Solutions

CHEM 1423 - Exam 1 – February 11, 2016

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
1
H
1.008 – Atomic Number, Symbol, Atomic Mass

	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

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

1. Consider the hypothetical reaction, $2A + B \rightarrow 3C$. If the rate of change of [C] is $\Delta[C]/dt = +0.60$ M hr^{-1}. What is the rate of change of [A], $\Delta[A]/dt$?

   (A) -0.20 M hr^{-1} [✓ (B) -0.40 M hr^{-1}]

   (C) -0.30 M hr^{r} (D) +0.40 M hr^{-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 tripled, keeping the B concentration the same, the rate increases by a factor of 27 (relative to the first experiment). If the concentrations of both A and B are doubled, the rate increases by a factor of 32 (relative to the first experiment). The rate law for this reaction is: Rate =

   (A) $k[A]^2[B]^3$ (B) $k[A]^2[B]^2$ (C) $k[A]^3[B]$ [✓ (D) $k[A]^3[B]^2$]

For #3 - #4: 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 0.50 M/s

When $[A]_o = 0.60$ M, the initial rate is 13.5 M/s

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

   [✓ (A) +3] (B) +2 (C) +1 (D) -1

4. The rate constant for this reaction (i.e. "k") is:

   (A) 313 M^{-3}s^{-1} (B) 12.5 M^{-1}s^{-1} [✓ (C) 62.5 M^{-2}s^{-1}] (D) 2.5 s^{-1}

5. Radioactive decay follows first order kinetics. Thallium-201 is a radioisotope which is used for myocardial imaging tests. Its half-life is 73 hours. If 300 mg of ^{201}Tl is injected into a patient, how many mg will remain 185 hours after the injection ?

   (A) 124 mg [✓ (B) 52 mg] (C) 34 mg (D) 83 mg.

6. For the **zeroth** order reaction, $A \rightarrow$ Products, when the initial concentration of A is 0.90 M, it takes 25 s for the concentration to decrease to 0.30 M. Therefore, the rate constant for this reaction is approximately:

   (A) 0.044 Ms^{-1} (B) 0.089 Ms^{-1} (C) 0.015 Ms^{-1} [✓ (D) 0.024 Ms^{-1}]

For #7 - #8: Consider a reaction, A → Products, which is of **second** order; i.e. Rate = $k[A]^2$. For this reaction, the rate constant is 8.5×10^{-3} $M^{-1}s^{-1}$.

7. 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]

8. If the initial concentration of A is 0.75 M, what will be the approximate concentration of A 600 seconds after the start of the reaction.

(A) 0.20 M [✓ (B) 0.16 M] (C) 0.28 M (D) 0.046 M

9. Which **one** statement below is correct? The frequency factor in the Arrhenius equation can best be described as:

(A) A numerical description of the amount of energy released by colliding reactant molecules when they form products.

(B) The probability that a collision between molecules will have the correct relative orientation for reaction to occur.

[✓ (C) A numerical description of how often molecules collide with the proper orientation to react at a specific concentration.]

(D) A numerical description of the amount of energy needed by colliding reactant molecules in order to form products.

10. Which of the following statements is/are **NOT** true?

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

False (2) The enthalpy change of the reaction is lower for the catalyzed reaction than for the uncatalyzed chemical reaction.

True (3) The catalyst in a reaction is present at the start of the reaction and is regenerated during the reaction.

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

(A) 2 & 4 (B) 2 & 3 & 4 (C) 1 & 3 [✓ (D) 2 & 4]

11. For the reaction, $Cd_2^{2+}(aq) + Zr^{3+}(aq) \rightarrow 2\ Cd^{2+}(aq) + Zl^{+}(aq)$,. the accepted reaction mechanism is:

$$Cd_2^{2+} \overset{K}{\rightleftharpoons} Cd + Cd^{2+} \qquad \text{Fast Pre-Equilibrium}$$

$$Zr^{3+} + Cd \xrightarrow{k_2} Zr^{+} + Cd^{2+} \qquad \text{Slow Rate Determining Step}$$

An acceptable rate law for the rate, Rate = $\Delta[Zr^{+}]/\Delta t$, is:

(A) $Rate = k'\frac{[Zr^{3+}][Cd_2^{2+}]}{[Cd]}$

(B) $Rate = k'\frac{[Zr^{3+}][Cd^{+}]^2}{[Cd^{2+}]}$

(C) $Rate = k'[Zr^{3+}][Cd_2^{2+}][Cd^{2+}]$

[✓ (D) $Rate = k'\frac{[Zr^{3+}][Cd_2^{2+}]}{[Cd^{2+}]}$]

12. Consider a reaction, R → P (i.e. Reactants → Products). If the activation energy for the **reverse** reaction is 85 kJ//mol and the overall energy (aka enthalpy) change for the reaction is -30 kJ/mol. Therefore, the activation energy for the **forward** reaction is:

(A) +115 kJ/mol [✓ (B) +55 kJ/mol] (C) +105 kJ/mol (D) -55 kJ/mol

13. In an enzyme catalyzed reaction, when the Substrate Concentration is much greater than the Michaelis-Constant, K_M, then the rate of the reaction is _____ order with respect to [S]

(A) Second order (B) First Order [✓ (C) Zeroth Order]
(D) Indeterminate without know the values of K_M and [S].

