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Chondritic Meteorite Outgassing Experiments: Implications for the Volatile Composition and Early Atmospheres of Terrestrial Planets

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We are at the beginning of an observational revolution in exoplanet science, with the advanced capabilities of NASA's JWST and upcoming 25-40-meter-class ground-based telescopes like the ELT that will allow us to begin characterizing the physics and chemistry of low-mass terrestrial exoplanets. Such observations will provide an early opportunity to place Earth and the other terrestrial planets in our Solar System in the wider context of planet formation and evolution across the universe. In preparation for this upcoming observational data, we need a strong theoretical basis for the formation history, bulk composition and atmospheric properties of terrestrial planets. Outgassing is a central process during the formation and evolution of terrestrial planets and their atmospheres. Although rocky planets' initial atmospheres likely form via outgassing during and after their accretion, the connection between a planet's bulk (i.e., interior) composition and its initial atmospheric properties is not well understood. An important step towards establishing this connection is to analyze the outgassing compositions of meteorites. For the foreseeable future, meteorites are the only direct analog building-blocks of terrestrial planets that can be rigorously studied in the laboratory.

To inform the connection between terrestrial planets' interior compositions and their early outgassed atmospheres, we present a novel experimental technique to measure the outgassing compositions from various meteorite samples. The experimental set-up consists of a thermogravimetric analyzer (TGA) with a high-temperature furnace coupled to a gas chromatograph (MicroGC). The TGA-MicroGC heats samples to 1600 ^{o}C under atmospheric pressure (1 bar) while simultaneously measuring changes in the mass of the sample and the abundances of different outgassed species (e.g., H_2, H_2O, N_2, CO, CO_2, CH_4, SO_2, H_2S). Various background gases can flow through the system, including argon and O_2 allowing us to explore outgassing under different redox conditions. These experiments provide new ground-truth information on the thermal decomposition and release of volatile species from meteorites as a function of temperature, pressure, and redox state. We discuss our current experimental results from heating and analyzing the outgassing compositions of a set of carbonaceous, ordinary and enstatite chondrites and their implications for terrestrial planets' volatile compositions and early atmospheres.