Homework 9

Chem 3321 homework #9 out of 50 marks – due April 24, 2023

Problem 1, 10 marks

In a double glazed window the panes of glass are separated by 5.0 cm. What is the rate of transfer of heat by conduction from the warm room (25 °C) to the cold exterior (-10 °C) through a window of area 1.0 m^2? What power heater is needed t o made up of the heat loss? (you may assume nitrogen at 1 atm is between the plates at a temperature midway between the cold and the warm pane of glass)

$J_z = -\kappa \frac{dT}{dz}$ and $\kappa = \frac{1}{2} \lambda v_{mean} \bar{C}_V [A]$

$v_{mean} = \sqrt{\frac{8RT}{\pi M}}$ $[A] = \frac{p}{N_A} = \frac{N}{N_A}$

and $\lambda = \frac{1}{\sqrt{2}\sigma p}$

TABLE 27.3 Collision diameters, d(pm) and collision cross sections σ(nm^2) for various molecules.

Gas	d/pm	σ/nm^2
He	210	0.140
Ar	370	0.430
Xe	490	0.750
H_2	270	0.230
N_2	380	0.450
O_2	360	0.410
Cl_2	540	0.920
CH_4	410	0.530
C_2H_4	430	0.580

$T_{mid} = \frac{298.15K + 263.15K}{2} = 280.65K$

$\kappa = \frac{1}{2}\left(\frac{1}{\sqrt{2}\sigma \cancel{p}}\right)\left(\sqrt{\frac{8RT}{\pi M}}\right)\left(\frac{5}{2}R\right)\left(\frac{\cancel{p}}{N_A}\right)$ (unit should be $J \cdot K^{-1} m^{-1} s^{-1}$)

λ v_{mean} C_V $[A]$

solve for κ, and plug into:

$J_z = -\kappa \frac{dT}{dz}$ → use $T_2 - T_1$ in Kelvin; dz → width in meters

unit of J_z: $J \cdot m^{-2} \cdot s^{-1}$

don't forget to convert units Kelvin, meters

then, $J_z \cdot 1m^2$ in order to get into Watts

Problem 2, 10 marks

A certain reaction is first order. 540 seconds after initiation of the reaction, 32.5% of the reactant remains.

(a) What is the rate constant for this reaction?

(b) At what time after initiation of the reaction will 10% of the reactant remain?

$$\frac{[A]}{[A_0]} = \frac{32.5}{100} = 0.325 \text{ at } 540\text{s}$$

a)

use first order rate law

$$k = -\frac{1}{t} \ln\left(\frac{[A]}{[A_0]}\right)$$

b)

$$t = -\frac{1}{k} \ln\left(\frac{10}{100}\right)$$

Problem 3, 10 marks

To a very good approximation, the cooling of a hot object to room temperature follows first order kinetics. This result is known as Newton's law of cooling. If the rate constant for an object is 0.0344 s^{-1}, how long would it take for this body to go from 1000 K to 298 K?

$$t = -\frac{1}{k} \ln\left(\frac{298K}{1000K}\right)$$

Problem 4, 10 marks

The elimination of carbon dioxide from pyruvate ions by a decarboxylase enzyme was monitored by measuring the partial pressure of the gas as it was formed in a 250 cm^3 flask at T=293 K. In one experiment, the partial pressure increased from zero to 100. Pa in 522 s in a first order reaction when the initial concentration of pyruvate ions in 100 cm^3 of solution was 3.23 mmol L^{-1}. What is the rate constant of the reaction? The reaction scheme is:

$$CH_3COCO_2^-(aq) + H^+(aq) \rightarrow CH_3CHO(aq) + CO_2(g) \quad (1)$$

1:1 ratio, assume ideal gas

$1 L\cdot atm = 101.325 m^3 Pa$

$n_{CO_2} = \frac{PV}{RT}$

↑ $0.082\ L\cdot atm\cdot K^{-1}$

Since the stochiometric ratio is 1:1, we can find pyruvate concentration from CO_2 concentration

For initial condition, $3.23\ mmol\cdot L^{-1} \times 0.1 L = 3.23\times10^{-4}$ mol of pyruvate.

$n_{CH_3CHO(aq)} = n_{CH_3COCO_2^-(aq)} - n_{CO_2} = 3.23\times10^{-4} mol - n_{CO_2}$

then, $k = -\frac{1}{t}\ln\left(\frac{n_{CH_3CHO(aq)}}{n_{CH_3COCO_2^-(aq)}}\right)$

Problem 5, 10 marks

Carbonic anhydrase is a zinc-based enzyme that catalyzes the conversion of carbon dioxide to carbonic acid. In an experiment to study its effect, it was found that the molar concentration of carbon dioxide in solution decreased from 220. mmol L^{-1} to 56.0 mmol L^{-1} in 1.22×10^4 s. The reaction is first order. What is the rate constant of the reaction?

$$k = -\frac{1}{t} \ln\left(\frac{[A]}{[A_0]}\right)$$