14. In an enzyme catalyzed reaction, for what ratio, $[S]/K_M$, is the initial velocity, $v_0 = 0.70\ V_m$?

(A) 1.75 (B) 0.43 [✓ (C) 2.33] (D) 3.41

15. Consider the gas phase equilibrium, $A(g) \rightleftharpoons B(g) + 3C(g)$,

$K_c = 1.0\times10^{-5}$. 3.0 mol of A(g) is placed in a 2.0 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) 8.2×10^{-2} M] (B) 1.1×10^{-1} M (C) 2.7×10^{-2} M (D) 9.7×10^{-2} M

For #16 - #20 For the gas phase reaction, $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$, K_c = 120. at 600 K. The Enthalpy change for this reaction is +95 kJ/mol

16. If a mixture is prepared with $[SO_2]$ = 0.4 M, $[O_2]$ = 0.3 M and $[SO_3]$ = 1.5 M, the reaction quotient is ______ and the reaction will proceed towards the ______.

[✓ (A) 47. , Right] (B) 188. , Left
(C) 63. , Right (D) 188. , Right

17. For the above reaction, if the equilibrium concentrations (at 600 K) of SO_3 and O_2 are 0.40 M and 0.10 M, respectively, what is the approximate equilibrium concentration of SO_2?

[✓ (A) 0.12 M]   (B) 0.18 M   (C) 0.013 M   (D) 0.26 M

18. For the above equilibrium reaction, if the temperature is **decreased**, the ratio $[SO_2]/[SO_3]$ will ______ and K_c will _____.

(A) decrease , increase   (B) decrease , decrease
(C) increase , remain constant   [✓ (D) increase , decrease]

19. For the above reaction, if $N_2(g)$ is added to the mixture in a container at fixed **volume**, the ratio $[SO_2]/[SO_3]$ will ______ and K_c will _____.

(A) increase , decrease   (B) decrease , remain constant
[✓ (C) remain constant , remain constant]   (D) increase , remain constant

20. What is the approximate equilibrium constant (at 600 K) for the related equilibrium, $4SO_2(g)+2O_2(g)\rightleftharpoons 4SO_3(g)$?

(A) 240   [✓ (B) 1.4×10^{4}]   (C) 6.9×10^{-5} (D) 8.3×10^{-3}

PART II. THERE ARE FOUR (4) PROBLEMS BELOW.

(10) 1. The measured value of the rate constant for a first order reaction is 1.50×10^{3} min^{-1} at a temperature of 120 °C, and 1.35×10^{5} min^{-1} at 180 °C.
Calculate the Arrhenius **Activation Energy** (in kJ/mol) and the **Frequency Factor** (in min^{-1}) for this reaction.

$k_1 = 1.5 \times 10^{3}\ \text{min}^{-1}$

$T_1 = 120°C$

$= 393\ K$

$k_2 = 1.35 \times 10^{5}\ \text{min}^{-1}$

$T_2 = 180°C$

$= 453\ K$

$\boxed{E_a}$

$$\ln\left(\frac{k_2}{k_1}\right) = -\frac{E_a}{R}\left[\frac{1}{T_2} - \frac{1}{T_1}\right]$$

$$-\frac{E_a}{R} = \frac{\ln(k_2/k_1)}{\frac{1}{T_2} - \frac{1}{T_1}} = \frac{\ln(1.35 \times 10^{5} / 1.5 \times 10^{3})}{\frac{1}{453K} - \frac{1}{393K}}$$

$$= -1.335 \times 10^{4}/R$$

$$E_a = -R(-1.335 \times 10^{4} K) = 8.31\ J/mol\text{-}K\,(-1.335 \times 10^{4} K)$$

$$= 1.110 \times 10^{5}\ J/mol = \boxed{111.\ kJ/mol}$$

$\boxed{A}$

$$\ln k_1 = \ln A - E_a/RT_1$$

$$\ln A = \ln k_1 + E_a/RT_1 = \ln(1.5 \times 10^{3}) + \frac{1.11 \times 10^{5}}{8.31(393)}$$

$$= 41.29$$

$$A = e^{41.29} = \boxed{8.52 \times 10^{17}\ \text{min}^{-1}}$$

$\epsilon = 800\,M^{-1}\,cm^{-1}$ $b = 0.50\,cm.$

(10) 2. Consider a molecule, B, which reacts to form Products via First Order kinetics:

$$A \rightarrow P \qquad R = -\frac{d[A]}{dt} = k[A]$$

The molecule, B, absorbs visible light at 480 nm. The Molar Absorptivity for this absorption is given by ε = 800 M^{-1} cm^{-1}.

