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**ATMOSPHERIC CHEMISTRY ON VENUS: CURRENT UNDERSTANDING, OPEN QUESTIONS, AND UPCOMING MISSIONS.** F. P. Mills<sup>1,2</sup>, A. C. Vandaele<sup>3</sup>, E. Marcq<sup>4</sup>, K. L. Jessup<sup>5</sup>, A. Mahieux<sup>6</sup> <sup>1</sup>Space Science Institute (Boulder, CO 80301), <sup>2</sup>Australian National University (Canberra ACT, Australia), <sup>3</sup>Planetary Aeronomy, BIRA (Brussels, Belgium), <sup>4</sup>LATMOS/IPSL, UVSQ Université Paris-Saclay, Sorbonne Université, CNRS (Guyancourt, France), <sup>5</sup>Southwest Research Institute (Boulder, CO), <sup>6</sup>University of Texas Austin (Austin, TX).

**Current Understanding:** Venus, Earth, and Mars formed in a similar region within the solar nebula, which has been presumed to imply similar starting compositions [1]. Isotopic studies support this for Earth and Mars [2]. Dynamical simulations [3], however, leave the potential for significant differences. Venus today has comparable carbon and nitrogen budgets to Earth [1]. Its atmosphere is primarily CO<sub>2</sub> (96.5%) and N<sub>2</sub> (3.5%) [4]. Atmospheric chemistry, though, is controlled by trace species [5]. Venus' is depleted in H<sub>2</sub>O but has a rich observed inventory of halides (HF, HCl), oxides (ClO, NO, OH, O<sub>2</sub>, O<sub>3</sub>, CO, OCS, SO, SO<sub>2</sub>, SO<sub>3</sub>, H<sub>2</sub>SO<sub>4</sub>), acids (HNO<sub>2</sub>, HNO<sub>3</sub>), polysulfur (S<sub>3</sub>, S<sub>4</sub>) and other compounds (H<sub>2</sub>S, CS, a phosphorus-bearing gas) [6,7,8].

Atmospheric chemistry is dominated by the carbon dioxide, sulfur oxidation, and polysulfur cycles [Mills et al., 2007]. The carbon dioxide cycle includes photolysis of CO<sub>2</sub>, transport and production of CO, O, O<sub>2</sub>, and O<sub>3</sub>, and production of CO<sub>2</sub>, predominantly via chlorine-catalyzed processes [6,9]. The sulfur oxidation cycle includes oxidation of OCS and SO<sub>2</sub> to SO<sub>3</sub> and H<sub>2</sub>SO<sub>4</sub>, condensation of H<sub>2</sub>SO<sub>4</sub>, transport of H<sub>2</sub>SO<sub>4</sub>, and thermal decomposition of H<sub>2</sub>SO<sub>4</sub> to regenerate SO<sub>2</sub> and H<sub>2</sub>O [6]. This cycle produces the global sulfuric acid cloud layers and contributes to but is not the sole mechanism removing SO<sub>2</sub> as it is transported upward through the cloud layers [10]. In the polysulfur cycle, sulfur from photolysis of SO<sub>2</sub> and OCS undergoes (catalyzed) association reactions to produce S<sub>x</sub> (2≤x≤8). S<sub>8</sub> can condense and be transported until it thermally decomposes, reacts with CO to form OCS, or oxidizes to SO<sub>2</sub> [6,11]. Polysulfur may contribute to the unidentified UV-blue absorption observed in the upper cloud [12,13].

Chemical regimes range from thermal equilibrium chemistry in the lowest scale height to photochemistry above the clouds. Heterogeneous chemistry and lightning are likely important as are interactions between chemistry and transport.

**Open Questions:** Within the broad understanding outlined above lie important, unresolved questions about the current and past composition and chemistry.

Observations show equatorial OCS decreasing with altitude at 30-40 km while CO increases [6]. Several reactions have been proposed to explain but only one

has been studied in the laboratory and it requires a means to generate S [6,10].

The cloud layers remain an enigma due to difficulties making remote measurements within them, conditions outside the range studied for terrestrial heterogeneous chemistry, and lack of modeling. In particular, observations above and below the cloud layers show SO<sub>2</sub> decreases with altitude much more than can be explained via oxidation to H<sub>2</sub>SO<sub>4</sub> [6,10]. Dissolution in cloud droplets with hydroxide salts may explain this [14].

The interactions of transport and chemistry are only beginning to be studied in detail with 2D and 3D models [15,16,17,18,19]. Observed geographic and time of day variations in species abundances suggest these interactions are important [20,21].

Even the chemical mechanisms stabilizing CO<sub>2</sub> are not quantitatively resolved; models predict much more O<sub>2</sub> than the observational upper limit [6,10].

**Upcoming Missions:** DAVINCI+, EnVision, Shukrayaan, and VERITAS, in conjunction with accompanying laboratory, ground-based observing, and numerical modeling studies, will provide data needed to improve our understanding of these and other open questions.

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