

The vapour pressure of 1,1,1,2-tetrafluoroethane (HFC-134a) is 132.9 kPa at -20°C and 292.9 kPa at 10°C . Estimate the normal boiling point of HFC-134a. [4]

recall $\ln P^{\circ} = -\frac{\Delta H_{\text{vap}}}{RT} + \text{constant}$

$\therefore \ln\left(\frac{P_2}{P_1}\right) = -\frac{\Delta H_{\text{vap}}}{R} \left(\frac{1}{T_2} - \frac{1}{T_1}\right)$ where $P_1 = 132.9 \text{ kPa}$ at $T_1 = 253.2 \text{ K}$
and $P_2 = 292.9 \text{ kPa}$ at $T_2 = 283.2 \text{ K}$

$\therefore \Delta H_{\text{vap}} = \frac{-\ln\left(\frac{P_2}{P_1}\right)}{\left(\frac{1}{T_2} - \frac{1}{T_1}\right)} = \frac{-(0.7902)(8.314 \text{ J mol}^{-1} \text{ K}^{-1})}{(-4.1837 \times 10^{-4} \text{ K}^{-1})} = 15700 \frac{\text{J}}{\text{mol}}$

BP is temp at which $P = 1 \text{ atm}$ (or 101.300 kPa)

So $\ln\left(\frac{P_{\text{BP}}}{P_1}\right) = \frac{-15700 \text{ J}}{8.314 \text{ J mol}^{-1} \text{ K}^{-1}} \left(\frac{1}{T_{\text{b}}} - \frac{1}{T_1}\right)$
 \uparrow 101.3 kPa \uparrow 132.9 kPa \uparrow 253.2 K

$\therefore \left(\frac{1}{T_{\text{b}}} - \frac{1}{253.2}\right) = 1.4375 \times 10^{-4} \text{ K}^{-1}$ and $T_{\text{b}} = 244.3 \text{ K}$

● Pure 1,4-dichlorobenzene (DCB) is still used as a disinfectant and 'air-refresher' in some public urinals. You want to calculate the concentration of DCB in g per m³ of air at 25 °C.

a) Estimate using only melting point ($T_m = 53.0\text{ °C}$) and boiling point ($T_b = 173.9\text{ °C}$) data. [3]

b) Refine your answer using the vapour pressure data given below. [2]

T (°C)	29.1	44.4	54.8	84.8	108.4	150.2
P° (mm Hg)	1	4	10	40	100	400

a) $T_m = 326.2\text{ K}$ $T_b = 447.1\text{ K}$

we want P° at 298 K where DCB is solid

∴ we need $P^\circ(s)$

use T_b to estimate $P^\circ(L)$, then T_m to estimate $P^\circ(s)$
convert to g/m³ using ideal gas law.

$$\ln P^\circ(L) \text{ in atm} \cong 19 \left(1 - \frac{447.1}{298}\right) + 8.5 \left(\ln \frac{447.1}{298}\right)$$

$$= -9.4506 + 3.448 = -6.058$$

$$\therefore P^\circ(L) = e^{-6.058} = 2.338 \times 10^{-3} \text{ atm}$$

$$\ln \frac{P^\circ(s)}{P^\circ(L)} \cong 6.8 \left(\frac{326.2}{298} - 1\right) = -0.6435$$

$$\text{so } P^\circ(s) = P^\circ(L) \cdot e^{-0.6435} = 1.228 \times 10^{-3} \text{ atm}$$

$$C_g = \frac{n}{V} = \frac{P}{RT} = \frac{1.228 \times 10^{-3} \text{ atm}}{(0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol K}})(298 \text{ K})} = 5.024 \times 10^{-5} \frac{\text{mol}}{\text{L}}$$

$$5.024 \times 10^{-5} \frac{\text{mol}}{\text{L}} \times 146.9 \frac{\text{g}}{\text{mol}} \times \frac{10^3 \text{ L}}{1 \text{ m}^3} = 7.38 \text{ g/m}^3$$

b) from a plot of $\ln P_{(s)}^{\circ}$ vs $\frac{1}{T}$
 the slope is equal to $-\frac{\Delta H_{\text{sub}}}{R}$
 (see attach graph)

$$\therefore -\frac{\Delta H_{\text{sub}}}{R} = -8688 \text{ K}$$

$$\left(\text{or } \Delta H_{\text{sub}} = 72232 \frac{\text{J}}{\text{mol}} \right)$$

$$\text{Since } \ln\left(\frac{P_2}{P_1}\right) = -\frac{\Delta H_{\text{sub}}}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$$

we can write,

$$\ln\left(\frac{P_2}{1 \text{ torr}}\right) = -8688 \text{ K}^{-1} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$$

