KEY

MC, Chem1B, Spring17, Test 2

Read questions carefully before answering. No outside paper is allowed. Write **set up equation** for a mathematical problem, then put the raw data with **units**, before showing the calculation. Use the reverse side of your answer paper as scratch. Use the periodic table and important constants charts provided. (Total points = 68 + (17*3=)51 = 119).

2 decimal places

Show your calculation with set up and units (when appropriate)

1) The following experimental data were obtained at constant temperature for the reaction: 1) ____________

$$2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$$

Experiment	Initial Concentrations [NO]	[O2]	Initial Rate (M s-1)
1	0.0010	0.0010	7.0×10^{-6}
2	0.0010	0.0020	1.4×10^{-5}
3	0.0010	0.0030	2.1×10^{-5}
4	0.0020	0.0030	8.4×10^{-5}
5	0.0030	0.0030	1.9×10^{-4}

2nd order with respect to NO → $2 = m$

$\frac{\log 4}{\log 2} = \frac{m \log 2}{\log 2}$

$\log 4 = \log 2^m$

$4 = 2^m$

a. Following **formal** method calculate the order of the reaction with respect to each reactant (6 pts.).

$\frac{Rate_2}{Rate_1} = \frac{k[NO]_2^m[O_2]_2^n}{k[NO]_1^m[O_2]_1^n}$

$\frac{1.4\times10^{-5} M/s}{7.0\times10^{-6} M/s} = \frac{[.001]^m[.002]^n}{[.001]^m[.001]^n}$

$2 = 2^n \quad \log 2 = \log 2^n \Rightarrow \frac{\log 2}{\log 2} = \frac{n \cdot \log 2}{\log 2}$

$n = 1$ ← 1st order with respect to O_2

$\frac{Rate_4}{Rate_3} = \frac{k[NO]_4^m[O_2]_4^n}{k[NO]_3^m[O_2]_3^n}$

$\frac{8.4\times10^{-5} M/s}{2.1\times10^{-5} M/s} = \frac{[.002]^m[.003]^n}{[.001]^m[.003]^n}$

b. Write the rate law for the reaction (3 pts.).

$Rate = k[NO]^2[O_2]^1$

$\frac{7.0\times10^{-6} M/s}{[.001]^2[.001]} = \frac{k[.001]^2[.001]}{[.001]^2[.001]}$

$k = 7000\ M^{-2}s^{-1}$ ✓

$Rate = 7000\ M^{-2}s^{-1}[NO]^2[O_2]$

c. Calculate rate of NO_2 formation when $[NO] = [O_2] = 0.005$ M (3 pts.).

$Rate = 7000 M^{-2}s^{-1}[NO]^2[O_2]^1 \rightarrow Rate = 7000 M^{-2}s^{-1}[.005]^2[.005]$

$= 8.75\times10^{-4}\ M/s$ ✓

2) If the rate of foramtion of oxygen gas is 6.0×10^{-5} M/s in the following conversion: $2\ O_3\ (g)$ -------> $3\ O_2$, then calculate the rate of disappearance of O_3 (g) at that same time. (4 pts.) 2) ____________

$$-\frac{1}{2}\frac{\Delta[O_3]}{\Delta t} = \frac{1}{3}\frac{\Delta[O_2]}{\Delta t}$$

6.0×10^{-5} M/s

$$-\frac{\Delta[O_3]}{\Delta t} = \frac{2}{3}(6.0\times10^{-5}\ M/s) = 4.0\times10^{-5}\ M/s$$

3) In the reaction $N_2\ (g) + 3\ H_2\ (g) \leftrightarrow 2\ NH_3\ (g)$, if the K_c = 9.60 at 573 K, then calculate the Kp at this temperature (4 pts.). 3) ____________

$$K_p = K_c(RT)^{c+d-(a+b)}$$

$$= 9.60((0.0821\ atm\cdot L/mol\cdot K)(573\ K))^{2-4}$$

$$= \frac{9.60}{(.0821\cdot 573)^2}$$

$$= 4.34\times10^{-3}$$

4) In the equilibrium rxn. Butane (g) $\leftrightarrow$ Isobutane (g), assume equlibrium has reached in a 1.0 L flask with [Butane] = 0.5 M and [Isobutane] = 1.23 M at 298 K. The equlibrium constant for the reaction = 2.5 and afterwards 1.5 mol of Butane was added to the mixture. Calculate the new values of [Butane] and [Isobutane] when equilibrium was reestablished (8 pts.)? 4) ____________

$$K_c = \frac{[Isobutane]}{[Butane]}$$

[Butane] = 2.0 − 1.077 = 0.92 M

[Isobutane] = 1.23 + 1.077 = 2.31 M

	Butane	Isobutane
I	2.0	1.23
C	−x	+x
E	2.0−x	1.23+x

$$K_c = \frac{1.23+x}{2.0-x}$$

$$2.5 = \frac{1.23+x}{2.0-x}$$

$$5 - 2.5x = 1.23 + x$$

$$\frac{3.77}{3.5} = \frac{3.5x}{3.5} \quad x = 1.077$$

5) Equilibrium was established when a mixture of 0.20 mol of NO(g), 0.10 mol of H_2(g), and 0.20 mol of H_2O(g) is placed in a 2.0-L vessel at 400 K. The equilibrium reaction is : 2 NO(g) + 2 H_2(g) <——> N_2(g) + 2 H_2O(g). If at equilibrium [NO] = 0.062 *M*, then calculate K_p. (10 pts.)

