Chemistry | 2017-2018 Assessment Report

1. Please give a brief overview of the assessment data you collected this year.

1. Introduction

Learning Outcome #4

Have knowledge of kinetics.

Course Assessed

CHEM 212: Principles of Chemistry II. This is a mid level course designed to teach a broad overview of the chemical equilibrium process. Before a system attains equilibrium it has to first reach it from the initial chemical composition it starts with. Kinetics is taught before equilibrium is discussed.

Nature of Assessment

Kinetics deals with the rate of a chemical reaction (defined as change in concentration versus time). The students learn how to define the rate for a given reaction. Next we discuss the significance of kinetics. Kinetics is important for two main reasons: First, it lets us determine how fast a chemical reaction occurs through the integrated rate laws. These laws tell us how the concentration of a chemical species changes with time. This is important if you want to know how much reactant is present after a chemical reaction has started or how much radioactive material is present in a radioactive material. Second, and perhaps most important, is that by studying kinetics we can determine (or at least postulate) the potential mechanism by which reactants are converted into products.

This knowledge is also re-enforced in the laboratory by having students conduct kinetics experiments where they determine the rate law as well as the possible mechanisms

Assessment of this topic took place over the semester as question on the first exam as well as questions on the (cumulative) final exam.

II. Assessment

Exam 1 had 3 questions dealing with kinetics

Exam #1 Question5.

5. Which would be a suitable definition for the rate of the following reaction

$$2\,C_2H_6(g) + 7\,O_2(g) \rightarrow 4\,CO(g) + 6\,H_2O(g)$$

(a) $-\frac{\Delta[C_2H_6]}{\Delta t}$ (b) $\frac{\Delta[C_2H_6]}{\Delta t}$ (c) $-2\frac{\Delta[C_2H_6]}{\Delta t}$

(d) $\frac{1}{2}\frac{\Delta[C_2H_6]}{\Delta t}$ (e) $-\frac{1}{2}\frac{\Delta[C_2H_6]}{\Delta t}$

This question requires the students to understand how to define the "rate" of a chemical reaction.

Exam #1 Question 6.

6. Determine the **overall order** of the following reaction given the initial rate table shown below.

$$BrCH_3(aq) + OH^-(aq) \rightarrow Br^-(aq) + CH_3OH(aq)$$

Experiment	Initial $[BrCH_3]$	Initial $[OH^-]$	Relative Rate
1	1	1	1
2	1	2	4
3	2	2	8

This question requires the student to understand the rate law – which must be experimental determined, so an 'experimental table' is provided. This is exactly analogous to how they calculate the rate law in their laboratory period.

Exam #1 Question 8.

8. The rate for the chemical reaction

$$2\,NO(g) + O_2(g) \rightarrow 2\,NO_2(g)$$

has a rate law given by $rate = k[NO]^2[O_2]$. Which of the following proposed mechanisms are consistent with this rate law?

I. $2\,NO(g) + O_2(g) \rightarrow 2\,NO_2(g)$

II. $2\,NO(g) \rightleftarrows N_2O_2(g)$ $(fast)$
$N_2O_2(g) + O_2(g) \rightarrow 2\,NO_2(g)$ $(slow)$

III. $2\,NO(g) \rightleftarrows N_2(g) + O_2(g)$ $(fast)$
$N_2(g) + 2\,O_2(g) \rightarrow 2\,NO_2(g)$ $(slow)$

(a) I only (b) II only (c) III only (d) I and II

(e) I and III (f) II and III (g) none (h) I, II, and III

This question requires the student to be able to determine the rate law predicted from various mechanisms.

Score	0 = incorrect	1 = correct

III. Results

STUDENT	Q5	Q6	Q8	TOTAL	STUDENT	Q5	Q6	Q8	TOTAL	STUDENT	Q5	Q6	Q8	TOTAL
1	1	1	0	2	22	1	1	1	3	43	0	0	0	0
2	1	1	0	2	23	1	1	0	2	44	1	0	0	1
3	1	1	1	3	24	1	0	0	1	45	1	1	1	3
4	1	1	1	3	25	1	1	0	2	46	1	0	1	2
5	1	0	0	1	26	1	1	1	3	47	1	1	1	3
6	1	0	0	1	27	1	0	0	1	48	1	0	0	1
7	1	0	0	1	28	1	0	1	2	49	0	0	0	0
8	0	0	0	0	29	1	1	0	2	50	1	1	0	2
9	0	1	0	1	30	0	0	0	0	51	1	1	0	2
10	0	0	0	0	31	0	1	0	1	52	1	1	0	2
11	1	1	0	2	32	0	0	0	0	53	1	1	0	2
12	0	0	1	1	33	1	1	0	2	54	1	0	1	2
13	1	0	0	1	34	1	0	0	1	55	1	0	1	2
14	1	0	0	1	35	1	1	1	3	56	1	1	1	3
15	1	1	1	3	36	1	1	0	2	57	1	0	0	1
16	1	0	0	1	37	1	1	0	2	58	0	0	0	0
17	1	1	1	3	38	1	0	0	1	59	1	1	0	2
18	1	1	1	3	39	1	1	0	2	60	1	1	1	3
19	1	1	0	2	40	1	1	1	3	61	1	0	0	1
20	1	1	0	2	41	1	1	1	3	62	1	0	0	1
21	1	0	0	1	42	1	0	0	1	63	1	0	0	1

* Only data for students completing both the first exam and final exam were analyzed.

