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Selective Gold Recovery via Thermally Generated Water Microdroplets at Oil-Water Interfaces

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Efficient and environmentally benign recovery of precious metals from complex aqueous systems remains a major challenge for sustainable resource management. Here we demonstrate that thermally generated water microdroplets at water-oil interfaces act as highly reactive interfacial microenvironments that enable selective gold reduction and macroscopic particle growth without external reductants. Mild heating of oil-water mixtures containing Au^{3+} produces abundant interfacial water microdroplets (5–50 μm) that continuously generate highly reactive species, including solvated electrons, hydrogen atoms, and hydroxyl radicals, allowing reduction reactions that do not occur in bulk water. Gold is selectively recovered because it is both thermodynamically reducible and chemically stable, whereas other metals are excluded by either redox limits or instability in acidic solutions. Dynamic microdroplet coalescence and rupture further promote nanoparticle collision, heterogeneous growth, and aggregation, yielding micrometer- to millimeter-scale gold particles that can be readily separated from solution. The oil phase can be reused over multiple cycles, enabling high-yield gold recovery with minimal inputs and waste generation. Our results reveal how interfacial water microdroplets couple redox selectivity with particle growth, linking microdroplet chemistry to sustainable manipulation of metal reactions in complex aqueous systems.