BCIT

Winter 2016

Chem 0012

Exam #1

Name: _____

Attempt all questions in this exam. Read each question **carefully** and give a complete answer in the space provided.

Part marks given for wrong answers with partially correct reasoning/calculations.

Equations, constants and aperiodic table are attached at the back.

Total points = 30

Section I: Multiple choice (*15 points total, 1 point each*)
Choose the **BEST** answer to the following questions.

1. Which of the following reactions will be slowest at room temperature?

   (a) $Zn(s) + S(s) \rightarrow ZnS(s)$

   b) $Cu(s) + 2AgNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2Ag(s)$

   c) $Pb(NO_3)_2(aq) + 2KI(aq) \rightarrow PbI_2(s) + 2KNO_3(aq)$

   d) $HC_2H_3O_2(aq) + KOH(aq) \rightarrow KC_2H_3O_2(aq) + H_2O(\ell)$

2. Nitrogen monoxide and hydrogen react according to the following equation:

$$2NO(g) + 2H_2(g) \rightarrow N_2(g) + 2H_2O(\ell)$$

   If the rate of hydrogen consumption is 0.087 g/min, what is the rate of nitrogen production?

   a) 0.044 g/min

   (b) 0.61 g/min

   c) 1.2 g/min

   d) 2.4 g/min

3. Increasing the temperature of a reaction increases the reaction rate by

I	Increasing the frequency of collisions
II	Increasing the kinetic energy of collisions
III	Decreasing the potential energy of collisions

   a) I only

   (b) I and II only

   c) II and III only

   d) I, II and III

4. What effect does a catalyst have on a reaction?

   a) It changes the ΔH of a reaction.

   b) It increases the kinetic energy of the reactants.

   c) It decreases the potential energy of the products.

   (d) It provides a reaction mechanism with lower activation energy.

5. Which of the following would result in a successful collision between reactant particles?

   a) particles have sufficient kinetic energy

   b) particles convert all their potential energy into kinetic energy

   c) particles are in an excited state and are catalyzed

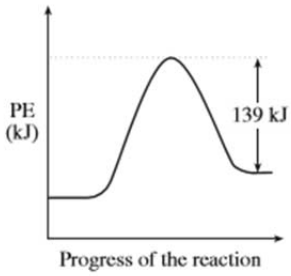
   d) particles have sufficient kinetic energy and proper molecular orientation

6. The following reaction has an E_a = 167 kJ:

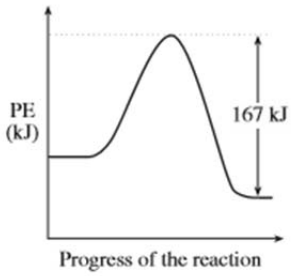
$$28\ kJ + H_2(g) + I_2(g) \rightarrow 2HI(g)$$

   Which of the following potential energy diagrams below represents this reaction?

A.



B.



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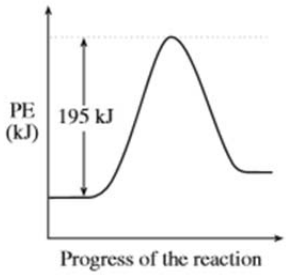
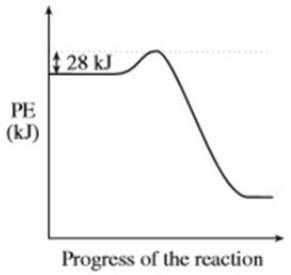


D.



7. Consider the following reaction mechanism:

Step 1	$Ce^{4+} + Mn^{2+} \rightarrow Ce^{3+} + Mn^{3+}$
Step 2	$Ce^{4+} + Mn^{3+} \rightarrow Ce^{3+} + Mn^{4+}$
Step 3	$Tl^{+} + Mn^{4+} \rightarrow Tl^{3+} + Mn^{2+}$

   The catalyst is

   a) Ce^{4+}

   b) Mn^{2+}

   c) Mn^{3+}

   d) Tl^{3+}

8. The following reaction is first order with respect to A and second order with respect to B.

   $A + B \rightarrow C + D$

   The concentrations of both A and B are doubled. Assuming no temperature change, which statement makes an accurate comment about the reaction rate?

   a) the reaction rate would stay the same

   b) the reaction rate would increase by a factor of 2

   c) the reaction rate would increase by a factor of 4

   (d) the reaction rate would increase by a factor of 8

9. Consider the following equilibrium:

   $2O_3(g) \rightleftharpoons 3O_2(g)$ $\quad K_{eq} = 65$

   Initially, 0.10 mol of O_3 and 0.10 mol O_2 are placed in a 1.0 L container. Which of the following describes the changes in the concentration as the reaction proceeds toward equilibrium?

