Electronic Supplementary Material (ESI) for Chemistry Education Research and Practice.

Appendix

The characterization of cognitive processes involved in chemical kinetics using a blended processing framework

Kinsey Bain,[a] Jon-Marc G. Rodriguez,[a] Alena Moon,[b] and Marcy H. Towns[a]

[a]*Department of Chemistry, Purdue University, West Lafayette, Indiana, 47907, United States*

[b]*Department of Chemistry, University of Michigan, Ann Arbor, Michigan, 48109, United States*

Kinetics Study Interview Protocol (NSF DUE-1504371)

Thank you for agreeing to participate in this study on students' understanding of kinetics. During this interview you will be answering various questions. While you are thinking and working through each problem, I would like you to think aloud as you go. I will likely ask you follow-up or clarifying questions about the problem and what you are doing to try understand what you are doing and thinking as you work.

I am not here to determine if you are right or wrong. I simply want to know how you think about and work through these types of problems. This will be very helpful, as we want to help improve how we teach students about these concepts. Just a reminder, this will have no effect on your chemistry grade. This interview is confidential. I will keep your files and identity protected, and you will be given a pseudonym.

1. The second-order reaction, 2 $C_4H_6(g) \rightarrow C_8H_{12}(g)$, was run first at an initial concentration of 1.24 M and then again at an initial concentration of 2.48 M. They were run under the same reaction conditions (e.g., same temperature). Data collected from these reactions is provided in the table below. Is the rate constant for reaction 1 (1.24 M) greater than, less than, or equal to the rate constant for reaction 2 (2.48 M)?

Time (hrs)	**[C_4H_6] (M)**	
	Rxn 1	Rxn 2
0	1.24	2.48
1	0.960	1.55
2	0.775	1.13
3	0.655	0.89
4	0.560	0.73
5	0.502	0.62
6	0.442	0.54
7	0.402	0.48
8	0.365	0.43
9	0.335	0.39
10	0.310	0.35

Potential follow-up probing questions

How would you go about solving this problem?
What is this question asking? What information is given? How can you use it to reach an answer?
Do you need an equation to solve this problem? If yes, which one?
What is [A] in this problem?
How is [A] (or [C_4H_6]) changing? What does that mean is happening in the chemical reaction?
What is k? What type of information does this give you?
What is t?
Would your answer change if you were to compare this data to that of a different second-order reaction?
Do k's change from reaction to reaction? Why? How?
Is k always constant? (What could you change to make k a variable?)
Does your answer make sense to you?
(If they actually solved for rate constants and compared) Could you have answered this problem without doing calculations? How?
What does second-order mean? Mathematically? Chemically/physically?
What other reaction systems could be called second-order?
How does this mathematical model relate to the physical mechanism of the chemical reaction?
Could you have determined that this reaction was second-order mathematically? If so, how would you?

2. Here's an integrated rate law equation you may have seen in class/used above:

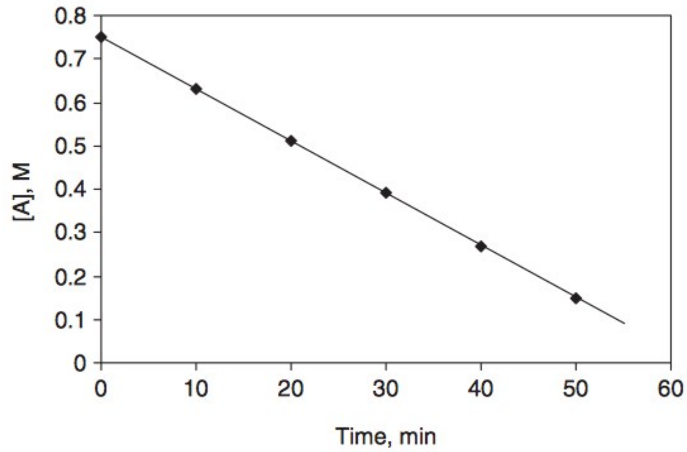
$$\frac{1}{[A]} = kt + \frac{1}{[A]_0}.$$

How would you explain this equation to a friend from class? How would you explain this on an exam?