When a sample of B is prepared in a 0.5 cm cell, the Percent Transmission at the beginning of the reaction was 25%. After the reaction has run for 50 minutes, the percent transmission is 70%. Calculate the rate constant for this reaction **(give the units)**

$t = 0$, $\%T = 100 \times \frac{I}{I_0} = 25\%$, $A = \log\left(\frac{I_0}{I}\right) = \log\left(\frac{100}{25}\right)$

$$= 0.602$$

$$\text{conc} = [A]_0 = \frac{A}{\epsilon b} = \frac{0.602}{(800\,M^{-1}\,cm^{-1})(0.50\,cm)} = 1.51 \times 10^{-3}\,M$$

$t = 50\,min$ $\%T = 70\%$ $A = \log\left(\frac{I_0}{I}\right) = \log\left(\frac{100}{70}\right) = 0.155$

$$\text{conc} = [A]_t = \frac{A}{\epsilon b} = \frac{0.155}{(800\,cm^{-1})(0.50\,cm)} = 3.87 \times 10^{-4}\,M$$

$\boxed{k}$ First order: $\ln([A]_t) = -kt + \ln([A]_0)$

$$\therefore\ k = \frac{\ln[A]_0 - \ln[A]_t}{t} = \frac{\ln(1.51\times10^{-3}) - \ln(3.87\times10^{-4})}{50\,min}$$

$$\boxed{\begin{aligned} k &= 0.0272\ min^{-1} \\ &\approx 0.027\ min^{-1} \end{aligned}}$$

(10) 3. Consider the reaction: $Cl_2(g) + 2\ NO_2(g) \rightleftharpoons 2\ NOCl(g)$.

If 1.50 mol of $Cl_2(g)$ and 1.50 mol of $NO_2(g)$ are placed in a 5.0 Liter container, which is heated to 200 °C, the equilibrium concentration of $NO_2(g)$ is 0.120 M. Calculate the equilibrium constant, K_c, for this reaction at 200 °C.

$[Cl_2]_0 = [NO_2]_0 = \frac{1.5\ mol}{5.0\ L} = 0.30\ M$

	Cl_2 +	$2NO_2$ ⇌	$2NOCl$
Init	0.30	0.30	0.0
Chg	$-x$	$-2x$	$+2x$
Equil	$0.3-x$	$0.3-2x$	$2x$

calc. of x

Equil. $[NO_2]_{eq} = 0.12\ M = 0.3 - 2x$

$x = 0.09\ M$

Concs. at Equil

$[NO_2]_{eq} = 0.12\ M$

$[Cl_2]_{eq} = 0.3 - x = 0.21\ M$

$[NOCl]_{eq} = 2x = 0.18\ M$

Kc

$$K_c = \frac{[NOCl]^2}{[Cl_2][NO_2]^2} = \frac{(0.18)^2}{(0.21)(0.12)^2}$$

$$\boxed{= 10.7}$$

(10) 4. Consider the reaction: $H_2(g)+I_2(g) \overset{K_c}{\rightleftarrows} 2HI(g)$ Kc = 9.0 (at 550 K)
8.0 mol of HI(g) is placed in a 20.0 L container and heated to 550 K, where equilibrium is established.
Calculate the equilibrium concentrations **(in M)** of H_2(g) , I_2(g) and HI(g) ?

$$[HI]_0 = \frac{8\text{ mol}}{20\text{ L}} = 0.40\text{ M}$$

	H_2 +	I_2 =	$2HI$
Init.	0	0	0.40
Chg	+1x	+1x	−2x
Equil	x	x	0.40−2x

$$K_c = \frac{[HI]^2}{[H_2][I_2]} = \frac{(0.40-2x)^2}{x \cdot x} = 9.0$$

$$\therefore \frac{0.40-2x}{x} = \sqrt{9} = 3.0 \rightarrow 0.40-2x = 3x$$

$$5x = 0.40$$

$$x = 0.08\text{ M}$$

$$\therefore \boxed{[H_2] = [I_2] = x = 0.08\text{ M}}$$

$$[HI] = 0.40-2x = 0.40-2(0.08)$$

$$= \boxed{0.24\text{ M}}$$