

Please follow the instructions for each section of the exam. Show your work on all mathematical problems. Provide answers with the correct units and significant figures. Be concise in your answers to discussion questions. I have intentionally left a great deal of space for each problem. I do not expect each problem to take up all of the space provided!

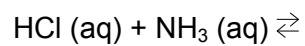
Part 0: Warmup. 4 points each

- The reaction $A \rightarrow \text{products}$ has been determined to be first order in A. The reaction is run with $[A]_0 = 0.20 \text{ M}$ and is found to have a half-life of 124 seconds. What is the rate constant for the reaction?
 - $8.06 \times 10^{-4} \text{ s}^{-1}$.
 - $8.06 \times 10^{-4} \text{ M}^{-1} \text{ s}^{-1}$
 - $5.59 \times 10^{-3} \text{ s}^{-1}$
 - $5.59 \times 10^{-3} \text{ M}^{-1} \text{ s}^{-1}$Answer _____
- For the reaction $A + B \rightarrow 2C$, which proceeds by a single-step bimolecular elementary process,
 - $t_{1/2} = 0.693/k$.
 - the rate of appearance of C = - rate of disappearance of A.
 - rate of the reaction = $k[A][B]$.
 - $\ln[A]_t = -kt + \ln[A]_0$Answer _____
- The volume of the reaction vessel containing an equilibrium mixture in the reaction $\text{SO}_2\text{Cl}_2(\text{g}) \rightleftharpoons \text{SO}_2(\text{g}) + \text{Cl}_2(\text{g})$ is increased. When equilibrium is reestablished,
 - the amount of Cl_2 will have increased.
 - the amount of SO_2 will have decreased.
 - the amounts of SO_2 and Cl_2 will have remained the same.
 - the amount of SO_2Cl_2 will have increased.Answer _____
- For the reaction $\text{CO}(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{H}_2(\text{g}) + \text{CO}_2(\text{g})$ at 1000K, $K_c = 0.66$ and $\Delta H^\circ = -42 \text{ kJ}$. After an initial equilibrium is established in a 1.00 L container, the equilibrium amount of H_2 can be increased by,
 - adding a catalyst.
 - increasing the temperature.
 - transferring the mixture to a 10.0 L container.
 - some way other than (a), (b), or (c).Answer _____
- Which of the acids below would have the *weakest conjugate base*?
 - CH_3COOH (acetic acid, $K_a = 1.8 \times 10^{-5}$)
 - HCl (hydrochloric acid, $K_a = 1000$).
 - HOCl (hypochlorous acid, $K_a = 3.0 \times 10^{-8}$).
 - HCO_2H (formic acid, $K_a = 1.8 \times 10^{-4}$)Answer _____

Bonus (5 points). I wrote a concentration on the board at the start of class one day and said it would be an answer on the exam. Write that concentration here with the correct units.

Part I: Complete all of problems 6-8.

6. Complete the following reaction and identify the conjugate acid-base pairs. For each pair, identify the acid and the conjugate base. (8 points)

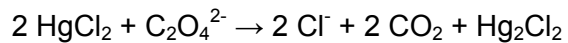


7. Briefly describe what we mean when we say that a system is *at equilibrium*. Why do we use a double-headed arrow (like \rightleftharpoons) when we write these reactions? (12 points)

8. How does a catalyst impact the rate of a reaction and the extent to which the reaction goes to completion? (8 points)

Part II Kinetics. Answer two (2) of problems 9-11. Clearly mark the problems you do not want graded. 14 points each.

