

6 March 2025

9:40-10:55

Physical Chemistry II (Chm 252/442)

Midterm Exam 1

(**Chm252**: Provide justified answers to all questions, except those marked "AC Chm442". **Chm442** augmented credit: Answer all questions.)

Show all work explicitly on the sheets provided, front & back.

Respecting the University of Rochester policies on Academic Honesty, I affirm that this is submitted as my own work, and that I have neither received assistance by another person nor consulted sources other than my own prepared summary sheets.

Signed (Student Name and ID)

1. Probabilities



The U.S. air carriers, including commuter airlines, have a good safety record. With approximately 20 Million yearly flying hours in the 5 most recent calendar years, only 0.162 accidents occurred per 100,000 flying hours. However, in early 2025, there have already been 2 accidents (KDCA and CYYZ). Analyze these data in terms of statistical probability.

15 Pts

a) What statistical probability distribution is most suitable for a quantitative analysis of this safety statistics (and why)?

5 Pts

b) Calculate the mean airline accident rate per month.

15 Pts

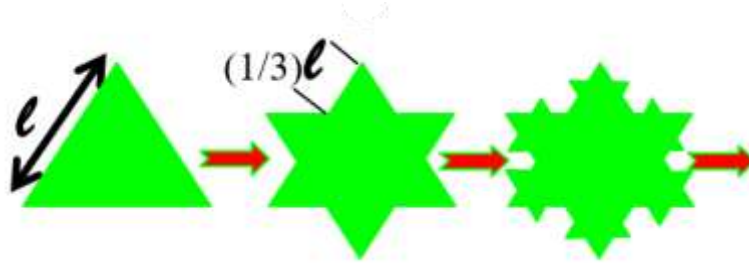
c) Based on the historic record, calculate the statistical likeliness for the two 2025 accidents to have occurred within the period of one month. Provide the formula used in the calculation.

AC

20 Pts

d) (AC Chm442) How do these 2025 accidents change similar accident expectations for future years, assuming that they remain the only accidents for 2025?

2. Self-Similar Crystal Growth



In an iterative, self-similar aggregation growth process, in each step n , additional smaller crystal dendrites mirroring the parent isosceles triangle form on

the sides of the previous generation 2D crystal. As illustrated in the sketch, in each iteration $n=1, \dots$, the side length (ℓ) of the new addition is reduced by a factor of $1/3$ from to the previous size at $n-1$.

10 Pts a) Write down an expression for the circumference L_n of the crystal as a function of side length ℓ for $n=0$, $n=1$, and $n=2$.

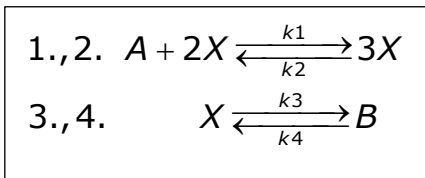
10 Pts b) Write down a down the power law for $L_n(\ell)$.

10 Pts c) Does the circumference of the crystal remain finite for $n \rightarrow \infty$?

AC

20 Pts d) AC Chm 442) Derive expressions for the covered areas A_n and the relation between area A_n and circumference L_n of the crystal.

3. Coupled Chemical Reactions



Consider the set of coupled chemical reactions **1.** and **2.** with constant concentrations $\mathbf{a} = [\mathbf{A}]$ and $\mathbf{b} = [\mathbf{B}]$. The rate constants for forward and reverse reactions are respectively k_1, k_2, k_3, k_4 .

15 Pts a) Write down the differential rate equation for the time evolution of the concentration of the product $\mathbf{x} = [\mathbf{X}]$.

20 Pts b) Derive an expression for the dependence of the concentration \mathbf{x} in the stationary, equilibrium final state of the reaction system.

AC

20 Pts c) (AC Chm 442) Derive an expression for the condition of the concentrations \mathbf{a} and \mathbf{b} sustaining such a chemical equilibrium.

Extra sheet for work.