CHM 152 Exam I, Burk Fall 2009

Name KEY **Date** **Score**

Multiple Choice: Circle the BEST answer!
(2 points each)

1) What would you plot in order to find out the **activation energy**, **E_a**, for a chemical reaction?
    - [✓ a.] ln k versus 1/T
    - b. $[A]_t$ versus t
    - c. ln $[A]_t$ versus t
    - d. ln k_1/k_2 versus R
    - e. $1/[A]_t$ versus t

2) Which of the following statements is TRUE if the real rate law is rate = $k[H_2][ICl]$:

    mechanism: step one: $H_2(g) + ICl(g) \rightarrow HI(g) + HCl(g)$
    step two: $HI(g) + ICl(g) \rightarrow I_2(g) + HCl(g)$

    - a. Step one is the rate-determining step and HCl is the intermediate.
    - b. Step two is the rate-determining step and HCl is the intermediate.
    - [✓ c.] Step one is the rate-determining step and HI is the intermediate.
    - d. Step two is the rate-determining step and HI is the intermediate.
    - e. Step one is the rate-determining step and ICl is the intermediate.

3) Calculus is used to find the Integrated Rate Law
    - [✓ a.] True - Remember the IRL was generated for us through the "magic of calculus"
    - b. False

4) K_c values have units.
    - a. True
    - [✓ b.] False

5) Rate Constants have units.
    - [✓ a.] True
    - b. False

6) A catalyst will _______________ an equilibrium.
    - a. Shift to the right
    - b. Shift to the left
    - [✓ c.] Does nothing to equilibrium – A catalyst does nothing to equilibrium (i.e. does not shift it at all)
    - d. None of the above

7) What would you plot in order to find if a reaction is **second order** with respect to a specific reactant?
    - a. ln k versus 1/T
    - b. $[A]_t$ versus t
    - c. ln $[A]_t$ versus t
    - d. ln k_1/k_2 versus R
    - [✓ e.] $1/[A]_t$ versus t

8) If the reaction quotient, Q, is greater than K_c, then … (Too much product)

- a. The reaction will proceed forward to reach equilibrium
- [✓ b.] The reaction will proceed in the reverse direction to reach equilibrium
- c. The reaction is at equilibrium
- d. None of the above

9) What is the overall order of the reaction if the rate law is: $Rate = k\frac{[NH_4]^2[Cl^-]}{[NH_3]}$

$2 + 1 - 1 = \mathbf{2}$

- a. Zero
- b. First
- [✓ c.] Second
- d. Third
- e. None of the above

For the reaction shown below, indicate the direction of shift (left, right, or none) when the following changes are made:

$\mathbf{2\ SO_{2\ (g)} + O_{2\ (g)} \leftrightharpoons 2\ SO_{3\ (g)}}$ **+ Heat** ⍰H° = -397.8 kJ/mol

3 moles gas 2 moles gas

10) SO_2 is added

- a. Left
- [✓ b.] Right
- c. None

11) Temperature is decreased

- a. Left
- [✓ b.] Right
- c. None

12) Pressure is increased → same as decreasing volume

- a. Left
- [✓ b.] Right
- c. None

13) Which of the following is the definition of a catalyst?

- [✓ a.] Consumed in the first step and produced in the last
- b. Produced in the first step and consumed in the last
- c. Produced in the first step and also produced in the last
- d. None of the above

14) Only a fraction of collisions result in the formation of the product.

- [✓ a.] True
- b. False

15) What is the molecularity of the following elementary step? $HI(g) + ICl\ (g) \rightarrow I_2(g) + HCl\ (g)$

- a. Unimolecular
- [✓ b.] Bimolecular
- c. Trimolecular
- d. None of the above

16) What is the Rate Determining Step in the following reaction mechanism?

$N_2O_{5(g)} \rightarrow NO_{2(g)} + NO_{3(g)}$	Fast, Reversible
$NO_{2(g)} + NO_{3(g)} \rightarrow NO_{(g)} + NO_{2(g)} + O_{2(g)}$	Slow
$NO_{(g)} + NO_{3(g)} \rightarrow 2NO_{2(g)}$	Fast

a. First step
[✓ b.] Second step
c. Third step
d. None of the above

17) The rate of reaction depends on which of the following?

[✓ a.] Activation Energy (E_a)
b. Change in energy (ΔE)
c. Transition state
d. All of the above

18) As temperature is increased, it is observed that the reaction rate increases. This is because:

a. The molecules are closer together.
[✓ b.] The molecules have more kinetic energy and thus collide more often.
c. The molecules move faster away from each other and collide less often.
d. The molecules expand and touch each other more often.
e. The molecules solidify and solid state reactions are faster.

19) Which of the following is the definition for homogeneous equilibria?

[✓ a.] All substances in the reaction are in the same phase
b. The substances in a reaction are in different phases
c. The mixture is not completely mixed
d. None of the above

20) Which of the following statements is true if $[SO_2] = 0.754$ M, $[O_2] = 0.085$ M, and $[SO_3] = 1.4$M? Given this reaction: $\mathbf{2\ SO_{2\,(g)} + O_{2\,(g)} \leftrightharpoons 2\ SO_{3\,(g)}}$ and $K_c = 756$

Calculate Q: $Q = \frac{[SO_3]^2}{[SO_2]^2[O_2]} = \frac{(1.4)^2}{(0.754)^2(0.085)} = 41$

Therefore: Q < K → too much reactants

a. This system is at equilibrium
b. This system must shift towards the reactants to reach equilibrium.
[✓ c.] This system must shift towards the products to reach equilibrium.
d. Equilibrium cannot be reached.
e. Pressure is needed to find K_p first, then the problem can be solved.

