Solutions

CHEM 1423 - Exam 1 – February 9, 2017

Constants and Equations: R = 8.31 J/mol-K

Beer-Lambert Law: $A = \log\left(\frac{I_o}{I}\right) = \varepsilon bc$

Michaelis-Menten Equation: $v_0 = \frac{V_m[S]}{K_M + [S]}$

PERIODIC TABLE OF THE ELEMENTS

Key: Atomic Number / Symbol / Atomic Mass (1 / H / 1.008)

	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 H 1.008																	2 He 4.003
2	3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 23.00	12 Mg 24.30											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3	71 Lu 175.0	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra 226.0	103 Lr (260)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)									

Approved by the I.U.P.A.C. Council in Geneva, August 30, 1997

Lanthanide series	57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.2	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0
Actinide series	89 Ac 227.0	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	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)

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Name Solutions

(76) **PART I. MULTIPLE CHOICE (Circle the ONE correct answer)**

1. For the reaction, A + B $\rightarrow$ Products, the rate law is $Rate = k\frac{[A]}{[B]^2}$. The units of the rate constant are:

   (A) M^3s^{-1} (B) M^2s^{-1} (C) $M^{-3}s^{-1}$ (D) $M^{-2}s^{-1}$

2. The rate of the chemical reaction involving two substances, A and B, is measured. It is found that if the initial concentration of A used is quadrupled, keeping the B concentration the same, the rate increases by a factor of 64 (relative to the first experiment). If the concentrations of both A and B are quadrupled, the rate increases by a factor of 16 (relative to the first experiment). The rate law for this reaction is: Rate =

   (A) $k[A]^2[B]$ (B) $k[A]^2[B]^{-1}$ (C) $k[A]^3[B]^{-1}$ (D) $k[A]^3[B]$

3. Consider a reaction, A $\rightarrow$ Products, which is of order "n"; i.e. Rate = $k[A]^n$. For this reaction, the following initial rate data was obtained.

   When $[A]_o$ = 0.20 M, the initial rate is 1.2 M/s

   When $[A]_o$ = 0.80 M, the initial rate is 19.2 M/s

   The order of this reaction (i.e. "n") is:

   (A) +3 (B) +2 (C) +1 (D) -1

4. For the above reaction (question immediately above), the rate constant is approximately:

   (A) 6.0 s^{-1} (B) 150 $M^{-2}s^{-1}$ (C) 30 $M^{-1}s^{-1}$ (D) 0.24 M^2s^{-1}

For #5 - #7: Consider a reaction, A $\rightarrow$ Products, which is of **first** order; i.e. Rate = k[A]. For this reaction, the rate constant is 0.015 s^{-1} at 100 °C. The Activation Energy for this reaction is 75 kJ/mol.

5. For this reaction, a plot of ____ vs. time is a straight line with a ____ slope.

   (A) $\ln([A]_t)$, negative (B) $[A]_t$, negative

   (C) $1/(A]_t)$, negative (D) $1/[A]_t$, positive

6. If the initial concentration of A is 1.30 M (at 100 °C), what will be the concentration of A 70 s after the start of the reaction?

(A) 0.25 M (B) 0.36 M (C) 0.45 M (D) 0.58 M

7. What will be the value of the rate constant at 150 °C?

(A) 0.26 s^{-1} (B) 0.057 s^{-1} (C) 8.6×10^{-4} s^{-1} (D) 17.5 s^{-1}

For #8 - #9: Consider a reaction, B → Products, which is 2nd. order; i.e. Rate = $k[B]^2$. The molecule, B, absorbs visible light at 500 nm. The Molar Absorptivitiy for this absorption is ε = 600 M^{-1} cm^{-1}.

When a sample of B with initial concentration, $[B]_o = 1.20 \times 10^{-3}$ M, is placed in a sample cell with cell pathlength = 2.0 cm, then the Percent Transmission 150 s after the start of the experiment is 30%.

