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Translational Chemistry on Time of War. A Molecular Dual-Edged Catalyst, How War Accelerated the Development of Chemistry and Civil Innovations

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War, by nature destructive, has paradoxically served as a potent catalyst for scientific innovation, especially in the realm of chemistry. Whether through the synthesis of explosives, gas weapons, or the creation of synthetic materials, warfare has both pushed the boundaries of chemical knowledge and inadvertently laid the groundwork for peacetime innovation (**Table 1**). War necessitates rapid solutions to complex problems-supply shortages, material failures, tactical dominance-often resulting in a 'forced acceleration' of scientific development [1].

The World War I (1914-1918) was considered the first 'chemical war'. The German military's deployment of chlorine gas at Ypres in 1915 marked the first large-scale use of chemical weapons. Fritz Haber, a Nobel laureate, spearheaded the German gas warfare effort. His work on ammonia synthesis via the Haber-Bosch process, originally developed for fertilizers, was repurposed to manufacture ammonium nitrate for explosives [2,4].The development of phosgene, mustard gas, and chlorine gas not only changed battlefield tactics but also led to a deeper understanding of gas behavior, atmospheric diffusion, and protective equipment chemistry. After the war, facilities developed for chemical weapons were converted into industrial plants producing fertilizers and pesticides, helping shape the modern agrochemical industry. The wartime chemical infrastructure directly fed into civilian production capacities in the 1920s, especially in nitrogen-based fertilizers and synthetic dyes.

The World War II (WWII) (1939-1945) catalyzed even more transformative changes. The war blocked access to natural rubber, prompting U.S. chemists to develop synthetic rubber (*e.g.*, Government Styrene-Butadiene Rubber (GR-S), or Buna-S, the historical and trade names for Styrene-Butadiene Rubber (SBR), a synthetic copolymer of styrene and butadiene, crucial as a natural rubber substitute, a breakthrough in polymer chemistry. This laid the foundation for modern plastics and elastomers. The Pharmaceutical industry enhance the Penicillin and Mass Synthesis. Penicillin, discovered earlier, was mass-produced for the first time during WWII due to military needs. On the other hands, Chemical engineers developed deep-tank fermentation, a chemical engineering feat still used in today's pharmaceutical industry [1]. The Allied effort led to innovations in TNT, RDX, and composite propellants. These chemicals required precise control of reaction kinetics, catalysis, and temperature-techniques later essential in fine chemical and petrochemical industries.

Table 1 | Peacetime Legacies: War-Inspired Technologies in Society.

Wartime Development	Civilian Application
Nerve agents (*e.g.*, Sarin)	Insecticides (organophosphates)
Synthetic rubber	Tires, gaskets, medical gloves
Penicillin synthesis	Mass production of antibiotics
Cryogenic fuels	MRI and medical gas systems
Gas masks	Industrial respirators, PPE
Rocket propellants	Space exploration, fuel cells
Chemical detection kits	Environmental testing, food safety

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During the Cold War era (1947-1991) was a time of covert scientific rivalry. Chemistry became a tool for deterrence, espionage, and space exploration. Hydrazine-based fuels, developed for missiles, found later applications in satellite maneuvering systems and spacecraft propulsion [3]. Cryogenic chemical handling methods from missile programs were adapted for cryopreservation and gas storage, technologies. In the field of Materials Chemistry, the research into heat-resistant ceramics, polymers, and composites for aircraft and reentry vehicles influenced the development of non-stick cookware, synthetic fibers, and insulation.

Later the Vietnam War's deployment of Agent Orange and related herbicides marked a low point in wartime chemical applications. It did, however, increase scrutiny of toxicology, long-term exposure effects, and led to the establishment of the U.S. Environmental Protection Agency (EPA) in 1970. The atrocities also fueled the development of environmental chemistry and green chemistry principles, aimed at reducing chemical harm and promoting sustainability [2].

Contemporary wars, such as in Iraq, Iran or Ukraine, involve not just traditional weaponry but also chemical sabotage, infrastructure degradation, and contamination risks. Modern military operations employ chemical sensors, spectroscopy tools, and AI-assisted detection systems to monitor chemical threats [5]. These technologies now underpin industrial leak detection, pollution monitoring, and hazmat emergency response. [6,7].

Military conflict has repeatedly proven to be a grim but effective incubator for chemical innovation. What begins in the laboratory for wartime often ends up transforming civilian life-from the medicines we take to the fertilizers that grow our food. This historical pattern underscores the importance of guiding scientific advancement ethically, ensuring that chemistry continues to serve life-not destroy it. Wartime nitrate synthesis (initially for bombs) became the basis for the nitrogen fertilizer industry. Wartime disease control led to drugs like chloroquine, sulfa drugs, and broad-spectrum antibiotics. War demand led to synthetic fuels research, especially coal-to-liquid (CTL) technology, now revisited.

While war has undeniably accelerated the development of chemistry through urgency and necessity, it is in times of peace that the most meaningful and lasting benefits of these discoveries truly flourish. History shows that many chemical advancements born out of conflict-ranging from life-saving medicines to synthetic materials and environmental technologies-have only reached their full potential when applied to serve society, improve lives, and foster global well-being.

Yet, scientific progress need not be the byproduct of destruction. On the contrary, peace offers a fertile ground where international collaboration, ethical research, and sustainable investment in science can thrive without the human cost of war. Science conducted in times of peace may be slower, but it is more inclusive, more ethical, and more enduring.

So while war may have acted as a molecular dual-edged catalyst, it is peace that transforms that catalyst into true progress. Let humanity learn to advance science not through the fires of conflict, but through the light of cooperation and shared purpose. After all, the greatest achievements in chemistry - and in civilization - are born not of fear, but of hope.

Notes

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