5) $K_p = 19.9$

	2 NO	2 H_2	1 N_2	2 H_2O
I	.2/2 = .1	.1/2 = .05	0	.2/2 = .1
C	-.038	-.038	+.038/2	+.038
E	0.062	.012	.019	.138

$$K_c = \frac{[N_2][H_2O]^2}{[H_2]^2[NO]^2} = \frac{[.019][.138]^2}{[.012]^2[.062]^2} = 653.68$$

$$K_p = K_c(RT)^{(c+d)-(a+b)} = 653.68(.082\ \text{l atm/mol K} \times 400K)^{3-4}$$

$= 19.9$

6) Calculate the pH of a solution made by dissolving 1.00 gram of NaOH in 300.00 mL water. (8 pts.)

6) pH = 12.9

$pH = -\log[H^+]$

$1g\ NaOH \cdot \frac{1\ mol}{39.9969g} = 0.025\ mol\ NaOH$

$NaOH \rightarrow Na^+ + OH^-$

strong base, complete dissociation

.025 mol NaOH → .025 mol Na^+ + .025 mol OH^-

$[OH^-] = \frac{0.025\ mol}{.3\ L} = 0.0833$

$pOH = -\log[.0833]$

$= 1.079$

$pH + pOH = 14$

$pH = 14 - 1.079 = 12.9$

$x = 1.9 \times 10^{-3} = [OH^-]$ $pH + pOH = 14$

$pOH = -\log[1.9 \times 10^{-3}] = 2.72$ $pH = 14 - pOH = 11.28$

7) Ammonia is a weak base with pKb = 4.74 at 25°C. Calculate the pH of a 0.2 M ammonia solution in water at that temperature (8 pts.).

7) $pH = 11.28$

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

	NH_3	NH_4	OH
I	.2 M	0	0
C	−x	+x	+x
E	.2M−x	x	x

$K_b = \frac{[NH_4^+][OH^-]}{[NH_3]} = \frac{x \cdot x}{.2 - x}$

$K_b = \frac{x^2}{.2 - x}$

$1.8197 \times 10^{-5} = \frac{x^2}{.2 - x}$

$pK_b = -\log K_b$

$4.74 = -\log K_b$

$-4.74 = \log K_b$

$10^{-4.74} = K_b$

$1.8197 \times 10^{-5} = K_b$

$0 = x^2 + 1.8197 \times 10^{-5} x - 3.6394 \times 10^{-6}$

$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ $+1.45526568 \times 10^{-5}$ $\rightarrow x = 1.9 \times 10^{-3}$

$3.6394 \times 10^{-6} - 1.8197 \times 10^{-5} x = x^2$

8) A 0.20-M solution of sodium nitrite, $NaNO_2$, has a pH of 8.57.

8) ______________

a) Write a chemical equation showing why this salt has the given pH. Hint: you should write a K_b chemical hydrolysis equation. (4 pts.)

$NaNO_2 \rightleftharpoons Na^+ + NO_2^-$

weak base, pH is slightly above 7

$\rightarrow NO_2^- + H_2O \rightleftharpoons HNO_2 + OH^-$

Na^+: doesn't interact with H_2O

$K_b = \frac{[HNO_2][OH^-]}{[NO_2^-]}$

b) Calculate K_b for the basic anion (6 pts.)

	NO_2^-	HNO_2	OH^-
I	.2	0	0
C	-3.72×10^{-6}	$+3.72 \times 10^{-6}$	$+3.72 \times 10^{-6}$
E	.19999628		3.72×10^{-6} M

$pH + pOH = 14$

$pOH = 14 - 8.57 = 5.43 = -\log[OH^-]$ $[OH^-] = 10^{-5.43} = 3.72 \times 10^{-6}$ M

$K_b = \frac{[3.72 \times 10^{-6}]^2}{[.199996284]} = 6.9 \times 10^{-11}$

c) And K_a for the corresponding conjugate acid given the measured pH (4 pts.).

$K_a \times K_b = K_w = 1.0 \times 10^{-14}$

$K_a = \frac{1.0 \times 10^{-14}}{K_b} = \frac{1.0 \times 10^{-14}}{6.9 \times 10^{-11}} = 1.45 \times 10^{-4}$

MULTIPLE CHOICE. On your scantron, start answering from number 9. Select the one alternative that best completes the statement or answers the question (3 pts each).