	$[O_3]$	$[O_2]$
a)	decreases	decreases
(b)	decreases	increases
c)	increases	decreases
d)	increases	increases

10. Consider the following system at equilibrium:

    $NH_3(aq) + H_2O(\ell) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

    How are K_{eq} and $[NH_3]$ affected by the addition of OH^- into the container?

	K_{eq}	$[NH_3]$
a)	no change	decreases
b)	no change	no change
(c)	no change	increases
d)	decreases	increases

11. Consider the following system at equilibrium:

$N_2O_4(g) + \text{heat} \rightleftharpoons 2NO_2(g)$

How are K_{eq} and $[N_2O_4]$ affected by an increase in the container's volume?

	K_{eq}	$[N_2O_4]$
(a)	no change	decreases
b)	no change	no change
c)	no change	increases
d)	decreases	increases

12. A container is initially filed with pure SO_3. After a period of time, the following equilibrium is established:

$H_2SO_3(aq) \rightleftharpoons 2H^+(aq) + SO_3^{2-}(aq)$ $\quad K_{eq} = 1.2 \times 10^{-9}$

What does this equilibrium mixture contain?

a) mostly products
(b) mostly reactants
c) ¼ reactants and ¾ products
d) equal amounts of reactants and products

13. Consider the following equilibrium:

$P_4(s) + 5O_2(g) \rightleftharpoons P_4O_{10}(s)$

Identify the equilibrium constant expression.

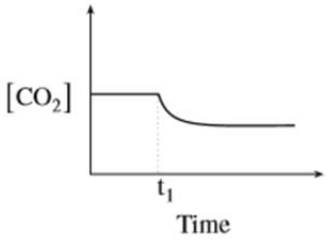
a) $K_{eq} = \frac{[P_4][O_2]^5}{[P_4O_{10}]}$
b) $K_{eq} = \frac{[P_4O_{10}]}{[P_4][O_2]^5}$
c) $K_{eq} = [O_2]^5$
(d) $K_{eq} = \frac{1}{[O_2]^5}$

14. Consider the following equilibrium:

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g) \qquad \Delta H = +175 \text{ kJ}$$

Which of the following diagrams best represents the change in concentration of CO_2 as the temperature is decreased at time t_1?

A.



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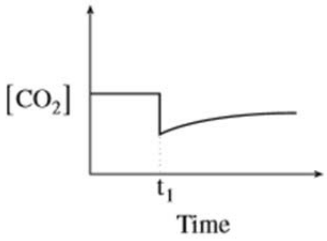

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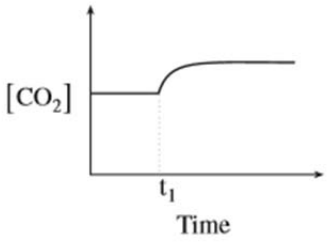
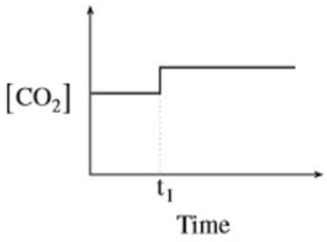


D.



15. Consider the following system:

$$NH_4NO_3(s) \rightleftharpoons N_2O(g) + 2H_2O(g) \qquad \Delta H = -37 \text{ kJ}$$

Which of the following is true?

	Enthalpy	Entropy	Outcome
a)	favours reactants	favours reactants	reaction does not occur
b)	favours products	favours products	reaction goes to completion
c)	favours reactants	favours products	reaction reaches equilibrium
d)	favours products	favours reactants	reaction reaches equilibrium

Section II: Written problems (*15 points total*).

