CHEMICAL EDUCATION RESEARCH CUMULATIVE EXAM
MAY 2017
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NOTES: The following pages contain excerpts from the target papers distributed previously. These are the only materials to be used during this cumulative exams. Students may not use their own copies of the target papers.

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1. Kelly and coworkers (*Chem. Educ. Res. Pract.* ASAP, 2017) present an approach where they have students view and critique molecular level presentations of oxidation-reduction reactions. (a-15 points) Describe how their perspective on learning theory informs their work, including issues of prior knowledge and the value of confronting students with conflicting (even incorrect!) information.

(b-20 points) Their results include an important observation that students who were able to provide correct answers about the particulate representation were those who were able to interpret the macroscopic information well. What role might this play in thinking about how to teach students with animations? Your answer can refer to their own suggestions about how to change thinking or you can provide your own practical thinking.

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2. Cooper et al (*J. Chem. Educ.* **2016**, *93*, 1703−1712) investigate student acid-base reasoning. They also engage in a process of evidence-centered design that includes specific revision steps in the questions they are asking.

(a—20 points) An example of their use of evidence-centered design is provided by their initial and final version of their assessment task (see attached sheet). Compare the specific prompts they give to the students and explain how the final version is an improvement on the first.

(b—15 points). Their analysis includes characterization of several different types of responses. Four are listed below. Explain how these 'work' in terms of the chemistry involved.

- Brønsted Descriptive
- Brønsted Causal
- Lewis Descriptive
- Lewis Causal

3. Cracolice et al (*J. Chem. Educ.*, **2008**, *85, 873-878*) compare student performance on algorithmic and conceptual questions. They use a test of logical reasoning to define students on the basis of reasoning ability. They examined how students did on different kinds of questions (Table 3 in their paper is given on the final page of this exam).

(a-10 points) Define, in your own words but possibly using their ideas, the difference between an algorithmic and a conceptual question.

(b—10 points). In general, they conclude that logical reasoning affects both kinds of questions. Comment on why logical reasoning may be an important part of learning theory.

(c—10 points). Remarkably, there are two cases where the difference between students (top one-third or bottom one-third) is not significant (for Algorithmic Density questions, for Algorithmic Gas law questions, and for Conceptual stoichiometry questions). Explain, using your knowledge of chemistry problems, why this occurs (HINT: Your answer should consider thevalues of the mean scores involved and how that may impact the statistics).

FOR QUESTION #2: Excerpt from Cooper et al.

For this reaction:

a. How would you classify the above reaction? Please explain your reasoning.
b. Please explain your reasoning for what you think is happening at the molecular level for this reaction.

Figure 1. Initial iteration of the assessment tasks (SP12).

For this reaction:

a. How would you classify this reaction? Please explain why you chose that classification.
b. Describe in full detail **what** you think is happening on the molecular level for this reaction. Specifically, discuss the role of each reactant.
c. Using a molecular level explanation, please explain **why** this reaction occurs. Specifically, why the reactants form the products shown.
d. Please draw arrows to indicate how this reaction occurs.

Figure 2. Final iteration of the assessment tasks (SP15).

FOR QUESTION #3: Table 3 from Cracolice et al

Table 3. Comparing Performance of Students Classified as Better and Poorer Reasoners

Concepts Tested	Question Types	Reasoning Levels	*N*	Mean Scores	Standard Deviation Values	*p*-Values
Density	Algorithmic	Top One-Third	26	0.77	0.43	0.082
		Bottom One-Third	23	0.52	0.51	
	Conceptual	Top One-Third	26	0.54	0.51	**0.016**
		Bottom One-Third	23	0.17	0.39	
Stoichiometry	Algorithmic	Top One-Third	24	0.88	0.34	**0.001**
		Bottom One-Third	20	0.40	0.50	
	Conceptual	Top One-Third	24	0.13	0.34	0.614
		Bottom One-Third	20	0.05	0.22	
Gas laws	Algorithmic	Top One-Third	20	0.90	0.31	0.065
		Bottom One-Third	19	0.63	0.50	
	Conceptual	Top One-Third	20	0.55	0.51	**0.048**
		Bottom One-Third	19	0.21	0.42	
Molarity	Algorithmic	Top One-Third	19	0.63	0.50	0.506
		Bottom One-Third	16	0.50	0.52	
	Conceptual	Top One-Third	19	0.47	0.51	**0.001**
		Bottom One-Third	16	0.00	0.00	
ACS Final	Raw Scores	Top One-Third	18	56.50	6.537	**0.000**
		Bottom One-Third	16	42.563	11.355	
ACS Final	Percentiles	Top One-Third	18	91		
		Bottom One-Third	16	57		

Notes: Bold type indicates $p < 0.05$; the Fisher exact probability test was used to generate *p*-values for the questions; a *t*-test was used to analyze the ACS final.