ICY COMPOSITION MEASUREMENTS IN SIMULATED PLUTO CONDITIONS.  C. J. Ahrens¹, Z. M. McMahon², V. F. Chevrier¹, M. E. Elwood Madden². ¹Arkansas Center for Space and Planetary Science, University of Arkansas, Fayetteville, AR 72701, (ca006@email.uark.edu), ²School of Geology and Geophysics, University of Oklahoma, Norman, OK 73019.

Introduction: Ice comes in many compositions and therefore plays many roles in the development of geological and climatological processes on various planetary surfaces. Pluto has complex global and localized icy processes, as evidenced by the New Horizons’ observations [1]. To understand upcoming New Horizons data, we present the motivations, objectives, and experimental approaches for a new Pluto Simulation vacuum cryo-chamber.

Surface compositions of small outer Solar System bodies are determined mainly through spectroscopic means in the visible and near-infrared (NIR) with visual confirmation of albedo features and photometric colors [2]. Additional information into surface compositions comes from laboratory simulation for the purpose of validating theoretical modeling or extends previously known knowledge to farther limits.

Pluto’s surface temperatures through various literature ranges from 33 K – 55 K with a surface pressure of roughly 10 microbar [3,4,5]. The cryo-chamber objective will have temperature variation capabilities to observe any changes in spectra. This would be ideal to study the New Horizons LEISA data and for theoretical seasonal effects with ices and gases. The New Horizons LEISA data consists of the observational wavelength range 1.25 um – 2.5 um. To complement this data and expand this wavelength range for our own purposes, our motivations will include observing in the 2.5 um - 5 um range as well [6]. In particular interest would be methane bands at 3.1-3.2 um and an absorption feature mentioned in Young et al. [6] at 4.67 um.

The objective of this experimental data will bring more observations for geophysical modeling, mechanisms of ice and gases, constrain rates and dissociation processes on Pluto. We use combinations of observations and theories to relate our primary objectives to study the geomorphological processes on Pluto’s surface and the primary materials that could be involved. This includes a variety of gases, clathrates, and various compounds and hydrates.

Science Motivation: In response to recent observations from the New Horizons instruments to be modeled, we are developing an experimental initiative to understand icy compositions and mixtures on Pluto’s surface and implications toward other Kuiper Belt Objects.

Water ice, methane (pure or diluted with nitrogen), carbon monoxide, ethane, and other irradiated ices or hydrocarbons have in some way been discussed through literature on their possible detectability on TNOs [7]. It has also been noted that more laboratory data on CO diluted in N₂ and distributions of solid nitrogen, water ice, and CO via infrared observations for New Horizons data are needed [8].

Ice rigidity and rheology. Water ice is often observed for Trans-Neptunian objects (TNOs) in the outer solar system in the crystalline state. To identify these ices in the context of their physical states, such as pure or mixed, grain size, crystallography, and phase, laboratory data can be recorded, mainly through visible and infrared spectroscopy techniques and correlated to the atmospheric composition through mass spectroscopy.

The creep behavior, or the plasticity of ice, can relate to geomorphological observations on the surface of Pluto and TNOs. Understanding the crystallinity, grain size, and purity of an ice can lead to predictions about possible dynamic movement at low stresses.

The motivation to study these processes is to further our knowledge in icy planetary formation and any current and past geomorphologic evolution and seasonal changes.

Clathrates and stability. Gas molecules are surrounded by hydrogen bonds, which make up the cage-like structures of water molecules, and van der Waals interactions, which provide the repulsive interaction of the trapped gas molecule and the cage structure, to become gas hydrate clathrates [7].

Synthesis and stability would be a main objective with varying temperatures and pressures relative to Pluto and other TNO conditions. The stability of clathrates depends on: (1) guest gas partial pressure and phase; (2) mixture of gases as guest; (3) presence of compounds to affect the hydrogen bonds, such as ammonia or alcohols [7]. From any of these factors or a combination thereof, the stability curves for these gas hydrates can be predicted, then verified by our simulations through variable conditions relevant to Pluto.
Figure 1: Methane ice abundance color intensity map from the New Horizons mission [9]. Regional differences are of interest to our objective to hypothesize methane abundance and ice compositions on a global and local scale.

Studying these clathrates and respective stabilities at varying temperatures and pressures within the range of Pluto conditions could reveal insight into methane production or reservoirs.

Gas mixtures. Small bodies in the outer Solar System are considered to be to be rich in hydrocarbons, ices, and complex organics [10]. A mixture of these materials along with controlled percentage amounts of methane and nitrogen, should model the observed spectral colors and spectroscopic absorptions in the respective wavelength ranges ~1-5 um.

Evaluating gas mixtures on icy planetary bodies show the influences of ice geology and growth and also theories on seasonal changes and interactions of between the surface and atmosphere.

Recent analyses used gas and ice mixture experiments using FTIR and gas chromatography with mass spectrometry (GC-MS) [11]. Presence of nitriles and alcohols among other compounds were observed in the irradiated ice experiment. Our experimentation will expand spectral libraries with ice-gas combinations and condition variability for more precise spectral emissivities.

Experimental Approach: A range of experiments is being planned with our Pluto simulation vacuum chamber to improve our models on various icy composition measurements, especially completing phase diagrams and clathrate stability data, such as Figure 2.

![Figure 2: PT diagram of methane clathrates with variability of ammonia [12]. Implications from this study show that relative variations of solubility of methane and N2 are important in determining the dissociation curve of mixed clathrates.](Image)

Our planetary chamber is approximately 0.45 m. in diameter and 0.56 m. depth stainless steel vacuum chamber with a roughing pump, pressure gauges, fiber optics, refrigeration system, and several ports for observation, particularly for endoscopes for spectroscopic observations and the addition of a camera. Measurements are made by bringing the pressure down to the needed 10-microbar through stages and cooling to the desired temperature of 44 K ± 10 K.

A gas-mixing chamber will be included in the design to pre-mix gas (methane, ethane, nitrogen) to certain and controllable percentages before injection into the cryo-chamber for spectral analysis. This also includes our work with pre-synthesized clathrates and then synthesizes them in situ under Pluto temperatures and pressures in the IR range.

![Figure 3: Preliminary framework of our vacuum cryo-chamber to simulate Pluto conditions. Ports would include a Prisma pressure and gas leak check, CeramOptec endoscopes of varying wavelength ranges, and a possible camera.](Image)

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