8. The concentration of [B] 150 s after the start of the experiment is approximately:

(A) 4.36×10^{-4} M (A) 1.82×10^{-4} M (A) 1.00×10^{-3} M (A) 8.71×10^{-4} M

9. The rate constant for this second order reaction is approximately:

(A) 1.1 $M^{-1}s^{-1}$ (B) 2.1 $M^{-1}s^{-1}$ (C) 31.1 $M^{-1}s^{-1}$ (D) 9.7 $M^{-1}s^{-1}$

10. Which of the following statements is/are **TRUE**?

(1) The mechanism for a catalyzed reaction is the same as the mechanism of the same reaction without the catalyst.

(2) The enthalpy change of the reaction is the same for the catalyzed reaction as for the uncatalyzed chemical reaction.

(3) The intermediate in a reaction is generated in one of the earlier steps of a reaction and used up in later steps.

(4) The Rate Determining Step in a catalyzed reaction mechanism has a lower activation energy and, therefore, is slower than the Rate Determining Step for the uncatalyzed reaction.

(A) 1 & 4 (B) 2 only (C) 2 & 3 (D) 2 & 3 & 4

11. Consider a reaction, R → P (i.e. Reactants → Products). If the activation energy for the **forward** reaction is 40 kJ//mol and the activation energy for the **reverse** reaction is 85 kJ/mol, then the overall enthalpy (aka energy) change for this reaction is:

(A) +125 kJ/mol (B) -45 kJ/mol (C) -125 kJ/mol (D) +45 kJ/mol

12. For the reaction, $Sc^{3+}(aq) + 2\ Pd^{+}(aq) \rightarrow Sc^{+}(aq) + 2\ Pd^{2+}(aq)$, the reaction mechanism is:

$$2\,Pd^{+} \underset{}{\overset{K}{\rightleftarrows}} Pd + Pd^{2+} \quad \text{Fast equilibrium}$$

$$Pd + Sc^{3+} \xrightarrow{k} Pd^{2+} + Sc^{+} \quad \text{Slow step}$$

The overall rate equation for this reaction is:

(A) $Rate = k'\frac{[Pd^{2+}][Sc^{3+}]}{[Pd^{+}]^{2}}$ (B) $Rate = k'\frac{[Pd^{+}][Sc^{3+}]}{[Pd^{2+}]}$

(C) $Rate = k'\frac{[Pd^{+}]^{2}[Sc^{3+}]}{[Pd^{2+}]}$ (D) $Rate = k'[Pd][Sc^{3+}]$

13. When a substrate (S) binds **Strongly** to an enzyme (E) to form the complex, ES:

(A) K_m is small (B) V_m is small (C) V_m is large (D) K_m is large

14. In an enzyme catalyzed reaction, for approximately what ratio, $[S]/K_m$, does one find that $v_o = 0.4V_m$?

(A) $[S]/K_m = 1.50$ (B) $[S]/K_m = 1.20$ (C) $[S]/K_m = 0.83$ (D) $[S]/K_m = 0.67$

15. Consider the gas phase equilibrium, $A(g) \rightleftharpoons B(g) + 2C(g)$,

$K_c = 1.0\times10^{-4}$. 3.0 mol of A(g) is placed in a 4.0 L container and the mixture is allowed to come to equilibrium. Calculate the approximate concentration of C(g) at equilibrium.

NOTE: You can assume that very little A(g) reacts to form B(g) and C(g)

(A) 2.7×10^{-2} M (B) 5.3×10^{-2} M (C) 4.2×10^{-2} M (D) 8.4×10^{-2} M

16. Consider the gas phase equilibrium $A(g) \rightleftharpoons 2\,B(g)$. 3.0 moles of pure A(g) are placed in a 2.0 L container, and the reaction is allowed to proceed to equilibrium. It is found that after equilibrium has been established, the concentration of B(g) is 0.80 M. The value of the equilibrium constant, K_c, is approximately:

(A) 0.15 (B) 0.43 (C) 0.58 (D) 0.73

For #17 - #19: For the gas phase reaction, $2\,Br_2(g) + 4\,NO(g) \rightleftharpoons 4\,NOBr(g)$, $K_c = 50.$ at 400 K.

17. For the above reaction, if the equilibrium concentrations (at 400 K) of $Br_2(g)$ and NOBr(g) are each 2.5 M, then the equilibrium concentration of NO is approximately:

(A) 1.7 M (B) 2.8 M (C) 0.59 M (D) 0.35

18. If a mixture is prepared with $[Br_2] = 0.7$ M, $[NO] = 0.7$ M and $[NOBr] = 1.5$ M, the reaction quotient is approximately ______ and the reaction will proceed towards the ______.

