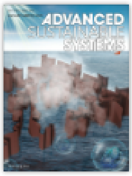
Revision for Unit 4 AOS 1 outcome 1 – media article

Take home booklet.

Dimethyl carbonate (DMC) is an important, versatile and environmentally friendly chemical used in various chemical industries. Below are some products made using dimethyl carbonate.

1. **Polycarbonates -** DMC is a building block in manufacturing polycarbonate plastics, which are used in electronic components, automotive parts, eyewear lenses, and construction materials.
2. **Pharmaceuticals -**It is involved in synthesizing intermediates and active pharmaceutical ingredients (APIs).
3. **Agrochemicals -** DMC helps produce herbicides, insecticides, and fungicides.
4. **Paints and Coatings -** As a solvent and chemical intermediate, it helps manufacture environmentally friendly paints and coatings.
5. **Lithium-Ion Batteries -** Electrolyte solutions using DMC improve battery efficiency in mobile devices and electric vehicles.
6. **Fuel additive**- It serves as an oxygenate additive to improve combustion efficiency and reduce emissions in gasoline.

ADVANCED SUSTAINABLE SYSTEMS



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Review

Green Synthesis of Dimethyl Carbonate from CO_2 and Methanol: New Strategies and Industrial Perspective

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Abstract

Dimethyl carbonate (DMC) is a commonly used and environmentally sustainable chemical compound and intermediate in a variety of industrial applications. To date, several large-scale industrial DMC synthesis routes have been developed, including methanol phosgenation, transesterification, and oxidative carbonylation of methanol. However, these manufacturing routes have several disadvantages, such as the use of hypertoxic phosgene as raw material, costly processing, and explosion risks. The most encouraging and ecofriendly path is the green production of DMC from CO_2 and methanol. Various catalytic materials have been examined concerning their suitability for DMC synthesis. The issues of low yield and difficulty in tests have not been resolved fundamentally, which is caused by the inherent problems of the synthetic pathway and limitations imposed by thermodynamics. The search for more efficient production routes has driven the activation of CO_2 via electro-assisted synthesis as well as membrane reactors, which can isolate products in real-time to maximize DMC yield. The green synthesis of dimethyl carbonate catalyzed by different catalysts including Zr/Ce/Cu-based nanocomposites, organometallic compounds, heteropoly acid, ionic liquid, metal-organic frameworks, etc, is discussed in detail. Further, the structure–activity relationships and insights into molecular activation and catalytic mechanisms, as well as the identification of active sites on catalysts are addressed.

References Related Information

Figure 1 – An abstract from a research paper on the green synthesis of dimethyl carbonate (DMC)

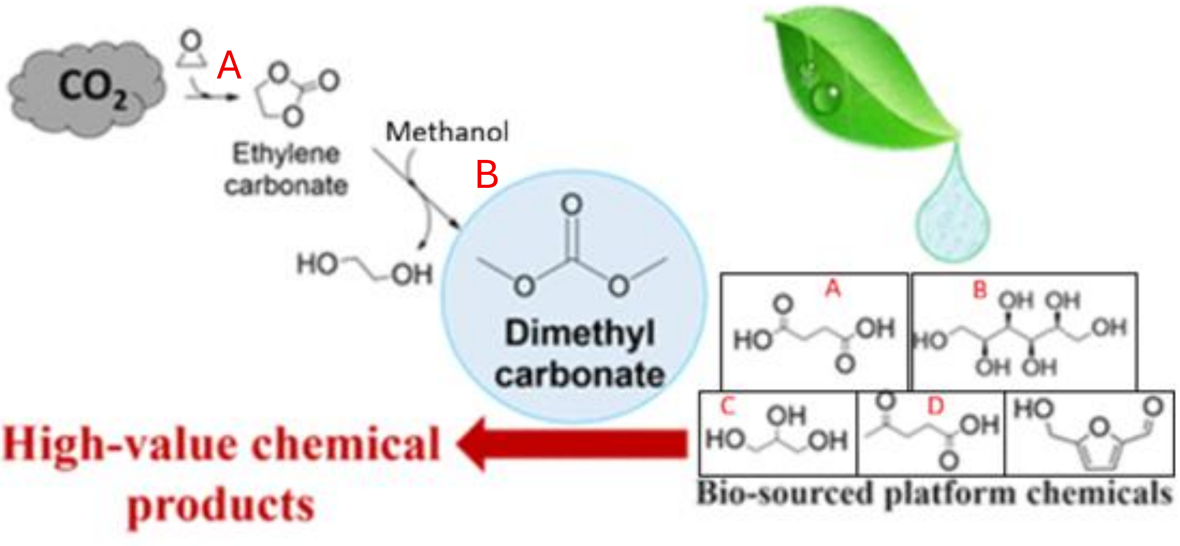


Figure 2 – A visual summary of the reaction to form DMC via CO_2 pathway and its use in the formation of other compounds

