E143 - May 25, 1993

Density of ammonia at the boiling point of nitrogen

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Requirement:

- minimize the contribution of the density of the target material to the experimental systematic uncertainties, through the dilution factor *f* and the packing fraction.

Solution:

- measure ρ_{NH3}, ρ_{ND3} at the boiling point of nitrogen (77.35 K) with better than 2% accuracy.

- extrapolate existing ρ_{NH3} data at higher (and lower) temperatures to the polarized target operating point: 1 K.

Technique:

- as reported at the experiment E143 meeting of Jan. 29, 1993, we use an electronic balance, with serial (RS-232) readout, connected to an IBM PC compatible computer. The balance reads the weight of the ammonia samples loaded in a volumetric flask immersed in a dewar full of liquid nitrogen, once per second, as the LN_2 evaporates. LN_2 is added to the flask and the total volume (LN_2 + ammonia) is read several times, while the computer records the weight.

The data are collected by a spreadsheet program (AS-EASY-AS.. V5.5) and stored directly in the cells of a worksheet for reduction and analysis

Results
Density of nitrogen at the boiling point.

Review of existing data:

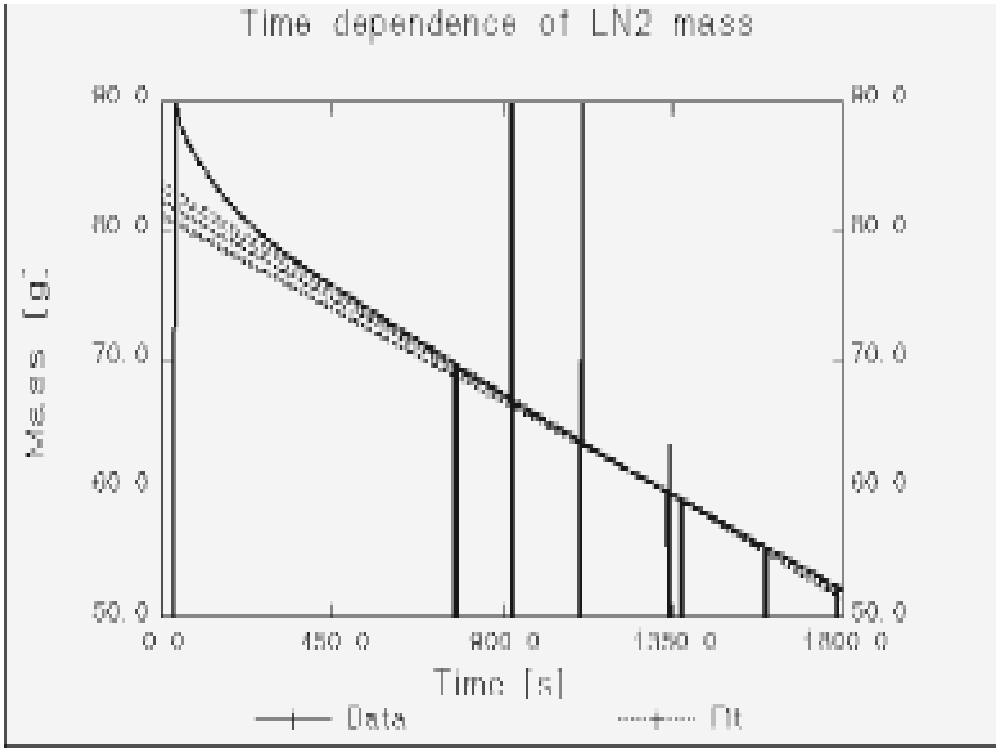
Temperature	Density	Reference
77.35 K (extrapolated from data at 70 to 76 K)	**805.9** [kg/m^3]	*Thermodynamic Properties of Nitrogen,* N.N. Sychev *et al.*, 1987, p.147-150.
77.25 K	28.881 [mol/l]= **809.1** [g/l]	*CRC Handbook of Chemistry and Physics,* 71st. Ed., 1991, p. 6-17.
-195.8° C (77.35 K)	**.8081** [g/cm^3]	Loc. cit., p. 4-84.
Liq. @ boiling pt.	**804** [kg/m^3]	Loc. cit., p. 6-97
77.35 K	1.239 [dm^3/kg]= **807.1** [kg/m^3]	*Tables of the Thermophysical Properties of Liquids and Gases,* N. Vargaftik, 1975, p. 433.
-195.84° C (77.31 K)	**.808$_4$**	A.I.P. *Handbook of Physics,* 2nd. ed. 1963, p. 2-155
77.35 K	**.81** [g/cm^3]	*Smithsonian Physical Tables,* 9 ed., rev., 1969, p. 291.

