Unit Exam: Kinetics

On the following pages are problems covering material in kinetics. Read each question carefully and consider how you will approach it before you put pen or pencil to paper. If you are unsure how to answer a question, then move on to another question; working on a new question may suggest an approach to a question that is more troublesome. If a question requires a written response, be sure that you answer in complete sentences and that you directly and clearly address the question. No brain dumps allowed! Generous partial credit is available, but only if you include sufficient work for evaluation and that work is relevant to the question.

Problem	Points	Maximum	Problem	Points	Maximum
1		25	4		17
2		17	5		17
3		17	6		17
			Total		100

A few constants are given here; other information is included within individual problems.

- density (d) of water is 1.00 g/mL
- specific heat (S) of water is 4.184 J/g • °C
- the gas constant (R) is 8.314 J/mol_{rxn} • K
- Faraday's constant (F) is 96,485 J/V • mol e^-
- water's dissociation constant (K_w) is 1.00×10^{-14}

Problem 1. One treatment for thyroid cancer is the radioactive isotope ^{131}I, which, when ingested, is taken up by the thyroid where it remains while it undergoes radioactive decay through the emission of beta particles. Radioactive decay is known to occur by a first-order process. In one study of its radioactive decay, the following data were obtained using a standard sample of ^{131}I.

time (days)	concentration (μg/mL)
4	11.99
8	8.48
12	6.01
16	4.24
20	2.98

In 1–2 sentences, explain why this data supports the claim of first-order kinetics.

What is the value of the rate constant, with units, for the radioactive decay of ^{131}I?

Someone forgot to record the initial concentration of ^{131}I! What was that concentration?

What percentage of ^{131}I will remain after five weeks?

Problem 2. Consider the hypothetical reaction $A + B \longrightarrow$ products. A kinetic analysis of this reaction produces the following set of observations:

- when the initial concentrations of A and of B are each 1.00×10^{-3} M, the reaction's initial rate is 1.46×10^{-3} M/s
- halving the initial concentration of A while maintaining the initial concentration of B at its original level, gives an initial rate of 7.28×10^{-4} M/s
- doubling the initial concentrations of both A and of B gives an initial rate of 1.17×10^{-2} M/s.

Report the rate law and the rate constant for this reaction (with units) and, in 2–4 sentences, explain how you arrived at this rate law.

Problem 3. Consider the hypothetical reaction $C + D \longrightarrow$ products. Because C is red in color and D is colorless, it is easy to follow the reaction's rate by monitoring the reaction mixture's absorbance (abs) as a function of time. A kinetic analysis of this reaction produces the following set of observations:

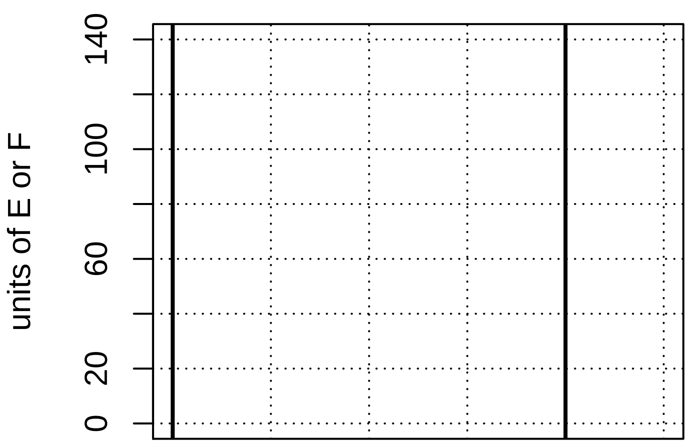
- when the concentration of C is 1.00×10^{-6} M and the concentration of D is 0.25 M, a plot of abs^{-1} as a function of time is linear with a slope of 0.135 min^{-1}
- when the concentration of C is 2.00×10^{-6} M and the concentration of D is 0.50 M, a plot of abs^{-1} as a function of time is linear with a slope of 0.540 min^{-1}

Report the rate law and the rate constant for this reaction (with units) and, in 2–4 sentences, explain how you arrived at this rate law.

Problem 4. Consider the hypothetical equilibrium reaction $E \rightleftharpoons F$ where the forward reaction is first-order in E with a rate constant of 3.0×10^{-3} s^{-1} and where the reverse reaction is first-order in F with a rate constant of 1.0×10^{-3} s^{-1}.

What is the equilibrium constant for this reaction?

Suppose you place 100 units of E and 40 units of F in a flask and allow the system to react until it reaches equilibrium. Use the axes below to show how the concentrations of E and of F will change as a function of time. The solid vertical line on the left is time = 0 and the solid vertical line on the right is the time where equilibrium is first established. Be sure your plot clearly distinguishes between E and F.



Problem 5. A kinetic study of the reaction $G + H_2 \longrightarrow GH + H$ shows that the reaction's rate is directly proportional to the concentration of H_2, independent of the concentration of G, and directly proportional to the concentration of I. Propose a two-step mechanism that is consistent with this information **and** explain, in 2–4 sentences, why your mechanism is plausible.

Problem 6. Suppose you are studying the reaction $J + K \longrightarrow$ products under pseudo-order conditions where the reaction's rate law is first order in J. Based on some theoretical modeling of the reaction's energetics you have reason to believe the activation energy is 58.4 kJ/mol$_{\text{rxn}}$. A kinetic analysis of the reaction at a temperature of 298 K gives a pseudo-first-order rate constant of 0.502 d^{-1}. Suppose you wish to run the reaction so that just 1% of J remains after 24 hrs. What is the minimum temperature you can use?