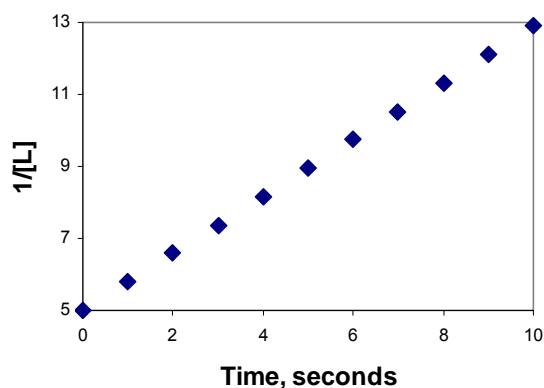
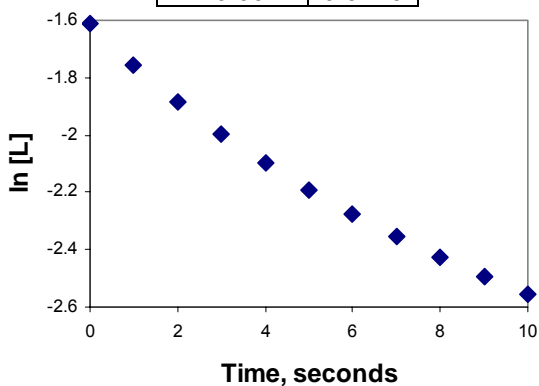
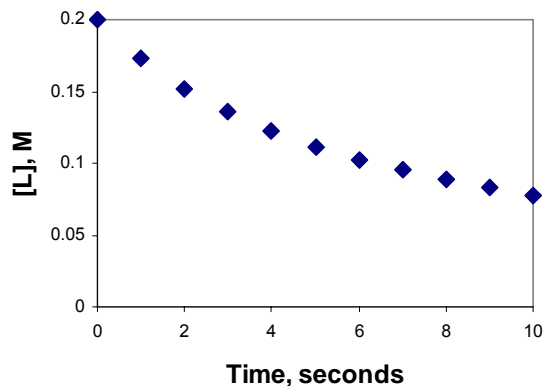
9. The initial rate data below is for the reduction of mercury with oxalate ion. Using this information, determine the rate law for the reaction as well as the rate constant (with appropriate units).



Experiment	[HgCl ₂], M	[C ₂ O ₄ ²⁻], M	Initial Rate, M min ⁻¹
1	0.105	0.300	7.18x10 ⁻⁵
2	0.052	0.300	3.56x10 ⁻⁵
3	0.208	0.600	5.69x10 ⁻⁴

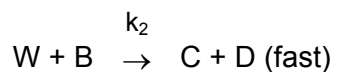
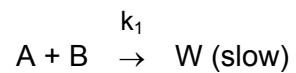
10. You are investigating the reaction of a newly discovered cancer drug named LAMPROCKS (abbreviated L). You have been charged with determining the rate law for the decomposition of LAMPROCKS into its two components, LAMP and ROCKS. The rate only depends on L and no other reactants. You have collected the following data and made the plots below. Based on this data, what is the rate law for this reaction and what is the value of the rate constant with the appropriate units? *Justify your choice for the rate law and show your work for the k determination.*

Time, sec	[L], M
0.00	0.200
1.00	0.173
2.00	0.152
3.00	0.136
4.00	0.123
5.00	0.112
6.00	0.103
7.00	0.0950
8.00	0.0884
9.00	0.0826
10.00	0.0776

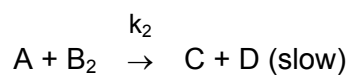
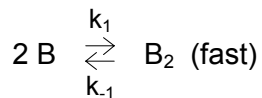


11. For the reaction $A + 2B \rightarrow C + D$, the rate law is: $\text{rate} = k[A][B]$.

- a. Show that the following mechanism is consistent with the stoichiometry of the overall reaction and with the rate law.



- b. Show that the following mechanism is consistent with the stoichiometry of the overall reaction, but not with the rate law.

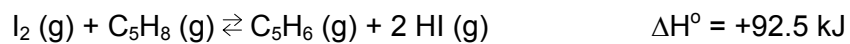


Part III Equilibrium. Answer two (2) of problems 12-14. Clearly mark the problems you do not want graded. 14 points each.