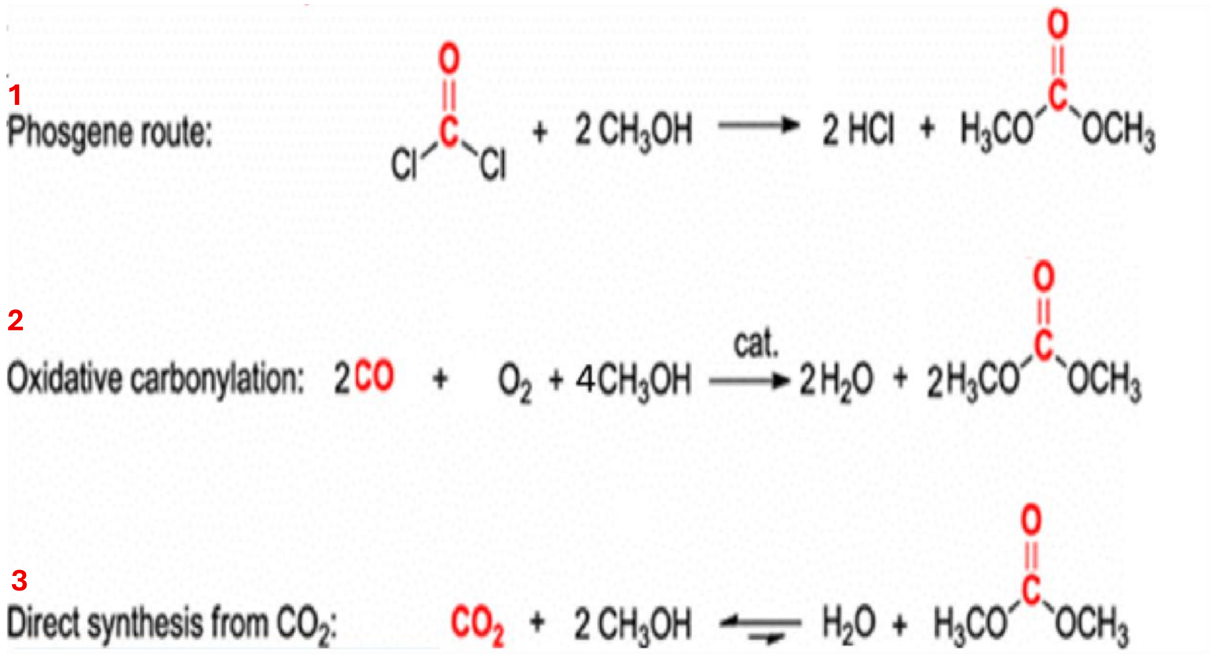


Figure 3 – Shows three chemical reactions forming DMC

Dimethyl carbonate (DMC) is a versatile, safe and environmentally friendly chemical widely used as a solvent, methylating agent, and intermediate in pharmaceutical and industrial synthesis. Its low toxicity and biodegradability make it an attractive alternative to more hazardous chemicals.

Currently, two main industrial processes produce DMC:

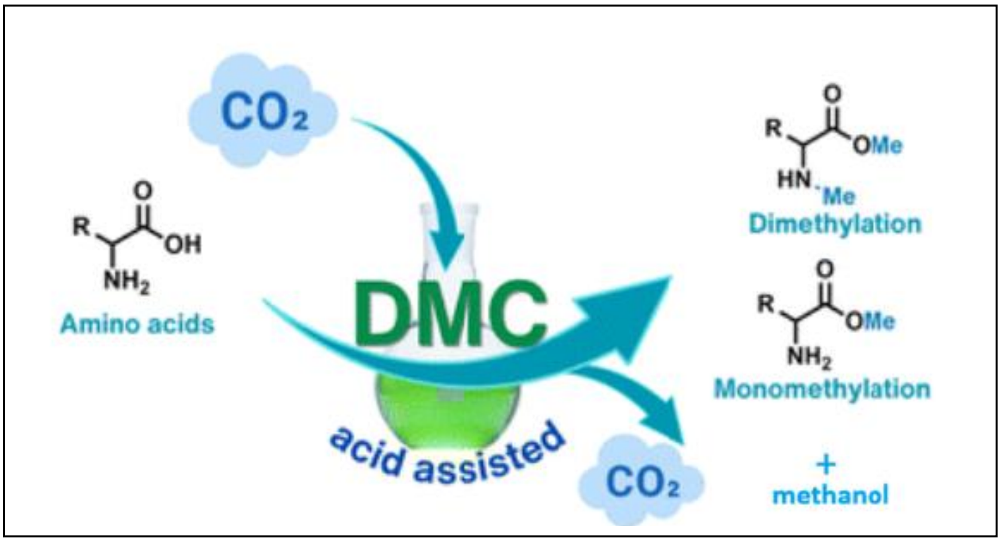
1. The phosgene reaction
2. The direct synthesis from carbon dioxide (CO_2)

