

## Section 1: Multiple Choice

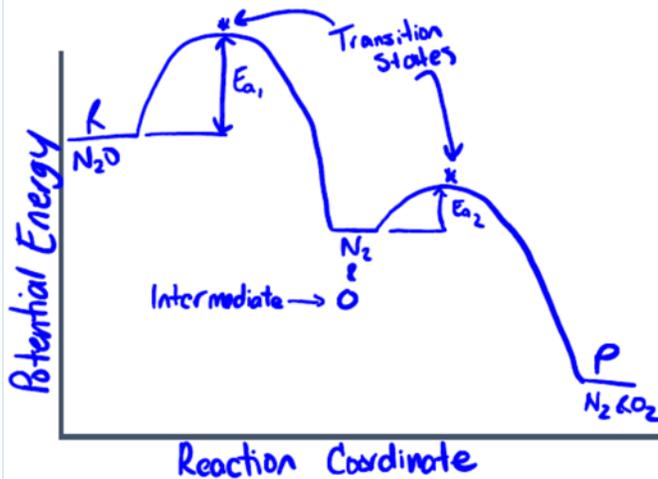
VERSION 1	Description / Hints
B	1. (Significant Figures) – Make sure you follow each step through, and obey the rules laid out in Appendix E of your lab manual for each type of calculation (addition/subtraction or multiplication/division)
D	2. (atoms & moles) – Check that you correctly converted grams to moles of the molecule, and moles of each molecule to moles of C atoms (e.g. 1 mol of benzene has 6 mol of C atoms).
C	3. (Kinetics concepts) – Read carefully. 1L of a 1M mixture and 2L of a 1M mixture each still have 1M of gas ( <i>compressing</i> 2L of a 1M mixture to 1L would indeed give a higher particle concentration though).
B	4. (Kinetics: rate laws) – What change was made to the concentration of acetaldehyde? When put in the rate law, how does this change the rate?
B	5. (Kinetics: rate laws) – Use the method of initial rates to find the order for both P <sub>4</sub> and H <sub>2</sub> . Knowing both of these, how can you determine the overall order?
A	6. (Kinetics – mechanisms) – <i>Note: this was the question with the typo! Replace [NO] with [NO<sub>2</sub>].</i> How do the elementary steps of a reaction mechanism influence the rate law? (Remember, in 209 we only deal with “slow step first” reactions in this way)
D	7. (Kinetics – mechanisms) – This is a <i>two step</i> mechanism. Chlorine is required for the reaction (and appears in the rate limiting step) but is regenerated in the end, so it is not truly a reactant. Transition states should be related to the product of that step (would the transition state shown be likely to produce ClO and O <sub>2</sub> as drawn?)
C	8. (Equilibrium – Q and Le Chatelier) – See the long answer section of the F2015 midterm for some guidance. Remember that a solution “containing” reagents may not already be at equilibrium (how can you tell?)
B	9. (Equilibrium – Van’t Hoff and Le Chatelier) – The question says the reaction is exothermic. How will temperature affect an exothermic reaction?
D	10. (Equilibrium – Q and Le Chatelier) – The question asks which will cause a <i>decrease</i> in pH. What shift in [H <sup>+</sup> ] does this mean? Why was it important to have “some” BaCO <sub>3</sub> present in the container initially?
B	11. (Equilibrium – ICE tables) – You are given information about the initial and final state of the reaction. Set this up in an ICE table. How can you find the change “x”? Watch your stoichiometry, and note that the answers are in mol (not M).
C	12. (Equilibrium – K <sub>c</sub> and K <sub>p</sub> ) – The standard SI unit for pressure is <i>bar</i> . You have a formula on your sheet to help with this calculation – just make sure you have the correct units (bar, temp in K, R in units to match).
C	13. (Equilibrium – K <sub>a</sub> ) – The question asks for the solution that would have the <i>highest</i> pH. How will the K <sub>a</sub> of the acid affect the pH of it in solution? Do you want a small or large K <sub>a</sub> ? How about concentration – how does that affect pH? Do you want a small or large concentration for this question?

## Section 2: Long Answer

This section was graded similarly to the tutorials – grades were given as much for showing the process correctly as for getting the correct answer. Thus, it is possible to have the correct answer but still have a low score, because insufficient work was shown (including the ‘chemical reasoning’ implicit in some of the calculation steps).

VERSION 1	Description / Hints
2.87 %	1. (Stoichiometry / % yield) – You have information on both the initial and final states of the reaction. It did not go “to completion” but you know how much of the peroxide was consumed (hint: the 5L volume <i>started</i> at 9.77 M and <i>ended</i> at 2.53 M. How much peroxide was consumed?). Based on this information, what was the theoretical yield? From the amount of hydrazine collected, what was the % yield?
$7.94 \times 10^{-11}$	2. (Equilibrium – $K_a$ ) – You are given the pH of solution (this is <i>always</i> an equilibrium value). What is the relevant reaction here? How does it relate to $K_a$ ? What information do you need to find in order to calculate the value of $K_a$ ? Use the reaction to make an ICE table. What is the value of the “change” row (besides just “x”)? Can you now determine all of the equilibrium concentrations?
	3. (Kinetics – rate laws) 3a) What type of reaction is <i>decomposition</i> ? How can the information in the question help you? “In the presence of a metal surface” means that a metal is involved somehow, but isn’t directly part of the reaction. What do we call a substance that “helps the reaction go” but doesn’t appear as part of the overall reaction?
	3b) Remember from Tutorial 2 – how can you determine the order of the reaction when all you know is the reaction and the rate constant?
	3c) “general” rate laws always have the form “rate = $k$ [concentrations] <sup>some power</sup> ”. Integrated rate laws are the linearized forms given on your data sheet.
20 s	3d) You wrote the general and integrated rate laws in part (c). Which will help you find the state of the reaction at a specific time? What is your initial ammonia concentration? Final concentration?
35 kJ	4. (Kinetics – mechanisms and energy) 4a) You have the values for $k$ at two temperatures and are asked to find $E_a$ . What relation tells us how $E_a$ changes with temperature? Do you need the $\Delta H$ for this? (What information does it tell you?)

