Technical Report: Thorium-Induced Radiolysis & Gas Evolution

An analysis of hydrogen and methane production mechanisms using thorium matrices and water radiolysis.

1. Core Mechanism of Water Radiolysis

Radiolytic gas evolution occurs when chemical bonds are broken by ionizing radiation. When alpha-emitting isotopes like Thorium-232 (^{232}Th) are in direct contact with water, the dense ionizing track of the alpha particles drive the dissociation of water molecules.

- **Energy Transfer:** Alpha particles possess high Linear Energy Transfer (LET), depositing concentrated energy along a short path.
- **Molecular Splitting:** Ionization breaks water molecules into highly reactive radicals: $H_2O \rightarrow e^-_{aq}$, •H, •OH, H^+.
- **Gas Recombination:** These short-lived radicals rapidly recombine within the particle track, yielding molecular hydrogen gas (H_2) and hydrogen peroxide (H_2O_2).

2. Mechanisms for Methane (CH_4) Co-Production

Because pure thorium or water does not contain carbon, methane co-production requires introducing a carbon source into the system. This typically occurs through two distinct pathways:

Pathway A: The Sabatier/Fischer-Tropsch Gas Phase Reaction

When the thorium-water matrix operates in an environment with dissolved carbon dioxide (CO_2), the thorium material itself acts as a heterogeneous catalyst. At elevated temperatures, the surface of compounds like thorium oxide (ThO_2) or thorium silicide drives the reduction of CO_2 by the freshly generated radiolytic hydrogen:
$\mathbf{CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O}$

Pathway B: Chemical Co-Hydrolysis of Mixed Carbides/Silicides

In synthesized intermetallic systems, such as a thorium silicide alloy blended with thorium carbide (ThC or ThC_2), exposure to water triggers a concurrent chemical reaction. While the silicide structure reacts with water to liberate hydrogen, the carbide bonds are simultaneously protonated by the water molecules, directly generating methane gas.

3. Summary of Reaction Pathways

System Component	Primary Reactants	Evolved Gases
Pure Thorium + Water	H_2O + Alpha Radiation	Hydrogen (H_2), Oxygen (O_2)
Thorium Matrix + CO_2	Radiolytic H_2 + CO_2 via surface catalysis	Methane (CH_4), Water vapor
Thorium Silicide/Carbide Blend	Direct chemical hydrolysis + radiation	Methane (CH_4), Hydrogen (H_2)

4. Interfacial Energy Transfer Efficiency

The physical structure of the thorium material greatly influences production efficiency. In highly porous ceramics, powders, or complex silicides, a high surface-area-to-volume ratio creates an 'interfacial effect'. Electronic excitations (excitons) generated within the solid thorium lattice travel to the surface interface rather than dissipating as heat. This directly transfers energy to adsorbed water molecules, significantly boosting the total radiolytic gas yield.