Potential follow-up probing questions

What type of equation is this? (integrated rate law, linear function, etc)
What does [A] represent? What type of mathematical term (symbol) is it?
If they say [A] is a variable: What is chemically happening for [A] to change?
How are [A] and $[A]_0$ different?
What does t represent? What type of mathematical term (symbol) is it?
What is k? What type of mathematical term (symbol) is it?
What type of information does k give you? Can k tell you anything about the second-order reaction?
What are the units of k? Does that give you any insight to the chemistry that is happening? (physical information?)
Why are there only positive signs in this equation?
What order rate law is this?
How does this equation relate to a rate law? (Like those you would write in class?)
What is the purpose of each of the mathematical operations in this equation? (multiplication, division, addition)
What type of chemistry would correspond to this mathematical equation?
How was this equation derived? (From where did this equation come?)

3. Below is a zero-order rate plot for the reaction $N_2O(g) \rightarrow N_2(g) + ½O_2(g)$, where $[N_2O]_0 = 0.75$ M and $k = 0.012$ M/min. [A], M on the graph below represents $[N_2O]$ (M). The reaction is conducted at 575 ˚C with a solid platinum wire, which acts as a catalyst.



If you were to double the concentration of N_2O and run the reaction again, how would the half-life change? At the half-lives for each reaction run, how do the chemical systems compare?

Potential follow-up probing questions

How would you go about solving this problem?
What is this question asking? What information is given? How can you use it to reach an answer?
What is a half-life? What does that mean chemically? What does that mean mathematically? Or how would you determine a half-life mathematically?
How do you characterize chemical systems when they are at their half-life?
Do you need an equation to solve this problem? If yes, which one?
What is [A] in this problem?
How is [A] (or $[N_2O]$) changing? What does that mean is happening in the reaction?
What is a zero-order half-life dependent upon? Is this true for other orders? Why/why not?
Why would a half-life change for the same reaction run at different concentrations?
Does your answer make sense to you?
If you had not been told the reaction order, could you have determined the order from this plot?
What does zero-order mean? Mathematically? Chemically/physically?
What are typical causes for a reaction to be zero-order?
What role does the catalyst play with regards to the kinetics of the reaction? Mathematically? Chemically/physically? What would happen if you changed the amount of catalyst?
How does this mathematical model relate to the physical mechanism of the chemical reaction?
Would the order of reaction change without the presence of a catalyst? How? Why?
Does the catalyst interact with the reactants and products? If yes, how? How does the catalyst increase the reaction rate?

4. Here is another equation you've probably seen in class: $[A] = -kt + [A]_0$.
How would you explain this equation to a friend from class? How would you explain this on an exam?

Potential follow-up probing questions

What type of equation is this? (integrated rate law, linear function, etc)
What does [A] represent? What type of mathematical term (symbol) is it?
If they say [A] is a variable: What is chemically happening for [A] to change?
How are [A] and $[A]_0$ different?
What does t represent? What type of mathematical term (symbol) is it?
What is k? What type of mathematical term (symbol) is it?
What type of information does k give you? Can k tell you anything about the zero-order reaction?
What are the units of k? Does that give you any insight to the chemistry that is happening? (physical information?)
What do the signs denote in this equation? (e.g. negative sign before the slope)
What order rate law is this?
How does this equation relate to a rate law? (Like those you would write in class?)
What is the purpose of each of the mathematical operations in this equation? (multiplication and addition/subtraction)
What type of chemistry would correspond to this mathematical equation?
How was this equation derived? (From where did this equation come?)
Compare to second-order equation? Why is there a different sign? Why is the concentration inverse in the second-order integrated rate law?