Comments:
These values have a standard deviation of 0.002 [g/ml]. It is not clear how to combine them. A weighted average with 0.001 [g/ml] uncertainties for all values except the last one (0.01 g/ml) is:

.806 [g/ml] +/- 0.004 [g/ml]

where the error reflects the contributions of different temperatures, techniques and age of the values.

Measurement:



Fitted values:

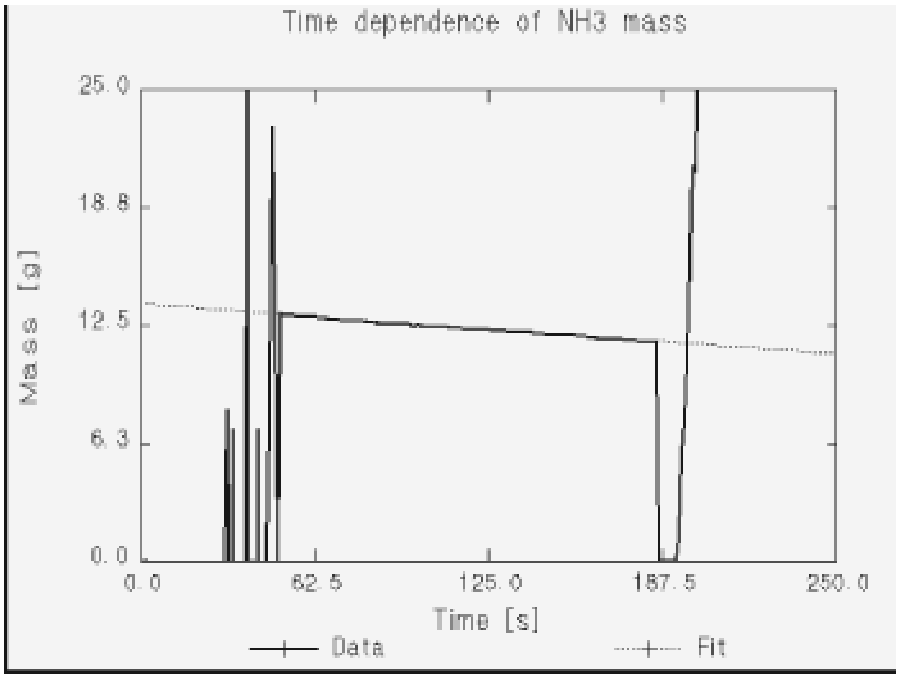
Reading	LN2 vol	LN2 mass	LN2 rho	(δρ_N/ρ_N)
	ml	g	g/ml	
1	103.3	83.67	0.810	0.11%
2	102.8	83.06	0.808	0.19%
3	102.5	82.12	0.801	0.13%
4	102.2	82.32	0.805	0.12%
5	102.1	80.95	0.793	1.41%
6	102.0	81.28	0.797	0.12%
7	101.9	81.28	0.798	0.16%