4b) Look at the mechanism provided. How many steps does this reaction have? How many activation energies does it have? How many transition states? Any intermediates? How do we know whether the products are at a higher or lower energy than the reactants? Do we know what energy the intermediates are at?



\*intermediate stage was accepted at either higher or lower energy than the reactants.

[COBr<sub>2</sub>]:  
0.27 M  
[CO]=[Br<sub>2</sub>]:  
0.23 M

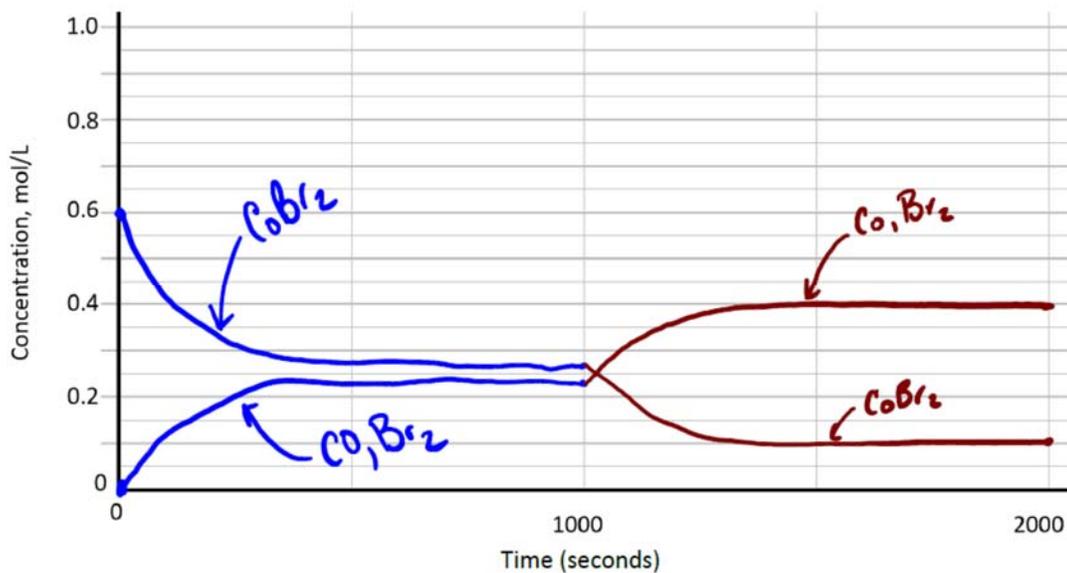
5. (Equilibrium – ICE tables and plots with concentration)

5a) These are gases, and you have been provided  $K_c$ . Do you need to find  $K_p$ ? When you set up your ICE table, where does the information about CoBr<sub>2</sub> given in the question go? Can you use the “small-x” approximation in your calculations? Do you need to use “1000 sec” anywhere in your calculations for an equilibrium? (*sanity check*: once you have your equilibrium concentrations, should you have “more products” or “more reactants” overall?)

(answers below with (c))

5b) Plotting the values for your concentrations on the graph is (hopefully) straightforward. Remember to stop at 1000! Though this is a question about equilibrium, your knowledge of kinetics can help you with your graph: As the reaction approaches equilibrium, how does the rate change? Since rate is the slope of the [reactant] vs. time plot, how should the shape of your line change as you approach equilibrium? What should the slope of your line be *at* equilibrium? Make sure you *label* each line (either directly or with a legend). If two lines overlap, that’s OK; as long as they’re labelled!

5c) Temperature changed! First – will the temperature change create an overall shift to create more products or more reactants between 1000 and 2000 sec? (i.e. which way will the equilibrium shift?) Second – Even if the temperature change was instantaneous, will the shift you identified first happen instantly? Think again about kinetics and how it will help you determine an appropriate shape for your [concentration] vs. time plots. Third – Stoichiometry still applies! We don’t know the  $\Delta H$  for this reaction, so we can’t find an exact amount for the change (hence “sketch” the curve). But if the CoBr<sub>2</sub> changes by one “unit” of concentration, how much should the CO and Br<sub>2</sub> change (and in what direction)? Pick a value here and go (no marks depended on the size of the change you proposed, as long as the direction and relative stoichiometry were correct).



\*Without knowing  $\Delta H$ , there is no guarantee the  $K$  would shift enough to become  $>1$  as drawn in this plot, but either  $K > 1$  or a smaller shift with  $K < 1$  were both accepted; as long as  $[\text{CoBr}_2]$  decreased and  $[\text{CO}]$  and  $[\text{Br}_2]$  increased, with correct stoichiometry.