

1. A 50.0 L gas cylinder contains 2080. g of oxygen ($O_{2(g)}$). Calculate its pressure at 27°C using:

- The ideal gas law
- The Van der Waals equation (i.e., the 'real' gas equation), where the Van der Waals constants for $O_{2(g)}$ are $a = 1.382 \text{ L}^2 \cdot \text{atm}/\text{mol}^2$, and $b = 0.03186 \text{ L}/\text{mol}$

$$a) PV = nRT$$

$$P = ?$$

$$V = 50.0 \text{ L}$$

$$n = 2080. \text{ g} \times \frac{1 \text{ mol}}{31.998 \text{ g}} = 65.00406275 \text{ mol}$$

$$R = 0.08206 \text{ L} \cdot \text{atm}/\text{mol} \cdot \text{K}$$

$$T = 27^\circ\text{C} + 273 = 300 \text{ K}$$

$$P = \frac{nRT}{V} = \frac{(65.00406275 \text{ mol})(0.08206 \text{ L} \cdot \text{atm}/\text{mol} \cdot \text{K})(300 \text{ K})}{(50.0 \text{ L})}$$

$$= 32.00540034 \text{ atm}$$

$$P = 32.0 \text{ atm}$$

$$b) \left(P + \frac{an^2}{V^2} \right) = \frac{nRT}{(V - nb)}$$

$$P + \frac{(1.382)(65.004 \text{ mol})^2}{(50.0)^2} = \frac{(65.00406275)(0.08206)(300)}{50.0 - (65.00406275)(0.03186)}$$

$$P + 2.335871975 = \frac{1600.270017}{50.0 - 2.071029439}$$

$$P + 2.335871975 = \frac{1600.270017}{47.92897056}$$

$$P = 33.38836612 - 2.335871975$$

$$P = 31.05249415 \text{ atm}$$

$$P = 31.1 \text{ atm}$$

2. Given the data below,

a. Show a Born-Haber cycle for magnesium oxide

b. Calculate the crystal lattice energy for magnesium oxide

$$\Delta H^\circ_f (\text{MgO}) = -601.6 \text{ kJ/mol}$$

$$\text{E.A.}_1 (\text{O}) = -142 \text{ kJ/mol}$$

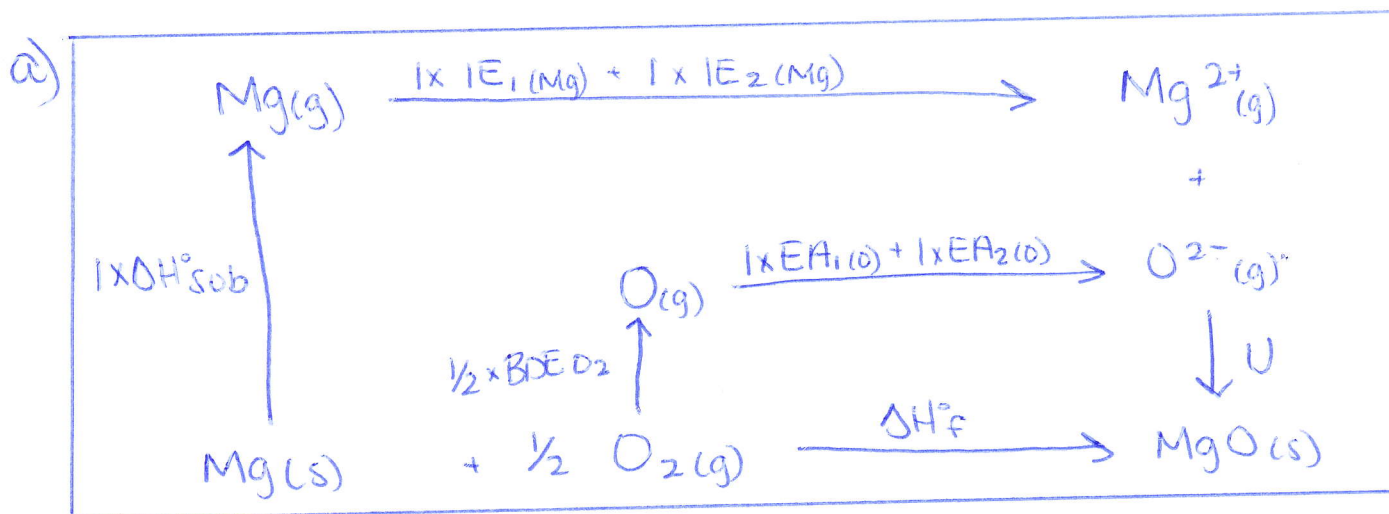
$$\text{E.A.}_2 (\text{O}) = 844 \text{ kJ/mol}$$

$$\text{BDE} (\text{O}_2) = 498 \text{ kJ/mol}$$

$$\text{I.E.}_1 (\text{Mg}) = 737.7 \text{ kJ/mol}$$

$$\text{I.E.}_2 (\text{Mg}) = 1451 \text{ kJ/mol}$$

$$\Delta H^\circ_{\text{sub}} (\text{Mg}) = 146 \text{ kJ/mol}$$



b)

$$\Delta H^\circ_f = 1(\Delta H^\circ_{\text{sub}}) + 1(\text{IE}_1) + 1(\text{IE}_2) + \frac{1}{2}(\text{BDE}) + 1(\text{EA}_1) + 1(\text{EA}_2) + U$$

$$-601.6 = 146 + 737.7 + 1451 + \frac{1}{2}(498) + (-142) + 844 + U$$

$$-601.6 = 3036.7 + 249 + U$$

$$U = -3887.3 \text{ kJ/mol}$$

$$U = -3887 \text{ kJ/mol}$$

or

$$-3.887 \times 10^3 \text{ kJ/mol}$$

3. Rubbing alcohol (isopropyl alcohol, C_3H_8O) purchased at your pharmacy has a molarity of 8.00 M, with a density of 0.85 g/mL. Calculate its molality.

