Name:

Chem 3321, test #3 practice solutions

I want complete, detailed answers to the questions. Show all your work to get full credit.

DATA:

R = 0.082 L atm mol^{-1} K^{-1} = 8.314 J mol^{-1} K^{-1}

1 atm = 1.01 $\times$ 10^5 Pa = 1.01 bar = 760 torr

1 mL = 1 cm^3

1 Pa = 1 N m^{-2}

0 °C = 273 K

Avogadro's constant = N_A = 6.022 $\times$ 10^{23} mol^{-1}

π = 3.14159

1 eV = 1.6022$\times 10^{-19}$ J (electron volt to joule conversion)

mass conversion from amu to kg: 1.66 $\times$ 10^{-27} kg/amu

$C_P - C_V = nR$ for any ideal gas

Problem 1

A solution containing 1.470 g of dichlorobenzene in 50.00 g of benzene (molar mass 78.11 g/mol) boils at 80.6 °C at a pressure of 1.00 bar. The boiling point of pure benzene is 80.09 °C, and the molar enthalpy of vaporization of pure benzene is 32.0 kJ/mol. Determine the molar mass of dichlorobenzene from these data.

1)
Boiling point elevation

$\Delta T_{fus} = T^*_{vap} - T_{vap} = \left\{\frac{M_A\, R\, (T^*_{vap})^2}{1000 \text{ g kg}^{-1}\ \Delta\bar{H}}\right\} m$

$|353.75 - 353.24|\text{K} = \left\{\frac{78.11 \text{ g mol}^{-1} * 8.3145 \text{ J K}^{-1}\text{mol}^{-1} * (353.24 \text{ K})^2}{1000 \text{ g kg}^{-1} * 32.0 * 10^3 \text{ J mol}^{-1}}\right\} m$

$m = 0.2014 \text{ mol kg}^{-1}$

$m = \text{molality} = \left\{\frac{\#\text{ of moles of solute}}{\text{kg of solvent}}\right\} = \frac{n_{DB}}{\text{kg of benzene}}$

$$m = \frac{n_{DB}}{50 * 10^{-3}\text{kg}} = \frac{\left(\frac{\text{mass}_{DB}}{M_{DB}}\right)}{50 * 10^{-3}\text{kg}}$$

$$M_{DB} = \frac{\text{mass}_{DB}}{50 * 10^{-3}\text{kg} * m}$$

$$M_{DB} = \frac{1.470 \text{ g}}{50 * 10^{-3}\text{kg} * 0.2014 \text{ mol kg}^{-1}}$$

$\underline{\underline{M_{DB} = 145.98 \text{ g/mol}}}$

Problem 2

a) Define: diffusion

Solution: Diffusion is the net movement of molecules from a region of higher concentration to a region of lower concentration.

b) From the transport property theory we derived for gases, we obtained an estimate of the diffusion coefficient of $D = \lambda\langle v\rangle/3$. Calculate D for perfume molecules of diameter $d = 2$ nm and molar mass 152 g/mol in a classroom at 20°C and 1 atm.

Solution: Using

$$\langle v\rangle = v_{\text{mean}} = \left(\frac{8k_BT}{\pi\, m}\right)^{1/2} \qquad (m = \text{mass of one molecule}) \tag{1}$$

and the mean free path ($\sigma = \pi d^2$ where d is the diameter of a molecule):

$$\lambda = \frac{k_BT}{\sqrt{2}\sigma P} \tag{2}$$

we can put the numbers in and convert units. The answer is 1.52×10^{-7} m^{2}s^{-1}

c) Calculate, in units of meters, how far these perfume molecules move across the room in $t =$ one hour. Use $x = (2Dt)^{1/2}$

Solution:

We just use the given formula to get (1 hour = 3600 seconds) $x = 0.033$ m = 3.3 cm

d) In a realistic classroom, what other contributions exist to transport perfume molecules around the room?

Solution:

Air currents from the HVAC and from people walking around and breathing.

