Investigating Boyle's Law & Charle's Law

Boyle's Law:

$pV = \text{constant}$ (for constant amount of ideal gas at constant temperature)

$$(p_a + \Delta p)V = \text{constant}$$

$$\Delta p = \frac{mg}{A} \qquad A = \frac{1}{4}\pi d^2$$

$$\Big(\underset{\text{constant}}{P_a} + \frac{4\overset{\text{variable}}{m}\overset{\text{constant}}{g}}{\underset{\text{constant}}{\pi d^2}}\Big)\underset{\text{variable}}{V} = \overset{\text{constants}}{k}$$

$$\boxed{P_a}\boxed{V} + \boxed{\frac{4g}{\pi d^2}}\boxed{m}\boxed{V} = \boxed{k}$$

$$\boxed{P_a} + \boxed{\frac{4g}{\pi d^2}}\boxed{m} = \boxed{k}\cdot\boxed{\frac{1}{V}}$$

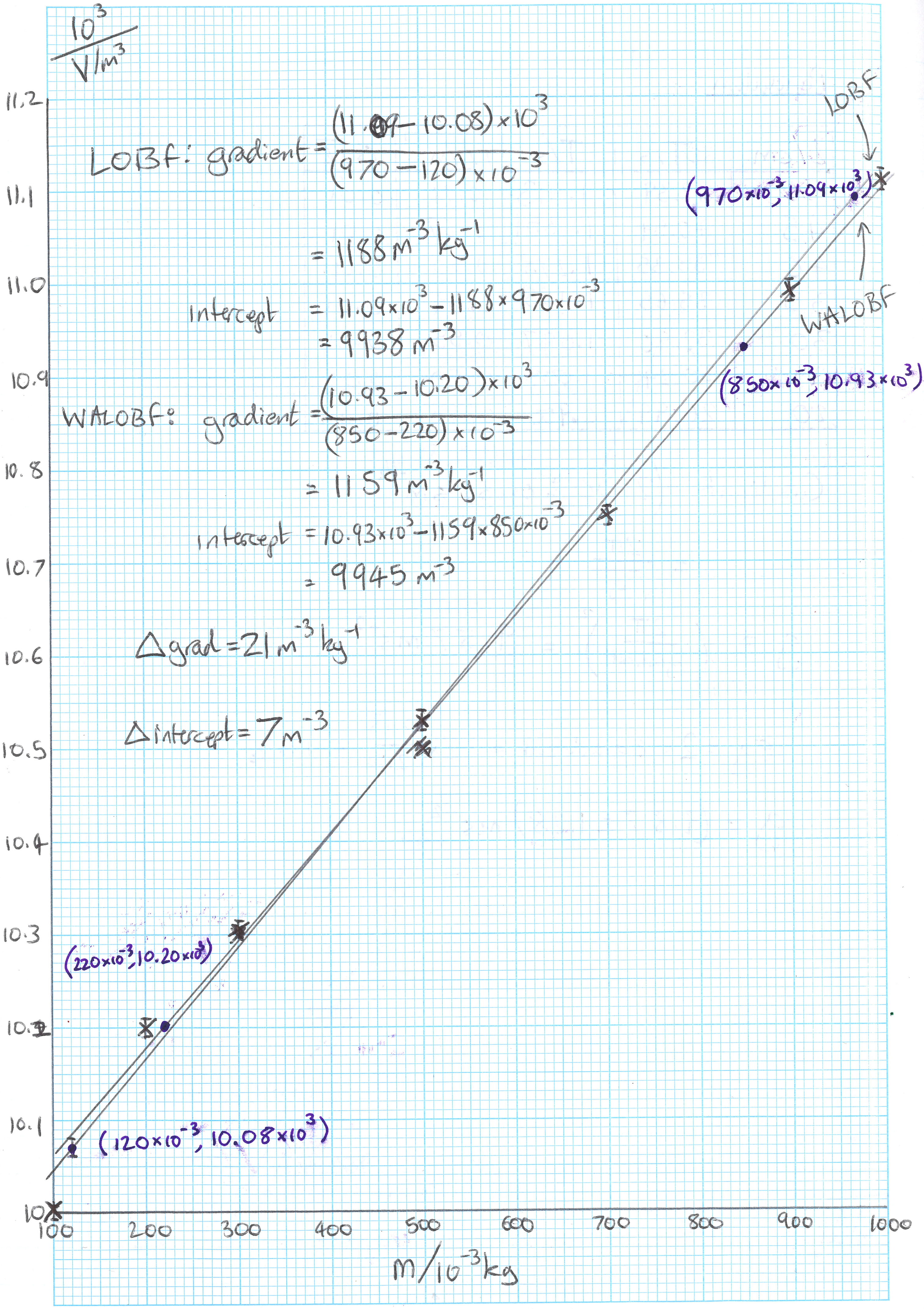
$$\boxed{\frac{1}{V}} = \boxed{\frac{4g}{\pi d^2 k}}\boxed{m} + \boxed{\frac{1}{k}P_a}$$

mass added, m/kg	volume, V/m^3	$1/(V/m^3)$
96.94×10^{-3} $\cancel{98.94\times10^{-3}}$	100×10^{-6}	10000
196.94×10^{-3}	98×10^{-6}	10204
296.94×10^{-3}	97×10^{-6}	10309
496.94×10^{-3}	95×10^{-6}	10526
696.94×10^{-3}	93×10^{-6}	10753
896.94×10^{-3}	91×10^{-6}	10989
996.94×10^{-3}	90×10^{-6}	11111

