Supplementary Online Material for ICARUS_2019_521, "On the Origin & Thermal Stability of KBO 2014 MU69's and Pluto's Ices"

Appendix : Experimental Laboratory Saturation Vapor Pressure Fits

These two tables present the best-fit parameters compiled/used by Prialnik *et al.* (2004) and Fray & Schmitt (2009) to describe the vapor pressure P_{sat} versus temperature T behavior of ices found in solar system bodies. We reproduce them here both to record the values used in making the vapor pressure versus temperature curves used in our manuscript's analysis and as a service to the reader in making their own future analyses.

The 2-parameter fits of Prialnik *et al.* (2004; Table 1) assume ice Heats of Vaporization (ΔH_{vap}'s) that are independent of temperature and use data collected at/near room temperature, and so are most accurate at/near room temperature and less so at low cryogenic temperatures. These parameters are most familiar to the cometary community of researchers at the time of this writing.

Table 1 – Prialnik *et al.* 2004 Empirical P_{sat} = A*exp$^{(-B/T)}$ Parameter Values Assuming ΔH_{vap} = Constant

Ice Component	Formula	A Value (10^{10} Nm^{-2})	B Value (Kelvin)
Water	H_2O	356.	6141.667
Carbon Monoxide	CO	0.12631	764.16
Carbon Dioxide	CO_2	107.9	3148
Methane	CH_4	0.597	1190.2
Propyne	C_3H_4	3.417	3000
Propadine	C_3H_4	2.382	2758
Ethane	C_2H6	0.459	1938
Methanol	CH_3OH	8.883	4632
Hydrogen Cyanide	HCN	3.8665	4024.66
Hydrogen Sulphide	H_2S	1.2631	2648.42
Ammonia	NH_3	61.412	3603.6
Acetylene	C_2H_2	9.831	2613.6

The more extensive compendium of laboratory measurements compounded by Fray & Schmitt (2009; Table 2), produced by an extensive search & comparison of the existing literature for laboratory data, expands the list of ices studied to encompass most of the materials expected in outer solar system icy bodies. It also includes the results of heat of vaporization and vapor pressure measurements at temperatures ranging from 10 to 300 K for the candidate ices, without assuming that ΔH_{vap} is constant with Temperature. The resulting polynomial fits of $\ln(P_{sat})$ in 1/T (i..e, $\ln(P_{sat}) = A_0 + \sum A_i/T^i$)were tabulated and compared to those of other works (like Huebner 2006) in their work with good results. These parameters, along with the subset used by Schaller & Brown (2007), are most familiar to the KBO/TNO community of researchers.

We recommend the use of the Fray and Schmitt 2009 values as being more completely researched and more accurate throughout the temperature range of interest for icy solar system bodies, especially at low temperatures below 50K, and this is what we have done in our analysis. On the other hand the Prialnik *et al.* 2004 formulation is much easier to use for a quick order of magnitude estimate of the P_{sat} vs Temperature behavior: the A coefficient tells one quickly the relative volatility of a species, while the B coefficient divided by 35 gives one a quick approximate temperature where P_{sat} climbs steeply from negligible to rapidly sublimating for an ice.

Table 2 - Coefficients of the polynomials of extrapolations $\ln(P_{sat}) = A_0 + \sum A_i/T^i$ **, from Fray & Schmitt 2009**