(A) 43. , Right (B) 84 , Left (C) 43 , Left
(D) None of the above

19. The equilibrium constant for the related reaction $2\,NOBr(g) \rightleftharpoons Br_2(g) + 2\,NO(g)$, at 400 K is approximately:

(A) 0.14 (B) 0.32 (C) 0.04 (D) 7.1

PART II. THERE ARE TWO (2) PROBLEMS ON FOLLOWING PAGES
You MUST show your work for credit.

(12) 1. Consider the reaction, A → Products, which is **third** order with respect to [A]; i.e. the rate is given by Rate = $k[A]^3$. It can be shown that the integrated rate equation for this reaction is given by:

The integrated rate equation for the reaction is: $\frac{1}{[A]^2} - \frac{1}{[A]_0^2} = 2kt$

$[A]_0$ and [A] are the concentrations at t = 0 and t, respectively, and k is the rate constant.

(8) (a) When the initial concentration of A is 0.90 M, the half-life for the reaction is $t_{1/2}$ = 60 s. Calculate the rate constant for the reaction (give units).

$[A]_0 = 0.90 M$
$[A] = \frac{1}{2}[A]_0 = 0.45 M$
when $t = t_{1/2} = 60 s$

$k = \frac{1}{2t}\left[\frac{1}{[A]^2} - \frac{1}{[A]_0^2}\right]$

$= \frac{1}{2(60 s)}\left[\frac{1}{(0.45 M)^2} - \frac{1}{(0.90 M)^2}\right]$

$= 0.0309\ M^{-2}s^{-1} \approx 0.031\ M^{-2}s^{-1}$

(4) (b) When the initial concentration of A is 0.90 M, calculate the concentration of A 100 s after the start of the reaction.

Note: If you don't like your answer for part (a), you can use k = 0.035 $M^{-2}s^{-1}$ (without loss of credit in this part).

$k = 0.0309\ M^{-2}s^{-1}$
$t = 100 s$
$[A_0] = 0.9 M$
$[A] = ?$

$\frac{1}{[A]^2} = \frac{1}{[A_0]^2} + 2kt$

$= \frac{1}{(0.9 M)^2} + 2(0.0309\ M^{-2}s^{-1})(100 s)$

$\frac{1}{[A]^2} = 7.41\ M^{-2}$

$[A]^2 = \frac{1}{7.415} = 0.135\ M^2$

$[A] = (0.135\ M^2)^{\frac{1}{2}}$

$\approx 0.37\ M$

(12) 2. Consider the reaction: $2NO(g) \overset{K_c}{\rightleftarrows} N_2(g) + O_2(g)$. The equilibrium constant is K_c = 2. at 1500 K.

2.0 mol of $N_2(g)$ an 2.0 mol of O_2 are placed in a 10 L container and heated to 1500 K, where equilibrium is established.

Calculate the equilibrium concentrations **(in M)** of NO, N_2 and O_2 in the equilibrium mixture.

$[N_2]_0 = [O_2]_0 = \frac{2.0\,mol}{10\,L} = 0.20\ M$

$[NO]_0 = 0$

	$2NO$	$\rightleftarrows$	N_2	$+O_2$
Init	0		0.20	0.20
chg	+2X		-X	-X
Equil	2X		0.20-X	0.20-X

$K_c = 2.0 = \frac{[N_2][O_2]}{[NO]^2} = \frac{(0.20-x)(0.20-x)}{(2x)^2} = \frac{(0.20-x)^2}{(2x)^2}$

Take Sq. Root

$\sqrt{K_c} = \sqrt{2} = 1.414 = \frac{0.20-x}{2x}$

$0.20 - x = 2(1.414)x = 2.828x$

$3.828x = 0.20$

$x = \frac{0.20}{3.828}$

$= 0.052\ M$

$[N_2] = [O_2] = 0.20 - x = 0.20 - 0.052$

$= 0.148\ M \approx 0.15\ M$

$[NO] = 2x = 2(0.052)$

$= 0.104\ M \approx 0.10\ M$