.

## The human meaning of convergence

Technology convergence may sound technical, but its impact is deeply human. Better semiconductor chemicals enable medical devices, communication systems, artificial intelligence tools, and safer transport. Better biotechnology-derived ingredients can support preventive health and cleaner manufacturing. Better nanomaterials can improve water purification, diagnostics, coatings, and energy systems. Better battery materials can support clean mobility and grid resilience. Better green chemistry can reduce pollution and protect future generations.

The responsibility is therefore significant. A convergent molecule can create progress, but it can also create hidden risk if poorly understood, poorly documented, poorly regulated, or poorly communicated. The future chemical marketer must be technically literate, ethically alert, and commercially disciplined.

The winning companies of the next fifty years will not merely ask, 'Can we make this molecule?' They will ask, 'Can this molecule help customers build a safer, cleaner, healthier, more resilient, and more intelligent world?' That is the true promise of technology convergence.

## Key Takeaways

- The next era of specialty chemicals will be defined by convergence between chemistry, electronics, biology, nanotechnology, artificial intelligence, sustainability, advanced manufacturing, and digital health.
- The value of a molecule will depend increasingly on its role inside a larger technology system, not only on its chemical identity.
- Semiconductor chemicals demonstrate how invisible molecular inputs can determine the success of the digital economy.
- Synthetic biology, fermentation, and biocatalysis are expanding the meaning of chemical manufacturing by turning biological systems into production platforms.

- Artificial intelligence will accelerate discovery and optimization, but expert human judgement will remain essential.
- Nanotechnology and surface science will create high-value materials where performance depends on interfaces, morphology, and controlled structure.
- Sustainability claims must move from decorative language to lifecycle evidence, regulatory readiness, and measurable customer benefit.
- Indian specialty chemical companies have a major opportunity if they move from product supply to application intelligence, documentation excellence, and global qualification discipline.

## Strategic Questions

- Which technology intersections are closest to the company's current capabilities?
- Which products in the portfolio can be repositioned as enabling technologies rather than ordinary chemicals?
- Where do customers face problems that require chemistry plus another discipline such as biology, electronics, data science, or sustainability?
- What application data, analytical proof, regulatory clarity, and technical documentation are needed to support convergence positioning?
- Which universities, startups, equipment companies, laboratories, or end users can become collaboration partners?
- Which adjacent industries may become future competitors or future customers?
- How can the company build a technical content library that educates customers about new convergent applications?

## Action Checklist

- Create a convergence map of the company's portfolio across electronics, biology, AI, nanotechnology, sustainability, energy, water, health, and advanced manufacturing.
- Identify five products that can be repositioned through application evidence rather than commodity specifications.
- Prepare one convergence value sheet for each selected product, covering application, customer pain point, proof required, regulatory issues, and target geography.
- Build a cross-functional internal team involving R&D, production, quality, regulatory, sales, and marketing.
- Start three customer conversations focused only on future application needs, not immediate orders.
- Identify one university or technology institute collaboration opportunity linked to a convergence theme.
- Develop at least two e-articles or technical notes explaining how one product supports a future technology sector.

## E-Article Ideas

- Why Specialty Chemicals Are Becoming Technology Platforms
- Chemistry Meets AI: The New Frontier of Molecular Discovery
- From Fermentation to Future Ingredients: Biology as a Chemical Factory
- Semiconductor Chemicals: Why Purity Is the New Performance

- Green Chemistry Beyond Claims: How Lifecycle Evidence Creates Market Advantage

## Mini Case Study: From solvent supplier to convergence partner

A mid-sized Indian chemical company manufactures high-purity solvents used in pharmaceuticals, coatings, and industrial cleaning. For years, the company sells mainly on purity percentage, price, availability, and delivery reliability. The product performs well, but the company remains trapped in competitive negotiations because customers see it as one more supplier of a known material.

A new opportunity appears when an electronics customer asks whether the same solvent can be upgraded for a wafer-cleaning application. The technical discussion immediately changes. The customer is not satisfied with ordinary industrial purity. It asks for trace metal limits, particle data, moisture control, clean packaging, filtration details, container compatibility, batch-to-batch consistency, change-control procedures, and analytical validation.

At first, the supplier treats this as a difficult specification request. Later, the management realizes that this is actually a convergence opportunity. The solvent is no longer simply a solvent. It is becoming part of the semiconductor manufacturing ecosystem. The company invests in improved analytics, cleaner handling, better packaging, electronic certificates of analysis, technical documentation, and a customer-specific qualification package.

The same knowledge later helps the company approach a medical-device customer requiring biocompatible cleaning chemistry and a battery-material customer requiring low-moisture solvent handling. One molecule has entered three different convergence zones. The lesson is clear: a future specialty chemical company grows not by selling the same product harder, but by understanding where the same molecule creates new technical meaning.

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