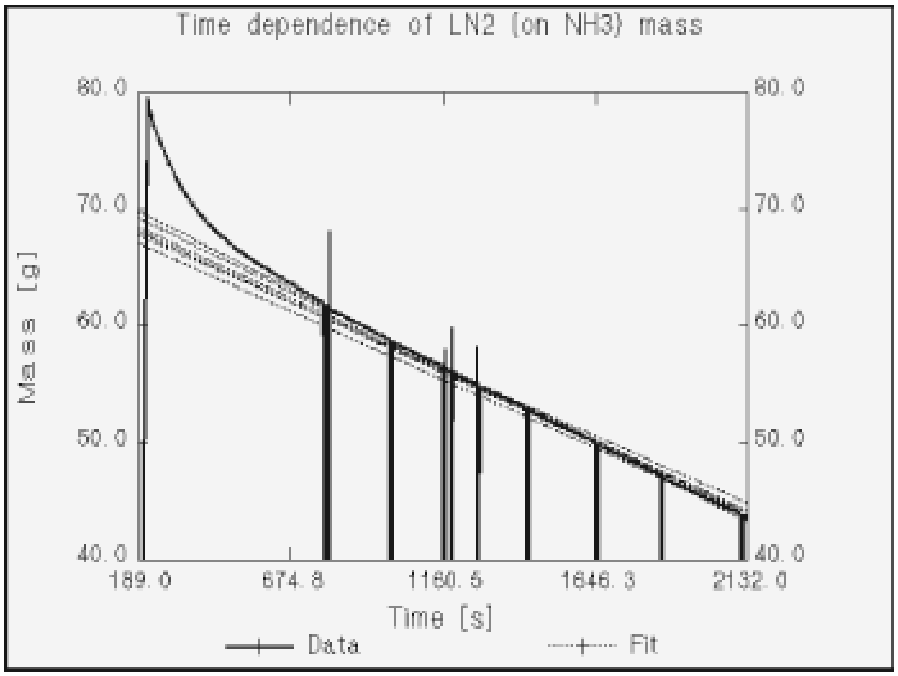
Results:

Density	Simple	Weighted	
<ρ>	0.8034	0.8051	**g/ml**
δρ	0.0024	0.0004	**g/ml**
δρ/ρ	0.3%	0.05%	

Density of ordinary ammonia

Measurements:





Fitted values:

Reading	Tot Vol	LN2 mass	LN2 Vol	NH3 Vol	NH3 rho	(δρ_A/ρ_A)
	ml	g	ml	ml	g/ml	
1	102.1	69.76	86.64	15.46	0.88	2.92%
2	101.7	69.17	85.92	15.78	0.86	2.82%
3	101.2	67.70	84.09	17.11	0.79	3.07%
4	100.9	68.40	84.96	15.94	0.85	2.85%
5	100.6	68.00	84.46	16.14	0.84	2.72%
6	100.4	68.04	84.51	15.89	0.86	2.81%
7	100.2	67.03	83.25	16.95	0.80	2.53%

Results:

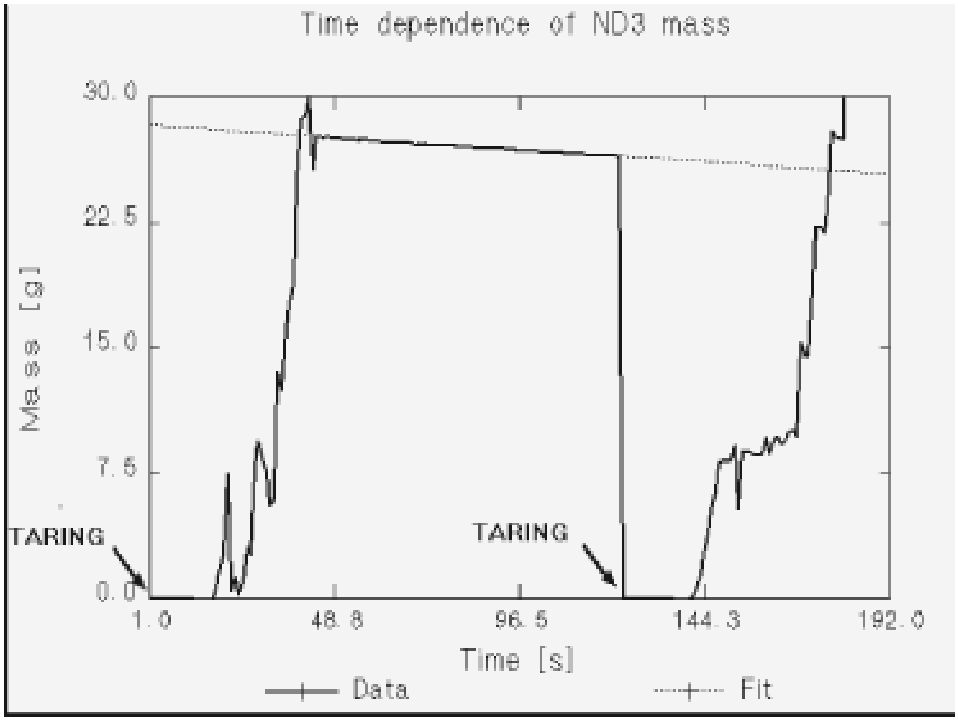
NH3 mass	13.595	**g**	
d_m_NH3	0.012	**g**	
Density	**Simple**	**Weighted**	
<ρ>	0.843	0.840	**g/ml**
δρ	0.012	0.009	**g/ml**
δρ/ρ	1.41%	1.06%	