$d/\text{mm} = 31.2, 31.2, 31.1, 31.1, 31.1, 31.2, 31.1$

$\langle d/\text{mm}\rangle = 31.143 \pm 0.05 = 31.14 \pm 0.05$

plunger mass = ~~49.06g~~, 96.94g



LOBF: $\text{gradient} = \dfrac{(11.09-10.08)\times10^{3}}{(970-120)\times10^{-3}}$

$= 1188\ m^{-3}\,kg^{-1}$

$\text{intercept} = 11.09\times10^{3} - 1188\times970\times10^{-3}$

$= 9938\ m^{-3}$

WALOBF: $\text{gradient} = \dfrac{(10.93-10.20)\times10^{3}}{(850-220)\times10^{-3}}$

$= 1159\ m^{-3}\,kg^{-1}$

$\text{intercept} = 10.93\times10^{3} - 1159\times850\times10^{-3}$

$= 9945\ m^{-3}$

$\Delta\text{grad} = 21\ m^{-3}\,kg^{-1}$

$\Delta\text{intercept} = 7\ m^{-3}$

$$\frac{4g}{\pi d^2 k} = (1188 \pm 21)\ m^{-3}kg^{-1}$$

$$\frac{1}{k}P_a = (9938 \pm 7)\ m^{-3}$$

$$d = (31.14 \pm 0.05) \times 10^{-3}\ m$$

$$g = 9.81\ N\,kg^{-1}$$

$$\cancel{k = \frac{4 \times 9.81}{\pi \times (31.14 \times 10^{-3})^2} = 12668\ Pa\,m^3}$$

$$\cancel{\varepsilon k = 2 \times \varepsilon}$$

$$k = \frac{4 \times 9.81}{\pi \times (31.14 \times 10^{-3})^2 \times 1188} = 10.66\ Pa\,m^3$$

$$\varepsilon k = 2 \times \varepsilon d + \varepsilon grad = 2 \times 0.16 + 1.8 = 2.1\%$$

$$k = (10.66 \pm 0.23)\ Pa\,m^3$$

$$P_a = 9938 \times 10.66 = 105900\ Pa$$

$$\varepsilon P_a = \varepsilon k + \varepsilon\, intercept = 2.2 + 0.070 = 2.2\%$$

$$P_a = (105900 \pm 2330)\ Pa = (105900 \pm 2300)\ Pa$$

Expected $P_a = 102440\ Pa$

Close to measured value but not within uncertainty.

Charles' Law:

$V = kT$ if pressure and amount of gas are constant

Length of air, L/cm	Temperature, θ/°C
16.2	16
19.7	90
18.8	66
18.3	55
17.8	43
17.2	29
17.5	37

$$V = A(L + \ell)$$

zero

measured length

$$L + \ell = kT = k(\theta + T_0)$$

$$L + \ell = k\theta + kT_0$$

$$L = k\theta + \underbrace{(kT_0 - \ell)}_{\text{y-intercept}}$$

y-axis   gradient   x-axis

$$kT_0 - \ell = (15.94 \pm 0.46)$$

$$(4.237 \pm 0.578) \times 10^{-2}\, T_0 - \ell = (15.94 \pm 0.46)$$

$$\ell = (2 \pm 1)\ \text{mm}$$

LOBF gradient $= \dfrac{18.95 - 16.45}{71 - 12} = 4.237 \times 10^{-2}\ \text{cm}\,^\circ\text{C}^{-1}$

