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Planetary and Anthropogenic Material Irradiations with Accelerated Beams at ASPIRE-TRIUMF

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ASPIRE (the AStrochemical and Planetary materials IRradiation Experiment) is a novel experimental facility based at TRIUMF (Canada's particle accelerator centre). ASPIRE enables irradiations of almost any type of solid, liquid, or gas, including hot-molten or frozen-icy materials, and organic/biologic media, with a comprehensive suite of stable or rare/exotic radioactive isotope beams up to 1.5 MeV/u with future possibilities up to 16.5 MeV/u. These sample irradiations offer unique capabilities for diverse, non-traditional accelerator-based research across fields. Beams of accelerated radioactive isotopes are produced at the adjoining complex by (a) fission, spallation, or fragmentation via the ISOL (Isotope Separation On-Line) method where 500 MeV protons from the main cyclotron impact solid-targets, or (b) at the upcoming ARIEL (Advanced Rare Isotope Experimental Laboratory) after 2027, again via the ISOL method, and also by Bremsstrahlung-induced photofission from the rapid deceleration of 30-50 MeV electrons. Accelerated stable beams of nearly any element are created at the Off-Line Ion Sources (OLIS) facility. This contribution describes the development of ASPIRE since its 2024 commissioning, including the custom control system and diagnostic sensors, science results from the first three experimental beamtimes between 2024-2025, and planned upgrades using advanced fabrication techniques to develop novel beams and to be less reliant on accelerator availability. Upgrades will offer low-energy <keV irradiations with stable light-isotope beams (H^+, He^+, N^+, O^+, etc) from a small Penning source, or low-energy sample irradiations with an electron source. The wide availability of beams at TRIUMF combined with a highly versatile irradiation chamber, enables ASPIRE to probe radiation dose effects and associated chemistries of targeted geologic minerals and anthropogenic materials. Experiments can represent unique environments including cold interstellar (nebular) settings, space weathering of planetary or asteroid surfaces, radiolytic conditions in deep subsurface environments, production or destruction of molecules with implications for habitability, and material degradation in the environment with implications to remediation and respectful integration of traditional Indigenous knowledge systems. ASPIRE also enables irradiation of materials with exotic highly-charged ions from ARIEL, for example, to simulate injections of radiochronometers from stellar sources into early protoplanetary disks around hot proto-stars.