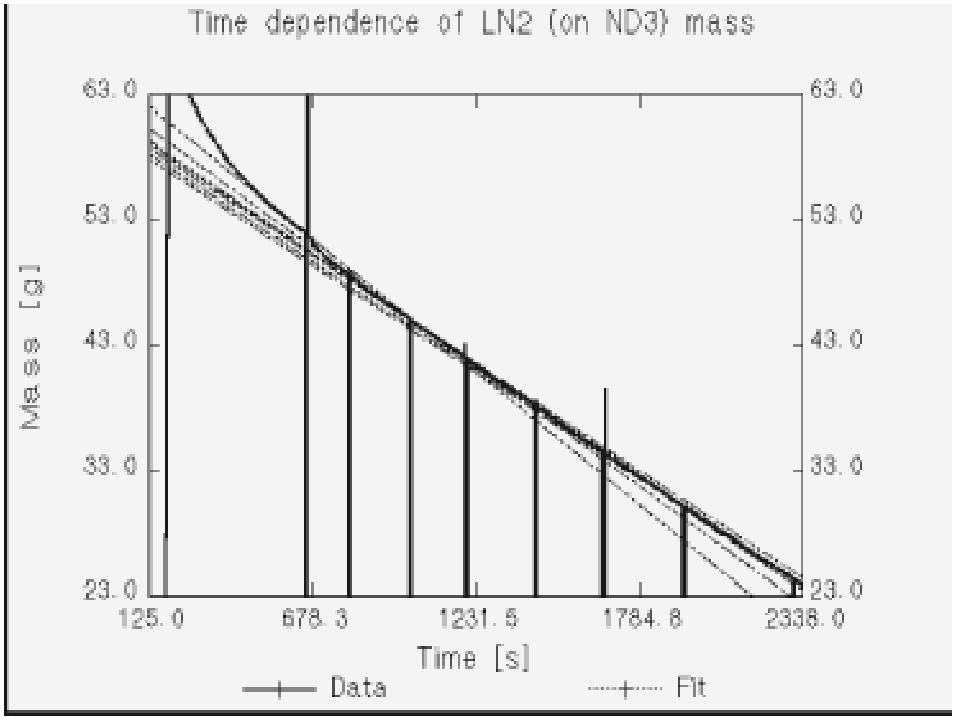
Comments:

Value agrees within errors with line fit to other measurements of solid ammonia density versus temperature, from the freezing point of ammonia to the boiling point of nitrogen.

Density of deuterated ammonia

Measurements:





Fitted values:

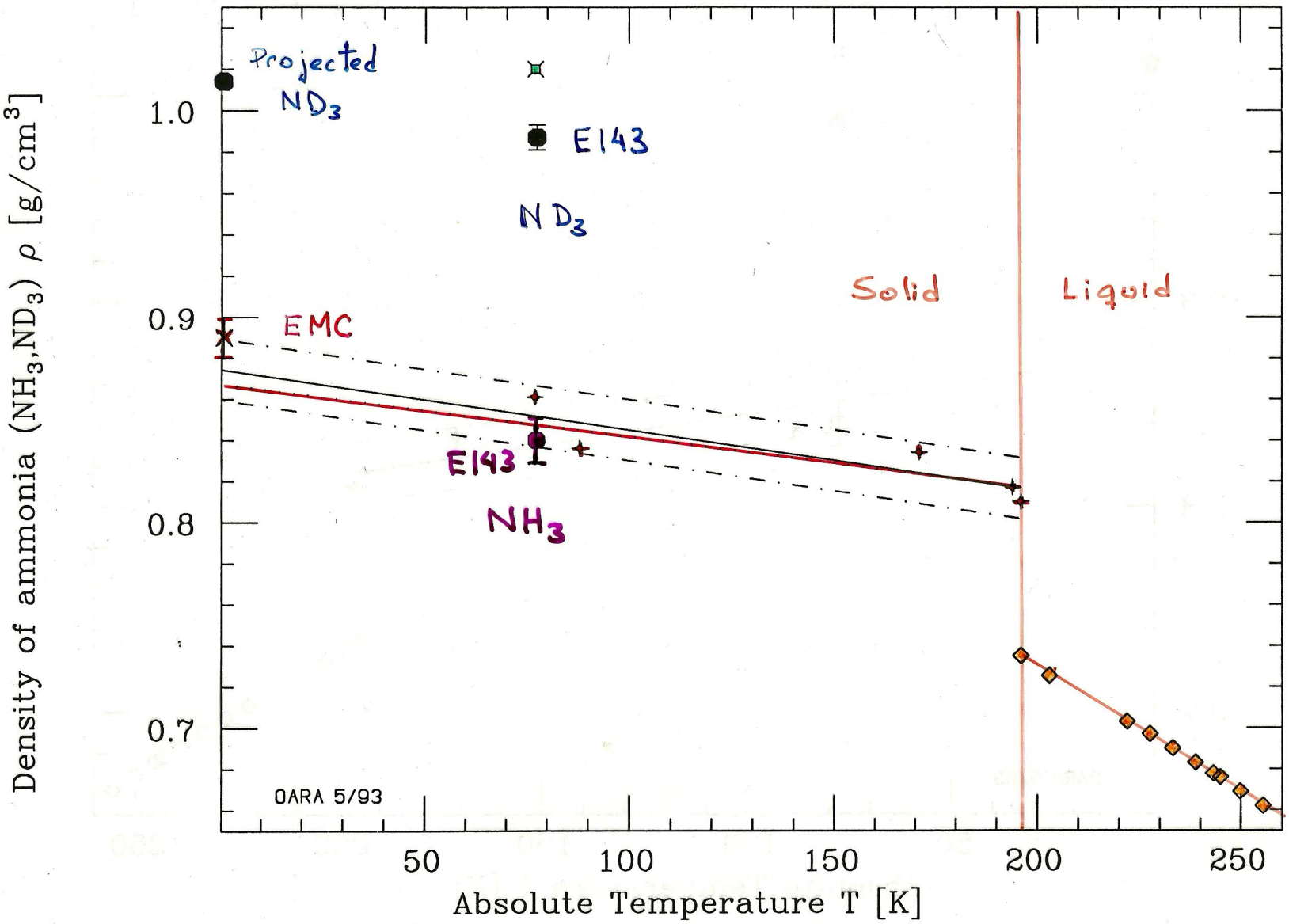
Reading	Tot Vol	LN2 mass	LN2 Vol	ND3 Vol	ND3 rho	(δρ_A/ρ_A)
	ml	g	ml	ml	g/ml	
1	103.9	61.99	77.00	26.90	1.05	1.53%
2	103.6	60.82	75.54	28.06	1.01	1.84%
3	103.4	59.82	74.30	29.10	0.97	1.92%
4	103.2	59.42	73.80	29.40	0.96	1.65%
5	103.0	59.77	74.24	28.76	0.98	1.74%
6	102.8	60.05	74.59	28.21	1.00	1.83%
7	102.7	58.96	73.23	29.47	0.96	1.65%
8	102.5	58.56	72.74	29.76	0.95	1.67%

Results:

ND3 mass	28.26	**g**	
d_m_ND3	0.02	**g**	
Density	**Simple**	**Weighted**	
<ρ>	0.988	0.987	**g/ml**
δρ	0.012	0.006	**g/ml**
δρ/ρ	1.19%	0.61%	

Comments:

The ratio of the densities (ρ_{NH3}/ρ_{ND3}) = **0.8511** is equal (within the uncertainties of the measurements) to the ratio of the molecular weights (M_{NH3}/M_{ND3}) = **0.8493**. This is expected to be the case since both material have the same crystalline structure. The same ratio is seen for the two measurements of the lattice constant: 0.861/1.02 = **0.8441**. This is also the case of H_2O/D_2O = 0.9047 for the density and 0.8995 for the weights. This would imply that both substances should have the same ρ(t) dependence.