intercept $= 18.95 - 4.237 \times 10^{-2} \times 71$

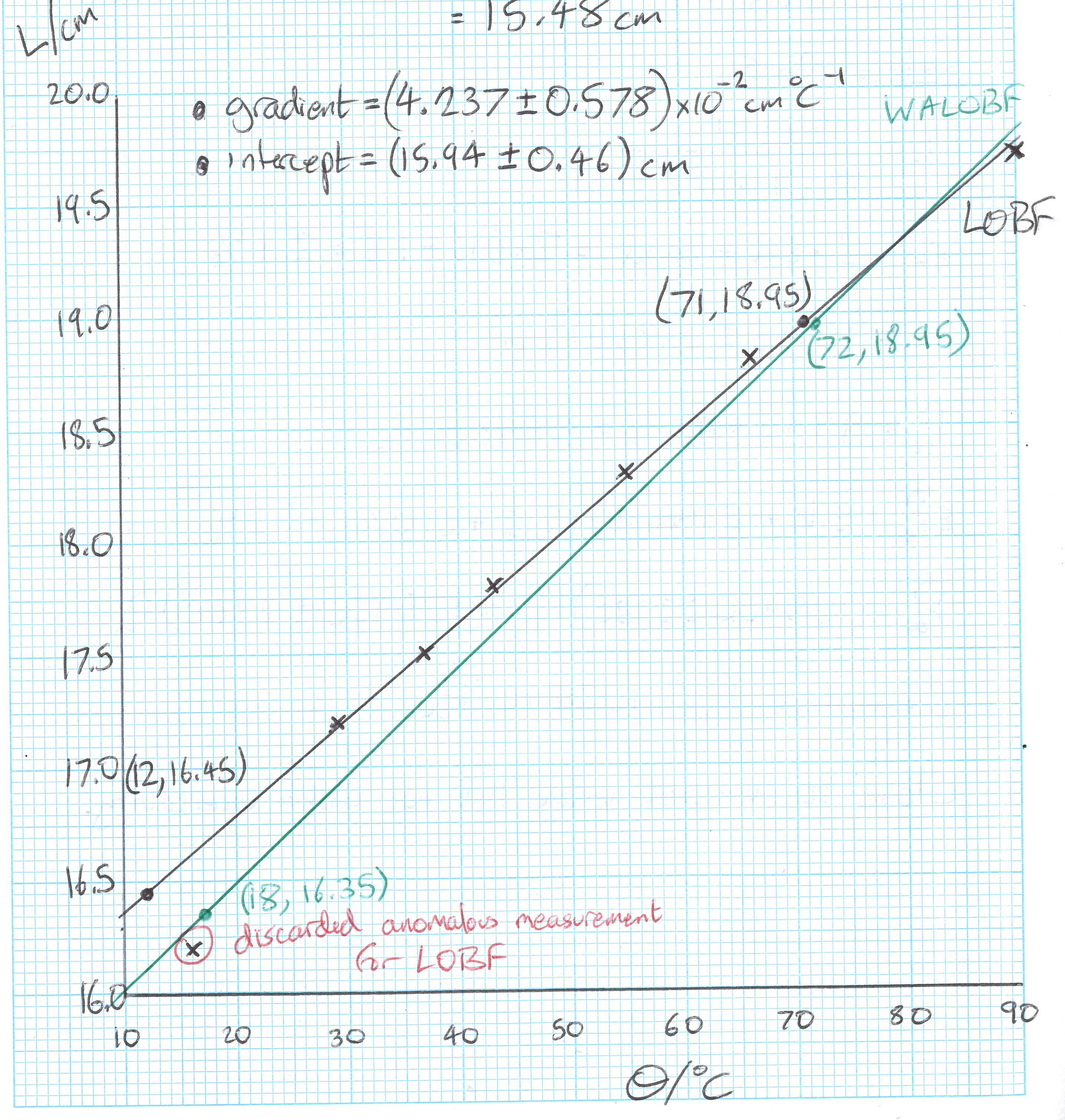
$= 15.94\ \text{cm}$

WALOBF gradient $= \dfrac{18.95 - 16.35}{72 - 18} = 4.815 \times 10^{-2}\ \text{cm}\,^\circ\text{C}^{-1}$

intercept $= 18.95 - 4.815 \times 10^{-2} \times 72$

$= 15.48\ \text{cm}$

- gradient $= (4.237 \pm 0.578) \times 10^{-2}\ \text{cm}\,^\circ\text{C}^{-1}$
- intercept $= (15.94 \pm 0.46)\ \text{cm}$



$$(4.237 \pm 0.578) \times 10^{-2}\, T_0 - (2 \pm 1) \times 10^{-1} = (15.94 \pm 0.46)$$

$$T_0 = \frac{(15.94 \pm 0.46) + (0.2 \pm 0.1)}{(4.237 \pm 0.578) \times 10^{-2}}$$

$$\langle T_0 \rangle = \frac{15.94 + 0.2}{4.237 \times 10^{-2}} = 380.93\ K$$

$$\Delta(15.94 + 0.2) = 0.46 + 0.1 = 0.56\ cm$$

$$\varepsilon(15.94 + 0.2) = 3.47\%$$

$$\varepsilon(4.237 \times 10^{-2}) = 13.64\%$$

$$\varepsilon T_0 = 13.64\% + 3.47\% = 17.1\%$$

$$T_0 = (380.93 \pm 65.18)K$$
$$= (381 \pm 65)K$$

Expected value for freezing point of water = 273 K
This value is not within uncertainty of measured value.

Expected value according to https://www.britannica.com/science-/absolute-zero

Accessed 29-Sept-2025 @ 07:56