\uparrow \uparrow
 298 K 302.3 K

$$= -0.4147$$

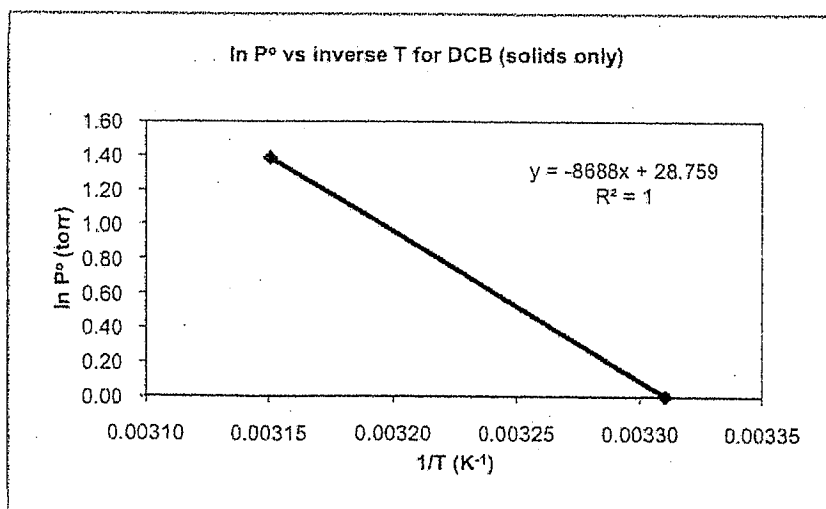
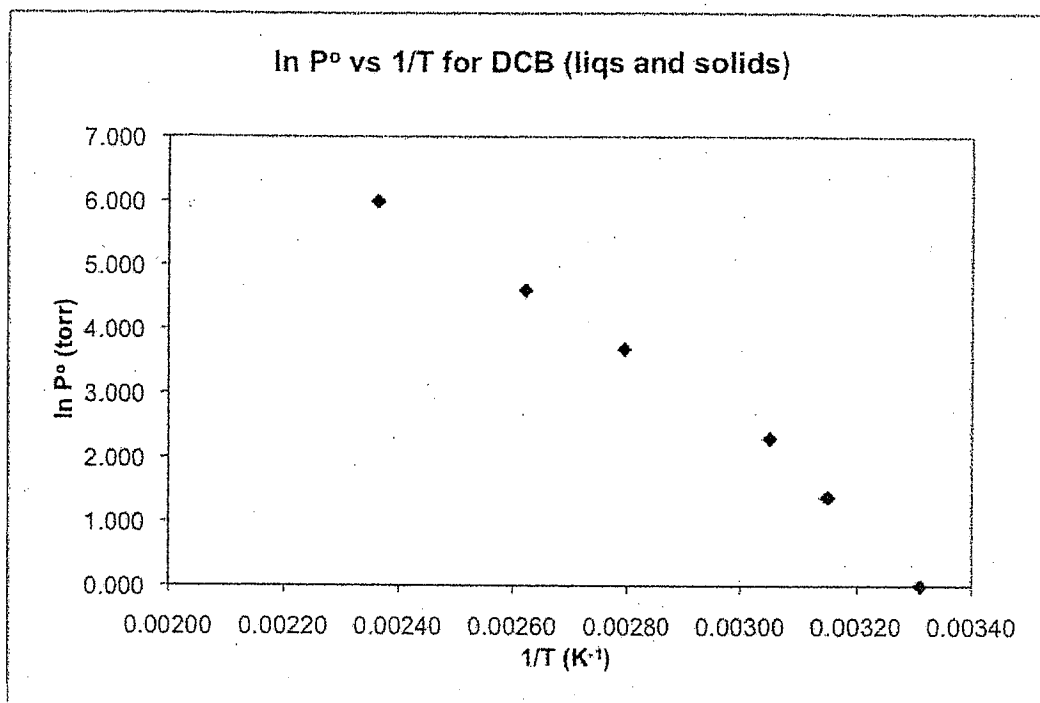
$$\therefore P_2 = (e^{-0.4147}) (1 \text{ torr}) = 0.661 \text{ torr}$$

$$0.661 \text{ torr} \times \frac{1 \text{ atm}}{760 \text{ torr}} \times \frac{1}{\left(\frac{0.08206 \text{ L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \right) (298 \text{ K})}$$

$$\times 146.9 \frac{\text{g}}{\text{mol}} \times \frac{10^3 \text{ L}}{1 \text{ m}^3} = 5.22 \frac{\text{g}}{\text{m}^3}$$

Data and Plots for 1,4-DCB Question

T(°C)	1/T (K ⁻¹)	P° (torr)	ln P°
29.1	0.00331	1	0.000
44.4	0.00315	4	1.386
54.8	0.00305	10	2.303
84.8	0.00279	40	3.689
108.4	0.00262	100	4.605
150.2	0.00236	400	5.991



slope = $-\Delta H_{\text{sub}}/R$