Projected
ND_3
E143
ND_3
Solid
Liquid
EMC
E143
NH_3
OARA 5/93
1.0
0.9
0.8
0.7
50
100
150
200
250
Density of ammonia (NH_3,ND_3) ρ [g/cm^3]
Absolute Temperature T [K]

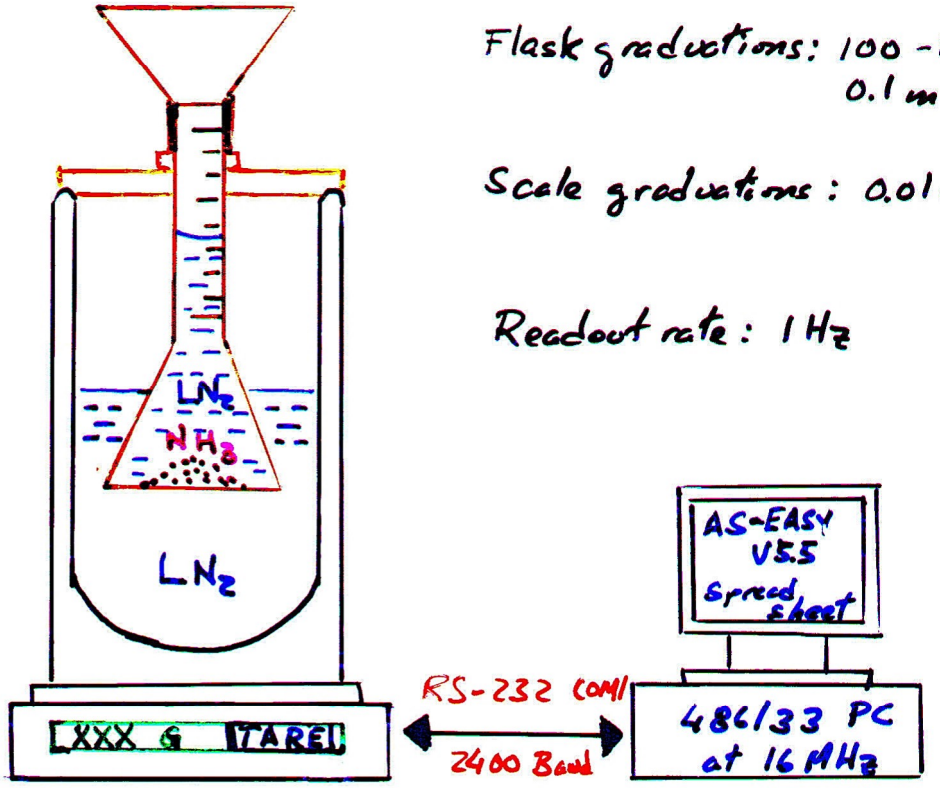
Technique for measuring $\rho(T = LN_2)$ and finding $\rho(T = 1K)$

1.- Determine weight of NH_3 material by loading into volumetric flask

2.- Add LN_2 to find volume of NH_3: $V_{NH_3} = V_{Total} - M_{LN_2}/\rho_{LN_2}$

3.- Compute $$\rho_{NH_3} = \frac{M_{NH_3}}{V_T - M_{LN_2}/\rho_{LN_2}} = \frac{M_A}{V_T - M_N/\rho_N}$$

Use an electronic serial output (RS-232) scale to determine losses of LN_2 by evaporation during weighing



Flask graduations: 100 - 110 ml
0.1 ml divisions

Scale graduations: 0.01 g to 3 Kg

Readout rate: 1 Hz