Species	Polynomial Designation	A0	A_1(K)	A_2(K^2)	A_3(K^3)	A_4(K^4)	A_5(K^5)	A_6(K^6)
H_2O	H_2O-1	- See below for special treatment of water ice vapor pressure -						
O_2	O_2-1	$1.541x10^{+1}$	$-1.148x10^{+3}$	$3.349x10^{+2}$	$6.021x10^{+1}$	0	0	0
	O_2-2	$1.335x10^{+1}$	$-1.012x10^{+3}$	$-2.971x10^{+3}$	$2.926x10^{+4}$	0	0	0
	O_2-3	$1.018x10^{+1}$	$-8.035x10^{+2}$	$-7.080x10^{+3}$	$7.553x10^{+4}$	0	0	0
O_3	O_3-1	$1.746x10^{+1}$	$-2.352x10^{+3}$	0	0	0	0	0
CO	CO-1	$1.043x10^{+1}$	$-7.213x10^{+2}$	$-1.074x10^{+4}$	$2.341x10^{+5}$	$-2.392x10^{+6}$	$9.478x10^{+6}$	0
	CO-2	$1.025x10^{+1}$	$-7.482x10^{+2}$	$-5.843x10^{+3}$	$3.939x10^{+4}$	0	0	0
CO_2	CO_2-1	$1.476x10^{+1}$	$-2.571x10^{+3}$	$-7.781x10^{+4}$	$4.325x10^{+6}$	$-1.207x10^{+8}$	$1.350x10^{+9}$	0
	CO_2-2	$1.861x10^{+1}$	$-4.154x10^{+3}$	$1.041x10^{+5}$	0	0	0	0
CH_3OH	CH_3OH-1	$1.918x10^{+1}$	$-5.648x10^{+3}$	0	0	0	0	0
	CH_3OH-2	$1.706x10^{+1}$	$-5.314x10^{+3}$	0	0	0	0	0
HCOOH	HCOOH-1	$2.189x10^{+1}$	$-7.213x10^{+3}$	0	0	0	0	0
	HCOOH-2	$2.164x10^{+1}$	$-6.942x10^{+3}$	$-6.579x10^{+4}$	$3.316x10^{+6}$	$-6.004x10^{+7}$	0	0
CH_4	CH_4-1	$1.051x10^{+1}$	$-1.110x10^{+3}$	$-4.341x10^{+3}$	$1.035x10^{+5}$	$-7.910x10^{+5}$	0	0
C_2H_2	C_2H_2-1	$1.340x10^{+1}$	$-2.536x10^{+3}$	0	0	0	0	0
C_2H_4	C_2H_4-1	$1.540x10^{+1}$	$-2.206\ 10^{+3}$	$-1.216x10^{+4}$	$2.843x10^{+5}$	$-2.203x10^{+6}$	0	0
C_2H_6	C_2H_6-1	$1.511x10^{+1}$	$-2.207x10^{+3}$	$-2.411x10^{+4}$	$7.744x10^{+5}$	$-1.161x10^{+7}$	$6.763x10^{+7}$	0
C_6H_6	C_6H_6-1	$1.735x10^{+1}$	$-5.663x10^{+3}$	0	0	0	0	0
HCN	HCN-1	$1.393x10^{+1}$	$-3.624x10^{+3}$	$-1.325x10^{+5}$	$6.314x10^{+6}$	$-1.128x10^{+8}$	0	0
HC_3N	HC_3N-1	$1.301x10^{+1}$	$-4.426x10^{+3}$	0	0	0	0	0
C_2N_2	C_2N_2-1	$1.653x10^{+1}$	$-4.109x10^{+3}$	0	0	0	0	0
C_4N_2	C_4N_2-1	$1.909x10^{+1}$	$-6.036x10^{+3}$	0	0	0	0	0
N_2	N_2-1	$1.240x10^{+1}$	$-8.074x10^{+2}$	$-3.926x10^{+3}$	$6.297x10^{+4}$	$-4.633x10^{+5}$	$1.325x10^{+6}$	0
	N_2-2	8.514	$-4.584x10^{+2}$	$-1.987x10^{+4}$	$4.800x10^{+5}$	$-4.524x10^{+6}$	0	0
NH_3	NH_3-1	$1.596x10^{+1}$	$-3.537x10^{+3}$	$-3.310x10^{+4}$	$1.742x10^{+6}$	$-2.995x10^{+7}$	0	0
	NO-1	$1.691x10^{+1}$	$-2.016x10^{+3}$	0	0	0	0	0
	NO-2	$1.2352x10^{+2}$	$-4.7607x10^{+4}$	$7.7292x10^{+6}$	$-6.4950x10^{+8}$	$2.7061x10^{+10}$	$-4.4739x10^{+1}1$	0
N_2O	N_2O-1	$1.622x10^{+1}$	$-2.971x10^{+3}$	0	0	0	0	0
	N_2O-2	6.5664	$-1.2711x10^{+3}$	$-6.6835x10^{+5}$	$4.4959x10^{+7}$	$-1.0967x10^{+9}$		0 0
H_2S	H_2S-1	$1.298x10^{+1}$	$-2.707x10^{+3}$	0	0	0	0	0
	H_2S-2	8.933	$-7.260x10^{+2}$	$-3.504x10^{+5}$	$2.724x10^{+7}$	$-8.582x10^{+8}$	0	0
SO_2	SO_2-1	$1.560x10^{+1}$	$-3.5.08x10^{+3}$	$-9.401x10^{+4}$	$4.152x10^{+6}$	$-6.946x10^{+7}$	0	0
	AsH_3-1	$1.176x10^{+1}$	$-2.382x10^{+3}$	0	0	0	0	0
Ne	Ne-1	9.886	$-2.699x10^{+2}$	$1.283x10^{+2}$	$-1.624x10^{+2}$	0	0	0
	Ne-2	$1.061x10^{+1}$	$-3.086x10^{+2}$	$9.860x10^{+2}$	$-9.069x10^{+3}$	$3.514x10^{+4}$	0	0
Ar	Ar-1	$1.069x10^{+1}$	$-8.932x10^{+2}$	$-3.567x10^{+3}$	$6.574x10^{+4}$	$-4.280x10^{+5}$	0	0
Kr	Kr-1	$1.077x10^{+1}$	$-1.223x10^{+3}$	$-8.903x10^{+3}$	$2.635x10^{+5}$	$-4.260x10^{+6}$	$3.575x10^{+7}$	$-s1.210x10^{+8}$
Xe	Xe-1	$1.098x10^{+1}$	$-1.737x10^{+3}$	$-1.332x10^{+4}$	$4.349x10^{+5}$	$-7.027x10^{+6}$	$4.447x10^{+7}$	0

The special case of Water (H_2O). As a unique case due to its prevalence, its highly hydrogen bonded nature, and its phase changes at relatively high temperatures (for ices), water ice has been studied most extensively by many researchers over the last century and thus modeled differently in the literature. For water in "Astrophysical

Applications" Fray & Schmitt 2009 recommend the special (i.e., different than the $\ln(P_{sat}) = A_0 + \sum A_i/T^i$ of Table 2) treatment presented by Feistel and Wagner (2007):

$$\ln (P_{subl}(T)/P_{triple}) = 3/2 \ln (T/T_{triple}) + (1- T_{triple}/T)\, \eta(T/T_{triple})$$

where

P_{triple} = Pressure of Triple Point = (6.116577 +/- 0.0001) x 10^{-3} bar
T_{triple} = Temperature of Triple Point = 273.16 K

and

$$\eta(T/T_{triple}) = \sum e_i(T/T_{triple})^i$$

with

i	e_i
0	20.9969665107897
1	3.72437478271362
2	-13.9205483215524
3	29.6988765013566
4	-40.1972392635944
5	29.7880481050215
6	-9.13050963547721

Appendix References

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