16. Consider the reaction: A(aq) + B(aq) → C(aq)

a) From the following data obtained at 20°C temperature, determine the rate law and the rate constant. (5 points)

[A] (M)	[B] (M)	Reaction Rate (M/s)
0.50	0.050	5.0×10^{-4}
0.50	0.150	4.5×10^{-3}
1.00	0.050	1.0×10^{-3}

Rate = $k[A]^x[B]^y$

$$\frac{R_2}{R_1} = \frac{4.5x10^{-3}\ M\ s^{-1}}{5.0x10^{-4}\ M\ s^{-1}} = \frac{k(0.50\ M)^x(0.150\ M)^y}{k(0.50\ M)^x(0.050\ M)^y} = \frac{(0.150\ M)^y}{(0.050\ M)^y} = 3^y$$

$$9 = 3^y \ \therefore y = 2$$

$$\frac{R_3}{R_1} = \frac{1.0x10^{-3}\ M\ s^{-1}}{5.0x10^{-4}\ M\ s^{-1}} = \frac{k(1.00\ M)^x(0.050\ M)^y}{k(0.50\ M)^x(0.050\ M)^y} = \frac{(1.00\ M)^x}{(0.50\ M)^x} = 2^x$$

$$2 = 2^x \ \therefore x = 1 \ \rightarrow Rate = k\ [A][B]^2$$

$$k = \frac{Rate}{[A][B]^2} = \frac{5.0x10^{-4}\ M\ s^{-1}}{(0.50\ M)(0.05\ M)^2} = 0.40\ M^{-2}\ s^{-1}$$

Rate = $(0.40\ M^{-2}\ s^{-1})\ [A]\ [B]^2$

b) What is the reaction rate when [A] = 0.50 M and [B] = 0.10 M at 20°C? (1 point)

Rate = $k[A]\ [B]^2 = = (0.40\ M^{-2}\ s^{-1})\ [0.50\ M]\ [0.10\ M]^2 = 2.0x10^{-3}\ M\ s^{-1}$

17. Consider the following equilibrium system:

$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$ $\quad K_c = 0.010$

Initially, 30.0 g $CaCO_3$ were placed in a 2.0 L container. What mass of CO_2 will be present at equilibrium? (2 points)

$K_c = [CO_2] = 0.010$

so the $[CO_2] = 0.010$ M

$$(2.0\ L)\left(\frac{0.010\ mol\ CO_2}{L}\right)\left(\frac{44.0\ \ g\ CO_2}{mol\ CO_2}\right) = 0.88\ g\ CO_2$$

18. Consider the following two equilibria:

Eq 1 $\quad HF(aq) \rightleftharpoons H^+(aq) + F^-(aq) \quad K_1 = 3.4\text{x}10^{-4}$

Eq 2 $\quad H_2O(\ell) \rightleftharpoons H^+(aq) + OH^-(aq) \quad K_2 = 1.0\text{x}10^{-14}$

a) What is the value of K_{eq} for the following equilibrium? (1 point)

$H^+(aq) + F^-(aq) \rightleftharpoons HF(aq)$

the equilibrium is the reverse of eq 1

$K = (K_1)^{-1} = (3.4\text{x}10^{-4})^{-1} = 2.9\text{x}10^{3}$

b) What is the value of K_{eq} for the following equilibrium? (2 points)

$F^-(aq) + H_2O(\ell) \rightleftharpoons HF(aq) + OH^-(aq)$

the equilibrium is the sum of the equilibrium in part a and eq 2

$K = (K_1)^{-1}\ K_2 = (3.4\text{x}10^{-4})^{-1}\ (1.0\text{x}10^{-14}) = 2.9\text{x}10^{-11}$

