

TABLE 2. Free energies and typical organisms of methanogenesis reactions

Reaction	$\Delta G'^{\circ}$ ^a (kJ/mol CH ₄)	Organisms
I. CO₂-type		
4 H ₂ + CO ₂ → CH ₄ + 2 H ₂ O	-135	Most methanogens
4 HCOOH → CH ₄ + 3 CO ₂ + 2 H ₂ O	-130	Many hydrogenotrophic methanogens
CO ₂ + 4 isopropanol → CH ₄ + 4 acetone + 2 H ₂ O	-37	Some hydrogenotrophic methanogens
4 CO + 2H ₂ O → CH ₄ + 3 CO ₂	-196	<i>Methanothermobacter</i> and <i>Methanosarcina</i>
II. Methylated Cl compounds		
4 CH ₃ OH → 3 CH ₄ + CO ₂ + 2 H ₂ O	-105	<i>Methanosarcina</i> and other methylotrophic methanogens
CH ₃ OH + H ₂ → CH ₄ + H ₂ O	-113	<i>Methanomicrococcus blatticola</i> and <i>Methanosphaera</i>
2 (CH ₃) ₂ -S + 2 H ₂ O → 3 CH ₄ + CO ₂ + 2 H ₂ S	-49	Some methylotrophic methanogens
4 CH ₃ -NH ₂ + 2 H ₂ O → 3 CH ₄ + CO ₂ + 4 NH ₃	-75	Some methylotrophic methanogens
2 (CH ₃) ₂ -NH + 2 H ₂ O → 3 CH ₄ + CO ₂ + 2 NH ₃	-73	Some methylotrophic methanogens
4 (CH ₃) ₃ -N + 6 H ₂ O → 9 CH ₄ + 3 CO ₂ + 4 NH ₃	-74	Some methylotrophic methanogens
4 CH ₃ NH ₃ Cl + 2 H ₂ O → 3 CH ₄ + CO ₂ + 4 NH ₄ Cl	-74	Some methylotrophic methanogens
III. Acetate		
CH ₃ COOH → CH ₄ + CO ₂	-33	<i>Methanosarcina</i> and <i>Methanosaeta</i>

SOURCE: Modified from Hedderich and Whitman¹ and Zinder.⁴³

^aThe standard changes in free energies were calculated from the free energy of formation of the most abundant ionic species at pH 7. For instance, CO₂ is HCO₃⁻ + H⁺ and HCOOH is HCOO⁻ + H⁺.