IV. Exam 1 Discussion

The students were very confident with the first question about defining the rate of a chemical reaction (out of 63 students, 53 answered correctly = 84.1%). The second questions had 33 out of 63 answer correctly (52.4%), while the third question had 19 out of 63 answered correctly (30.2%). The decline in percent correct is not surprise because questions 6 and 8 are much more difficult than question 5.

Another important factor I noticed during this first exam in question 8 was that many students mistaken thought that if the steps of a mechanism add to given you the overall balanced equation then the mechanism is consistent with the observed rate law. However this is NOT true, the mechanism steps must ALWAYS add up to the overall balanced reaction. In question 8 all the proposed mechanisms add up to the balanced reaction (as must happen). So in this question I fear that I did not take this into account, because the correct answer (which must be worked out for each mechanism) is all of the above. I decided that for the final exam I would propose three mechanisms (that all added up to the balanced equation) but only two would be consistent with the observed rate law. Also it seems the concept of rate definition was well understood so I decided not to test them on that for the final exam.

V. Final Exam Assessment

The final exam had 2 questions dealing with kinetics very similar to the questions asked in exam 1. The final exam was cumulative and equivalent to about two one-hour exams. The kinetics questions were,

1.2 Determine the **overall order** of the following reaction given the initial rate table shown below.

$$BrCH_3(aq) + OH^-(aq) \rightarrow Br^-(aq) + CH_3OH(aq)$$

Experiment	Initial $[BrCH_3]$	Initial $[OH^-]$	Relative Rate
1	1	1	1
2	1	2	1
3	2	2	8

(a) 5 (b) 4 (c) 3 (d) 2 (e) 1 (f) 0

1.3 The experimentally determined rate law for the reaction

$$2\,H_2(g) + 2\,NO(g) \rightarrow N_2(g) + 2\,H_2O(g)$$

is $rate = k[H_2][NO]^2$. Which of the following mechanisms are consistent with this rate law?

Mechanism I:

$$H_2 + NO \rightarrow H_2O + N \quad (slow)$$
$$N + NO \rightarrow N_2 + O \quad (fast)$$
$$O + H_2 \rightarrow H_2O \quad (fast)$$

Mechanism II:

$$H_2 + 2\,NO \rightarrow N_2O + H_2O \quad (slow)$$
$$N_2O + H_2 \rightarrow N_2 + H_2O \quad (fast)$$

Mechanism III:

$$2\,NO \rightleftarrows N_2O_2 \quad (fast, equilibrium)$$
$$N_2O_2 + H_2 \rightarrow N_2O + H_2O \quad (slow)$$
$$N_2O + H_2 \rightarrow N_2 + H_2O \quad (fast)$$

(a) I only (b) II only (c) III only (d) I and II

(e) I and III (f) II and III (g) All of them (h) none of them

Exactly analogous to the questions on exam 1. Notice in question 3, all of the mechanisms add up to the overall balanced equation, however, only two of the mechanism are consistent with the observed rate law.

VI. Final Exam Results

STUDENT	Q2	Q3	TOTAL	STUDENT	Q2	Q3	TOTAL	STUDENT	Q2	Q3	TOTAL
1	0	1	1	22	1	0	1	43	0	0	0
2	0	0	0	23	1	0	1	44	0	0	0
3	0	0	0	24	1	0	1	45	1	1	2
4	0	0	0	25	1	0	1	46	1	0	1
5	0	0	0	26	1	0	1	47	1	0	1
6	0	1	1	27	0	0	0	48	1	0	1
7	0	0	0	28	1	0	1	49	1	0	1
8	0	0	0	29	1	0	1	50	0	0	0
9	1	0	1	30	0	0	0	51	1	0	1
10	1	0	1	31	0	0	0	52	0	0	0
11	1	0	1	32	1	0	1	53	0	0	0
12	0	0	0	33	1	0	1	54	1	0	1
13	0	0	0	34	1	0	1	55	0	0	0
14	0	1	1	35	0	0	0	56	1	0	1
15	1	0	1	36	0	1	1	57	1	0	1
16	1	0	1	37	0	0	0	58	1	0	1
17	0	1	1	38	1	0	1	59	0	0	0
18	0	0	0	39	1	0	1	60	1	0	1
19	0	1	1	40	0	0	0	61	1	1	2
20	1	0	1	41	1	0	1	62	1	0	1
21	0	0	0	42	1	0	1	63	0	0	0

VII. Final Exam Results

The second questions had 33 out of 63 answer correctly (52.4%), the same percentage as the final exam. The third question had only 8 out of 63 answered correctly (12.7%).

VIII. Discussion

The second questions had 33 out of 63 answer correctly (52.4%), the same percentage as the final exam.

Analysis of the data for the second question on the final exam (concerning the overall order of the rate) shows that 16 students who got this question wrong on exam 1 got it correct on the final exam and 16 students who got it correct on exam 1 failed to answer it correctly on the final exam. I expected most people who got the question correct on exam 1 to also get it correct on the final exam along with some students getting it correct on the final that answered it incorrectly on exam 1.

The third question shows that most students were not sure how to determine the rate law from a given mechanism.

The recommendation is that more discussion problems highlight how to determine the overall rate law for a given mechanism. These concepts are needed later in chemistry and must be mastered in this course. For example in organic chemistry many reactions are named by their overall order (e.g. SN2, E1) and illustrate the connection between kinetics and mechanisms.