9) Which one of the following is not a valid expression for the rate of the reaction below? 9) E

$$4NH_3 + 7O_2 \rightarrow 4NO_2 + 6H_2O$$

A) $\frac{1}{4}\frac{\Delta[NO_2]}{\Delta t}$

B) $-\frac{1}{7}\frac{\Delta[O_2]}{\Delta t}$

C) $\frac{1}{6}\frac{\Delta[H_2O]}{\Delta t}$

D) $-\frac{1}{4}\frac{\Delta[NH_3]}{\Delta t}$

E) All of the above are valid expressions of the reaction rate.

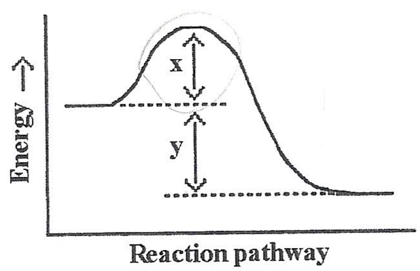
10) Of the units below, ________ are appropriate for a first-order reaction rate constant. 10) B

A) $M\ s^{-1}$
B) s^{-1}
C) $M^{-1}\ s^{-1}$
D) $L\ mol^{-1}\ s^{-1}$
E) mol/L

11) As the temperature of a reaction is increased, the rate of the reaction increases because the ________. 11) C

A) reactant molecules collide less frequently and with greater energy per collision
B) activation energy is lowered
C) reactant molecules collide more frequently and with greater energy per collision
D) reactant molecules collide less frequently
E) reactant molecules collide more frequently with less energy per collision

12) Which energy difference in the energy profile below corresponds to the activation energy for the forward reaction? 12) A



A) x B) y C) y - x D) x - y E) x + y

13) How does the reaction quotient of a reaction (Q) differ from the equilibrium constant (K_{eq}) of the same reaction? 13) ______

A) K does not depend on the concentrations or partial pressures of reaction components.
B) Q is the same as K_{eq} when a reaction is at equilibrium.
C) Q does not depend on the concentrations or partial pressures of reaction components.
D) K_{eq} does not change with temperature, whereas Q is temperature dependent.
E) Q does not change with temperature.

14) The equilibrium constant for reaction 1 is K. The equilibrium constant for reaction 2 is ________. 14) ______

(1) $SO_2\ (g) + (1/2)\ O_2\ (g) \rightleftharpoons SO_3\ (g)$
(2) $2SO_3\ (g) \rightleftharpoons 2SO_2\ (g) + O_2\ (g)$

A) 1/2K B) K^2 C) $-K^2$ D) 2K E) $1/K^2$

15) The reaction below is exothermic: 15) ______

$2SO_2\ (g) + O_2\ (g) \rightleftharpoons 2SO_3\ (g)$

Le Chatelier's Principle predicts that ________ will result in an increase in the number of moles of SO_3 (g) in the reaction container.

A) removing some oxygen
B) increasing the pressure
C) increasing the volume of the container
D) decreasing the pressure
E) increasing the temperature

16) The equlibrium reaction $Co(H_2O)_6^{2+}$ (aq) (Pink) + 4 Cl^- (aq) <-> $CoCl_4^{2-}$ (aq) (Blue) + 6 $H_2O(l)$ turns pink when placed in ice water mixture but turns blue in hot water. The reaction, as shown, is: 16) ______

A) Nonthermic
B) Endothermic
C) Exothermic
D) Insufficient data

17) In which of the following aqueous solutions does the weak acid exhibit the highest percentage ionization? 17) ______

A) 0.01 M HClO ($K_a = 3.0 \times 10^{-8}$)
B) 0.01 M HNO_2 ($K_a = 4.5 \times 10^{-4}$)
C) 0.01 M $HC_2H_3O_2$ ($K_a = 1.8 \times 10^{-5}$)
D) 0.01 M HF ($K_a = 6.8 \times 10^{-4}$)
E) These will all exhibit the same percentage ionization.

18) Which of the following aqueous solutions has the highest $[OH^-]$? 18) ______

A) a solution with a pOH of 12.0

B) a 1×10^{-3} M solution of NH_4Cl

C) a 1×10^{-4} M solution of HNO_3

D) a solution with a pH of 3.0

E) pure water

19) A 0.1 M aqueous solution of ________ will have a pH of 7.0 at 25.0 °C. 19) ______

NaOCl KCl NH_4Cl $Ca(OAc)_2$

A) NaOCl

B) KCl

C) NH_4Cl

D) $Ca(OAc)_2$

E) KCl and NH_4Cl

TRUE/FALSE. On the scantron, select answer 'A' if the statement is true and 'B' if the statement is false (3 pts each).

20) The half-life for a first order rate law depends on the starting concentration. T or F

21) Units of the rate constant of a reaction are independent of the overall reaction order. T or F

22) H_2SO_3 and H_2SO_4 are considered an acid-base conjugate pair. T or F

23) The conjugate base to HSO_4^- is SO_4^{2-}. T or F

24) At constant temperature, reducing the volume of a gaseous equilibrium mixture causes the reaction to shift in the direction that increases the number of moles of gas in the system. T or F

25) In an exothermic equilibrium reaction, increasing the reaction temperature favors the formation of reactants. T or F