Problem 3

Use the experimental value of the coefficient of thermal conductivity of neon (molar mass $20.18 \ \mathrm{g\,mol^{-1}}$) of $46.5 \ \mathrm{mW\,K^{-1}\,m^{-1}}$ to estimate the collision cross-section of Ne atoms at 273 K.

Solution:

$$\kappa = \frac{3}{4}\frac{k_B\,T}{\sqrt{2}\,\sigma\,P}\left(\frac{8k_B\,T}{\pi\,m}\right)^{1/2} k_B\frac{N}{V} \tag{3}$$

Use $N/V = P/(k_B\,T)$ and solve for σ to get $\sigma = 8.42 \times 10^{-20} \ \mathrm{m^2} = 8.42 \ \mathrm{\AA^2}$

Problem 4

At 400 K, the rate, $v(t)$, of decomposition of a gaseous compound was 9.71 $\mathrm{Pa\,s^{-1}}$ when 10.0% had reacted and 7.67 $\mathrm{Pa\,s^{-1}}$ when 20.0% had reacted. Identify the order of the reaction.

Solution: For the reaction $A \rightarrow P$

we write rate $= k[A]^n$

This gives

$9.71 = k(0.9A_0)^n$

$7.67 = k(0.8A_0)^n$

Dividing, we get $1.266 = (1.125)^n$ which yields

$$n = \frac{\ln(1.266)}{\ln(1.125)} = 2 \tag{4}$$

Problem 5

A spherical vessel of radius 10.0 cm contains argon gas at 0.980 atm pressure and 298.15 K. Calculate the number of argon atoms striking the inner surface of the container per second.

Solution:

The answer is given by $z_{\mathrm{wall}}\,A$ where A is the surface area of the inner vessel surface.

$$z_{\mathrm{wall}}\,A = \frac{P\,A}{(2\pi m k_B T)^{1/2}} = \tag{5}$$

$$\frac{(0.98\,\mathrm{atm})(4\pi(0.1\,\mathrm{m})^2)}{(2\pi(39.948\,\mathrm{amu})(1.66\times10^{-27}\,\mathrm{kg\,amu^{-1}})(1.381\times10^{-23}\,\mathrm{J\,K^{-1}})(298.15\,\mathrm{K}))^{1/2}} \tag{6}$$

$$= 2.973\times10^{21}\,\frac{\mathrm{atm\,m^2}}{\mathrm{kg\,m\,s^{-1}}}\,(1.01\times10^{5}\,\mathrm{Pa\,atm^{-1}}) = 3.00\times10^{26}\,\mathrm{s^{-1}} \tag{7}$$

Problem 6

Consider the first order reaction

$$C_6H_{11}Cl(g) \rightarrow C_6H_{10}(g) + HCl(g) \tag{8}$$

with rate constant $k = 0.150\,\mathrm{s}^{-1}$. 2.00 moles of $C_6H_{11}Cl(g)$ is placed into a 10.0 L rigid reaction vessel, and the vessel is then sealed and maintained at $T = 300$ K.

a) Derive an expression for the total pressure as a function of time.

b) What is the total pressure after 6.00 s?

Solution:

From the first order integrated rate law we know that

$$[C_6H_{11}Cl] = [C_6H_{11}Cl]_0 e^{-kt} \qquad \Rightarrow \qquad P_{C_6H_{11}Cl} = P_{C_6H_{11}Cl,0} e^{-kt} \tag{9}$$

where $P_{C_6H_{11}Cl,0} = 4.92$ atm.

Now, $[C_6H_{10}] = [HCl] = [C_6H_{11}Cl]_0 - [C_6H_{11}Cl]$ so that

$$P_{C_6H_{10}} = P_{HCl} = P_{C_6H_{11}Cl,0} - P_{C_6H_{11}Cl,0} e^{-kt} \tag{10}$$

from which we can write

$$P_{\mathrm{total}} = P_{C_6H_{11}Cl,0}(2 - e^{-kt}) \tag{11}$$

At $t = 6.00$ s, this gives $P_{\mathrm{total}} = 7.84$ atm