Toward a general thermodynamic model to interpret volcanic gases

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Volcanic gas compositions are geochemical fingerprints that track magma emplacement, differentiation, and hydrothermal interaction. Despite promise as a predictive tool, no standard model exists to quantitatively interpret volcanic gas compositions with respect to related magmatic processes. General relationships based largely on volatile solubility laws (e.g., CO_2/SO_2 ratios) can serve as qualitative indications of magma movements. The most quantitative models rely on extensive knowledge of the petrologic characteristics of the degassing magma, making them: a) difficult to apply widely; and b) less useful in forecasting eruptive behavior when the source magma is not well characterized. Now, volcanic gas measurements and underpinning thermodynamic data are of sufficient quality and quantity that a new generalized (and thus widely applicable) model can be developed.

Here I demonstrate how thermodynamic modeling can be used to combine minimal petrologic information about a volcanic plumbing system with surface gas measurements, resulting in quantitative predictive capabilities related to conditions of eruption triggering, magma movements, and even eruption sizes. This thermodynamic model calculates the compositions of a wide number of possible gas compositions that may exist in numerous underground magma reservoirs, based on pressure, temperature, fO_2, and magma composition. A mixing model then determines all possible combinations of those gases (where each individual gas may make up 0–100% of the total) that could produce the measured surface gas, to within a user defined threshold (e.g., 1 mol%). I will describe how this model has been successfully used to constrain the source regions of degassing at Erebus volcano [1], as well as its use in two predictive scenarios: 1) determination of eruption triggers and magmatic sources for the 2018 eruption of Poás volcano, Costa Rica [2]; and 2) in concert with ground deformation measurements, improvement of volcanic eruption size predictions using three recent eruptions in Alaska as test cases. Currently, the model is being expanded and rewritten as a python library to increase the accessbility of this first generalized thermodynamic model to interpret volcanic gases.

[1] Iacovino (2015), *EPSL*. [2] Iacovino et al., (2019), *AGU Fall Meeting*.