

1. Short answers (30 points total, 5 points each)

- (a) Give an example of experimental results that would prove to you that the reaction $\text{H}_2 + \text{I}_2 \rightarrow 2\text{HI}$ is not elementary (2 sentences).
- (b) Briefly explain the Greenhouse effect at a level suitable for a non-technical friend. Your explanation should include what the effect is, how it works, what it has to do with greenhouses and why it is important. (1 paragraph)
- (a) The Nernst equation is written $\xi = \xi^0 - (0.0592/n)\log_{10}Q$. Explain each what the variables ξ , ξ^0 , n and Q stand for and give the units of each (1 sent).
- (d) Give an example of when you would use the Nernst equation in part (c).
- (e) In lecture 20, I spent some time discussing the electrolysis of water which involves the half reactions
- $$2 \text{H}^+ + 2 \text{e}^- \rightarrow \text{H}_2(\text{g}) \quad \xi^0 = 0.00 \text{ V} \quad \text{and}$$
- $$\text{O}_2 + 4 \text{H}^+ + 4 \text{e}^- \rightarrow 2 \text{H}_2\text{O} \quad \xi^0 = 1.23 \text{ V}.$$

I showed that the acid concentration ($[\text{H}^+]$) does not affect the voltage required for electrolysis, calculating that it is 1.23 V under standard conditions (298 K, 1 M $[\text{H}^+]$) as well as for ordinary water of $\text{pH} = 7$ (298 K, 10^{-7} M $[\text{H}^+]$). Nevertheless, in practical electrolysis of water we add acid rather than use pure water even though it adds expense and reduces safety. Explain why.

- (f) What will happen if I dip a silver wire into a 1 M solution of $\text{Cu}(\text{SO}_4)$? Explain how you know (1 sent).

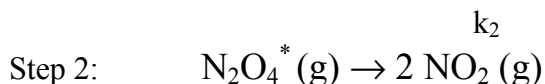
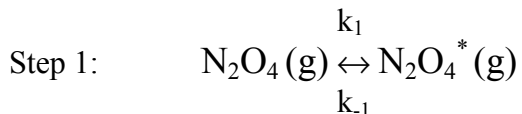
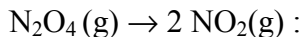
2. Kinetics (20 points, 5 each)

Ethyl chloride decomposes via the reaction $\text{C}_2\text{H}_5\text{Cl}(\text{g}) \rightarrow \text{C}_2\text{H}_4(\text{g}) + \text{HCl}(\text{g})$. The reaction is found to be first order and the rate constant is measured to be $4.2 \times 10^{-5} \text{ sec}^{-1}$ at 700 K and is found to double at 712 K.

- (a) Find the activation energy for the reaction in KJ/mol.
- (b) If the reaction is run at 700 K for 10 minutes, what fraction of the original amount of $\text{C}_2\text{H}_5\text{Cl}(\text{g})$ remains?
- (c) If I double the initial concentration of $\text{C}_2\text{H}_5\text{Cl}(\text{g})$, will I get a different result for (b)? Explain your answer.
- (d) If I add a catalyst, will I get a different result for (b)? Explain your answer.

3. Reaction Mechanisms and Rate Laws (20 points, 5 each)

Consider the following hypothetical mechanism for the overall reaction



- (a) Assume that the forward reaction in the equilibrium of step 1 is endothermic and that the overall reaction is exothermic. Sketch a well labeled diagram of energy versus reaction coordinate including reactants, products and intermediates on the diagram.
- (b) Suppose that the rates in step 1 are fast and step 2 is slow. Write the rate law for the reaction in terms of k_1 , k_{-1} and k_2 .
- (c) Suppose that step 2 is fast and the rates in step 1 are much slower. Write the rate law for the reaction in terms of k_1 , k_{-1} and k_2 .
- (d) If we did not know which step was fast, we learned that we can use the steady state approximation to determine a rate law from a mechanism. Briefly explain the premise behind this approximation and explain without mathematics how you would go about deriving a rate law (3 sents).

4. Electrochemistry and Batteries (30 points)

You are interested in making a tiny battery for a hearing aid based on the half reactions $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$ and $\text{Ni}^{2+} + 2\text{e}^- \rightarrow \text{Ni}(\text{s})$. Initially, you have 0.1 mL of 1 M $\text{Cu}(\text{SO}_4)$ with a Cu electrode as your cathode and 0.5 mL of 1 M $\text{Ni}(\text{SO}_4)$ with a Ni electrode as your anode.

- (a) Calculate the cell voltage at 25°C when the battery is fresh. (5 points)
- (b) When the battery is dead (i.e. reaches equilibrium), what will the voltage be? (5 points)
- (c) At equilibrium, what will the Ni^{2+} and Cu^{2+} concentrations be? (10 points)
- (d) Assuming that the voltage remains adequate until equilibrium is almost reached, will you be able to run a hearing aid that requires 10 milliamperere currents for the length of a 2 hour movie? Document your conclusion quantitatively. (10 points)