19. Consider the following equilibrium system:

$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$ $\quad K_c = 0.095$

Initially, 0.30 mol of N_2 and 0.30 mol of O_2 were placed in a 2.0 L reaction vessel. Calculate the concentrations of all the species at equilibrium. (4 points)

$$[N_2]_0 = [O_2]_0 = \frac{0.30\ mol}{2.0\ L} = 0.15\ M$$

	N_2	+	O_2	$\rightleftharpoons$	2NO
I	0.15		0.15		0
C	-x		-x		2x
E	0.15-x		0.15-x		2x

$$K_c = 0.095 = \frac{[NO]^2}{[N_2][O_2]} = \frac{(2x)^2}{(0.15-x)(0.15-x)} = \left(\frac{2x}{0.15-x}\right)^2$$

$$\left(\frac{2x}{0.15-x}\right) = \sqrt{0.095} \rightarrow 2x = \sqrt{0.095}(0.15-x)$$

note only the positive root needs to be considered since the number is the ratio of two concentrations

$$x = \frac{\sqrt{0.095}(0.15)}{2+\sqrt{0.095}} = 0.020$$

$[N_2] = [O_2] = 0.15 - 0.020M = 0.13$ M

$[NO] = 2(0.020\ M) = 0.040$ M

Equations and Constants

Rate = $k[A]^x[B]^y$

R = 0.0820575 L atm mol^{-1} K^{-1} = 8.314 J mol^{-1} K^{-1}

$$k = A\, e^{-\frac{E_a}{RT}}$$

$$\ln(k) = -\left(\frac{E_a}{R}\right)\left(\frac{1}{T}\right) + \ln(A)$$

y = mx + b

PV = nRT

$$K_P = K_C(RT)^{\Delta n}$$

ln(ab) = ln(a) + ln(b)

$\ln(a^b)$ = b ln(a)

The solution to the quadratic equation $ax^2 + bx + c = 0$ is

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

The Periodic Table of the Elements

1 **H** Hydrogen 1.00794																	2 **He** Helium 4.003
3 **Li** Lithium 6.941	4 **Be** Beryllium 9.012182											5 **B** Boron 10.811	6 **C** Carbon 12.0107	7 **N** Nitrogen 14.00674	8 **O** Oxygen 15.9994	9 **F** Fluorine 18.9984032	10 **Ne** Neon 20.1797
11 **Na** Sodium 22.989770	12 **Mg** Magnesium 24.3050											13 **Al** Aluminum 26.981538	14 **Si** Silicon 28.0855	15 **P** Phosphorus 30.973761	16 **S** Sulfur 32.066	17 **Cl** Chlorine 35.4527	18 **Ar** Argon 39.948
19 **K** Potassium 39.0983	20 **Ca** Calcium 40.078	21 **Sc** Scandium 44.955910	22 **Ti** Titanium 47.867	23 **V** Vanadium 50.9415	24 **Cr** Chromium 51.9961	25 **Mn** Manganese 54.938049	26 **Fe** Iron 55.845	27 **Co** Cobalt 58.933200	28 **Ni** Nickel 58.6934	29 **Cu** Copper 63.546	30 **Zn** Zinc 65.39	31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.61	33 **As** Arsenic 74.92160	34 **Se** Selenium 78.96	35 **Br** Bromine 79.904	36 **Kr** Krypton 83.80
37 **Rb** Rubidium 85.4678	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.90585	40 **Zr** Zirconium 91.224	41 **Nb** Niobium 92.90638	42 **Mo** Molybdenum 95.94	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.90550	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.8682	48 **Cd** Cadmium 112.411	49 **In** Indium 114.818	50 **Sn** Tin 118.710	51 **Sb** Antimony 121.760	52 **Te** Tellurium 127.60	53 **I** Iodine 126.90447	54 **Xe** Xenon 131.29
55 **Cs** Cesium 132.90545	56 **Ba** Barium 137.327	57 **La** Lanthanum 138.9055	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.9479	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.207	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.217	78 **Pt** Platinum 195.078	79 **Au** Gold 196.96655	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.3833	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.98038	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)	110 (269)	111 (272)	112 (277)	113	114				

58 **Ce** Cerium 140.116	59 **Pr** Praseodymium 140.90765	60 **Nd** Neodymium 144.24	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.964	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.92534	66 **Dy** Dysprosium 162.50	67 **Ho** Holmium 164.93032	68 **Er** Erbium 167.26	69 **Tm** Thulium 168.93421	70 **Yb** Ytterbium 173.04	71 **Lu** Lutetium 174.967
90 **Th** Thorium 232.0381	91 **Pa** Protactinium 231.03588	92 **U** Uranium 238.0289	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)