12. For the equilibrium below, $K_c = 2.0 \times 10^{-6}$. What is the equilibrium concentration of oxygen (in moles/L) if 0.20 mol CO_2 and 0.10 mol CO were initially placed into a 0.50 L vessel and the system is allowed to come to equilibrium?



13. In the gas phase, iodine reacts with cyclopentane to produce cyclopentadiene and hydrogen iodide. Explain how each of the following affects the amount of HI (g) present in the equilibrium mixture in the reaction:



a. raising the temperature of the mixture.

b. doubling the volume of the container holding the mixture.

c. introducing more $\text{C}_5\text{H}_6(\text{g})$.

14. For the reaction $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$ occurring at a temperature 1000K, $K_c = 100$. If 0.455 mol SO_2 , 0.183 mol O_2 , and 0.568 mol SO_3 are introduced simultaneously into a 1.90 L vessel at 1000K, is the system at equilibrium? If not, in which direction will a net change occur? *NOTE: you do not need to calculate the equilibrium concentrations, just clearly justify your answers.*

Possibly Useful Information

$\text{slope} = m = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$	$y = mx + b$	$R = 0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1}$
$\text{pH} + \text{pOH} = 14$	$K_a K_b = K_w$	$K_p = K_c (RT)^{\Delta n}$
$k = Ae^{-E_a/RT}$	$\ln k = -\left(\frac{E_a}{R}\right)\left(\frac{1}{T}\right) + \ln A$	$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$
$\text{rate} = k[A]^1$	$[A]_t = -kt + [A]_0$	$t_{1/2} = [A]_0/2k$
$\text{rate} = k[A]^2$	$\ln[A]_t = -kt + \ln[A]_0$	$t_{1/2} = 1/(k[A]_0)$
$\text{rate} = k[A]^0$	$\frac{1}{[A]_t} = kt + \frac{1}{[A]_0}$	$t_{1/2} = 0.693/k$

1 1A																			18 8A
1 H 1.00794	2 2A																		2 He 4.00260
3 Li 6.941	4 Be 9.01218											5 B 10.811	6 C 12.011	7 N 14.0067	8 O 15.9994	9 F 18.9984	10 Ne 20.1797		
11 Na 22.9898	12 Mg 24.3050	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 9B	10 10B	11 11B	12 12B	13 Al 26.9815	14 Si 28.0855	15 P 30.9738	16 S 32.066	17 Cl 35.4527	18 Ar 39.948		
19 K 39.0983	20 Ca 40.078	21 Sc 44.9559	22 Ti 47.88	23 V 50.9415	24 Cr 51.9961	25 Mn 54.9381	26 Fe 55.847	27 Co 58.9332	28 Ni 58.693	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.9216	34 Se 78.96	35 Br 79.904	36 Kr 83.80		
37 Rb 85.4678	38 Sr 87.62	39 Y 88.9059	40 Zr 91.224	41 Nb 92.9064	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.906	46 Pd 106.42	47 Ag 107.868	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.757	52 Te 127.60	53 I 126.904	54 Xe 131.29		
55 Cs 132.905	56 Ba 137.327	57 *La 138.906	72 Hf 178.49	73 Ta 180.948	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.967	80 Hg 200.59	81 Tl 204.383	82 Pb 207.2	83 Bi 208.980	84 Po (209)	85 At (210)	86 Rn (222)		
87 Fr (223)	88 Ra 226.025	89 †Ac 227.028	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (277)	109 Mt (268)	110 Ds (271)	111 Rg (272)									
*Lanthanide series		58 Ce 140.115	59 Pr 140.908	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.965	64 Gd 157.25	65 Tb 158.925	66 Dy 162.50	67 Ho 164.930	68 Er 167.26	69 Tm 168.934	70 Yb 173.04	71 Lu 174.967				
†Actinide series		90 Th 232.038	91 Pa 231.036	92 U 238.029	93 Np 237.048	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)				

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