$$\text{molality} = \frac{\# \text{ mol } C_3H_8O}{\# \text{ kg } H_2O}$$

$$M = \frac{8.00 \text{ mol}}{1L}$$

Assume 1 L:

$$n_{C_3H_8O} = 8.00 \text{ mol}$$

$$\text{mass sol}^n = 1000 \text{ mL} \times \frac{0.85 \text{ g}}{1 \text{ mL}} = 850 \text{ g}$$

$$\text{mass } C_3H_8O = 8.00 \text{ mol} \times \frac{60.096 \text{ g}}{1 \text{ mol}} = 480.768 \text{ g}$$

$$\therefore \text{mass } H_2O = \text{mass sol}^n - \text{mass } C_3H_8O$$

$$= 850 \text{ g} - 480.768 \text{ g} = 369.232 \text{ g} \times \frac{1 \text{ kg}}{1000 \text{ g}}$$

$$= 0.369238 \text{ kg}$$

$$\therefore \text{molality} = \frac{8.00 \text{ mol}}{0.369238 \text{ kg}}$$

$$= 21.66659444 \text{ m}$$

$$\boxed{= 22 \text{ m}}$$

4. Calcium chloride, $\text{CaCl}_{2(s)}$, can be added to roads as road salt. Collecting a sample of melt-water on the side of the road, you find that this solution contains 26.4 % (m/m) CaCl_2 . Calculate the normal freezing point of your solution in $^{\circ}\text{C}$, given that $K_f(\text{H}_2\text{O}) = 1.86^{\circ}\text{C/m}$

$$\Delta T_f = K_f \cdot m \cdot i \quad \text{CaCl}_2 \rightarrow \text{Ca}^{2+} + 2\text{Cl}^- ; i = 3$$

molality of solution :

$$26.4\% \text{ (m/m)} \rightarrow \text{In } 100 \text{ g} \begin{cases} \rightarrow 26.4 \text{ g CaCl}_2 \\ \rightarrow 73.6 \text{ g H}_2\text{O} \end{cases}$$

$$\text{molality} = \frac{n_{\text{CaCl}_2}}{\# \text{ kg H}_2\text{O}}$$

$$n_{\text{CaCl}_2} = 26.4 \text{ g} \times \frac{1 \text{ mol}}{110.97 \text{ g}} = 0.237889273 \text{ mol}$$

$$\# \text{ kg H}_2\text{O} = 73.6 \text{ g} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.0736 \text{ kg}$$

$$\text{molality} = \frac{0.237889273 \text{ mol}}{0.0736 \text{ kg}} = 3.232191214 \text{ m}$$

$$\begin{aligned} \Delta T_f &= (1.86^{\circ}\text{C/m})(3.232191214 \text{ m})(3) \\ &= 18.03562697^{\circ}\text{C} \end{aligned}$$

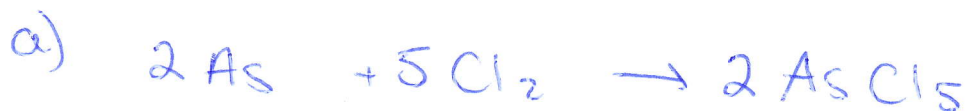
$$\therefore \text{Freezing point} = 0^{\circ}\text{C} - 18.03562697^{\circ}\text{C}$$

$$\boxed{= -18.0^{\circ}\text{C}}$$

5. Arsenic reacts with molecular chlorine to give arsenic pentachloride.



- Balance the above reaction.
- If you react 125 g of arsenic with 260. g of chlorine and allowed them to react to completion, what mass of AsCl₅ would be produced, in grams



$$b) \quad n_{\text{As}} = 125 \text{ g} \times \frac{1 \text{ mol}}{74.922 \text{ g}} = 1.668401805 \text{ mol}$$

$$n_{\text{Cl}_2} = 260. \text{ g} \times \frac{1 \text{ mol}}{70.9 \text{ g}} = 3.667136812 \text{ mol}$$

Limiting reagent:

If ALL As reacted,

$$n_{\text{Cl}_2 \text{ needed}} = 1.668401805 \text{ mol As} \times \frac{5 \text{ mol Cl}_2}{2 \text{ mol As}} = 4.171004513 \text{ mol Cl}_2$$

∴ We don't have enough Cl₂ to fully react all of the As.

∴ Cl₂ will run out first. Cl₂ is the limiting reagent.

$$n_{\text{AsCl}_5} = 3.667136812 \text{ mol Cl}_2 \times \frac{2 \text{ mol AsCl}_5}{5 \text{ mol Cl}_2} \\ = 1.466854725 \text{ mol AsCl}_5$$

$$\text{mass AsCl}_5 = 1.466854725 \text{ mol} \times \frac{252.172}{1 \text{ mol}} = 369.8996897 \text{ g}$$

$$= 370. \text{ g or} \\ 3.70 \times 10^2 \text{ g}$$