The phosgene reaction involves the reaction of phosgene ($COCl_2$) with methanol (CH_3OH) to form DMC and hydrogen chloride (HCl) as a byproduct. Both phosgene and methanol are toxic, with phosgene infamously used as a chemical warfare agent during World War I. Handling phosgene requires stringent safety precautions, and the corrosive HCl byproduct necessitates careful neutralization and disposal. This method typically achieves high yields of around 90.0%.

Alternatively, the direct synthesis from CO_2 uses carbon dioxide, a greenhouse gas and methanol, along with catalysts, to produce DMC and water as a byproduct. While far less toxic than phosgene, carbon dioxide's chemical stability demands high pressure and temperatures, and innovative catalysts to achieve high rates and moderate yields.

Developing sustainable and safe production methods for DMC remains a central challenge, as industries seek to balance yield, safety, environmental impact, and economic viability in line with green chemistry principles. This method typically achieves low yields of around 50.0%.

Dimethyl carbonate (DMC) is used for methylation in peptide synthesis because it is a mild, safe, and environmentally friendly methylating agent. Unlike traditional reagents such as diazomethane or methyl iodide, DMC has low toxicity and produces minimal hazardous waste, aligning with green chemistry principles. Its gentle reaction conditions help preserve the delicate structure and chirality of amino acids and peptides, minimizing the production of unwanted optical isomers and side reactions. Methylation itself is important in peptide synthesis because it protects reactive side chain groups, like carboxyl (–COOH) groups, from unwanted chemical reactions during the complex multistep synthesis process. By temporarily masking these functional groups, methylation improves the control, efficiency, and selectivity of peptide bond formation, ensuring the accurate assembly of biologically active peptides and enhancing stability and purity of the final product.



Dot points to be covered.

Structure, nomenclature and properties of organic compounds

- characteristics of the carbon atom that contribute to the diversity of organic compounds formed, with reference to valence electron number, relative bond strength, relative stability of carbon bonds with other elements, degree of unsaturation, and the formation of structural isomers
- molecular, structural and semi-structural (condensed) formulae and Skeletal structures of alkanes (including cyclohexane), alkenes, benzene, haloalkanes, primary amines, primary amides, alcohols (primary, secondary and tertiary), aldehydes, ketones, carboxylic acids and non-branched esters
- the International Union of Pure and Applied Chemistry (IUPAC) systematic naming of organic compounds up to C8, with no more than two functional groups for a molecule, limited to non-cyclic hydrocarbons, haloalkanes, primary amines, alcohols (primary, secondary and tertiary), aldehydes, ketones, carboxylic acids and non-branched esters
- in physical properties within homologous series (boiling point and melting point, viscosity), with reference to structure and bonding

Reactions of organic compounds

- organic reactions and pathways , including equations, reactants, products, reaction conditions and catalysts (specific enzymes not required):
  - synthesis of primary haloalkanes and primary alcohols by substitution
  - addition reactions of alkenes
  - the esterification between an alcohol and a carboxylic acid
  - hydrolysis of esters
  - pathways for the synthesis of primary amines and carboxylic acids
  - transesterification of plant triglycerides using alcohols to produce biodiesel
- calculations of percentage yield and atom economy of single-step or overall reaction pathways, and the advantages for society and for industry of developing chemical processes with a high atom economy
- the sustainability of the production of chemicals, with reference to the green chemistry principles of use of renewable feedstocks, catalysis and designing safer chemicals
- hydrolytic reactions of proteins, carbohydrates and fats and oils to break down large biomolecules in food to produce smaller molecules
- condensation reactions to synthesise large biologically important molecules for storage as proteins, starch, glycogen and lipids (fats and oil)