Short Answer: You MUST Show Work to get Credit!!! Circle your final answer.

21) According to the following **unbalanced** reaction, if the rate of appearance of oxygen gas is 0.125 M/s, what is the rate of disappearance of N_2O_5 (g)? $2N_2O_5\text{(g)} \rightarrow 4NO_2\text{(g)} + O_2\text{(g)}$ (6 points)

1 pt - balanced

$$Rate = -\frac{\Delta[N_2O_5]}{2\Delta t} = \frac{\Delta[NO_2]}{4\Delta t} = \frac{\Delta[O_2]}{\Delta t}$$

$$-\frac{\Delta[N_2O_5]}{2\Delta t} = \frac{\Delta[O_2]}{\Delta t}$$ 2 pts

$$-\frac{1}{2}Rate_{N_2O_5} = Rate_{O_2}$$

$$Rate_{N_2O_5} = -2\left(Rate_{O_2}\right)$$ 2 pts

$$Rate_{N_2O_5} = -2(0.125\ M/s) = -0.0250\ M/s$$

$\boxed{\textbf{Therefore, the rate of disappearance of } \mathbf{N_2O_5} \textbf{ is 0.0250 M/s}}$ 1 pt ans.

-2 pts for ½ instead of 2
- ½ for sig figs
- 1 for calc error

22) What is the K_p for the following reaction at 50.5°C? (6 points)

$2\ SO_{2\,(g)} + O_{2\,(g)} \leftrightharpoons 2\ SO_{3\,(g)}$ and $K_c = 654$

$K_p = K_c(RT)^{\Delta n}$ 1 pt

$K_c = 654$

$R = 0.08206$ 1 pt

$T = 50.5 + 273 = 323.5\ K$ 1 pt

$\Delta n = 2\ moles - 3\ moles = -1$ 1 pt

$K_p = 654(0.08206 \times 323.5)^{-1}$

$K_p = 654(0.03767)$

$\boxed{\boldsymbol{K_p = 24.6}}$ **2 pts**

23) For the following reaction, **$H_2(g) + Cl_2(g)$ ↔ 2 HCl(g)** calculate all the equilibrium concentrations, if the original concentrations were $[H_2] = 1.55M$ and $[Cl_2] = 1.55M$, and $K_c = 3.56 \times 10^5$. (10 points)

3 pts

	H_2 +	Cl_2 ↔	**2 HCl**
I	1.55 M	1.55 M	0
C	- X	- X	+ 2X
E	1.55 - X	1.55 - X	2X

$$\boldsymbol{K_c = \frac{[HCl]^2}{[H_2][Cl_2]}}$$

$$3.56 \times 10^5 = \frac{[2X]^2}{[1.55 - X][1.55 - X]}$$ 2 pt

$$\sqrt{3.56 \times 10^5} = \sqrt{\frac{[2X]^2}{[1.55 - X]^2}}$$

$$597 = \frac{2X}{1.55 - x}$$

$$597(1.55 - x) = 2x$$

$$925 - 597x = 2x$$

$$925 = 599x$$

$$\frac{925}{599} = x$$

$\boxed{\boldsymbol{x = 1.54\ M}}$ 2 pts

Equilibrium Concentrations:

$H_2 = Cl_2 = 1.55 - 1.54 = 0.01$ M

HCl = 2(1.54) = 3.08 M

3 pts Ans

24) Write the equilibrium expression K_c and the rate law for the reaction between sodium carbonate and calcium hydroxide in water. (8 points)

$Na_2CO_{3(aq)} + Ca(OH)_{2(aq)} \rightarrow 2\ NaOH_{(aq)} + CaCO_{3(s)}$ 2pts – 1 for RXN, 1 for balance

Equilibrium Expression:

$$K_c = \frac{[NaOH]^2}{[Na_2CO_3][Ca(OH)_2]}$$

3 pts: -1 pt for not squaring
-1 pt for including $CaCO_{3(S)}$
-1 pt for reactants over products

Rate Law:

$$Rate = k[Na_2CO_3]^m[Ca(OH)_2]^n$$

3 pts: all variables (k, m, and n) worth 1 pt each

25) What percentage of a sample would remain after 5 half lives? (4 points)

$$\frac{100}{2} = \frac{50}{2} = \frac{25}{2} = \frac{12.5}{2} = \frac{6.25}{2} = \boldsymbol{3.125\%}$$

2 pts Ans; work 2pts; -1 pt for not dividing by 2 five times

26) What is the reactant concentration after 80.4 seconds for a **second order** reaction with a half-life of 4.25 minutes if the initial concentration was 1.476M? (6 points)

$$t_{1/2} = \frac{1}{k[A]_0}$$

$$k = \frac{1}{t_{1/2}[A]_0}$$

2 pts

$$k = \frac{1}{4.25\ \text{min} \times 1.476M} = 0.159 min^{-1}M^{-1}$$

$$\frac{1}{[A]_t} = kt + \frac{1}{[A]_0}$$

$$80.4s \times \frac{1min}{60s} = 1.34min$$ 1 pt

$$\frac{1}{[A]_t} = 0.159 min^{-1}M^{-1}(1.34\text{min}) + \frac{1}{1.476M}$$ 1 pt

$$\frac{1}{[A]_t} = 0.891M^{-1}$$

$$[A]_t = \frac{1}{0.891M^{-1}} \boxed{= \boldsymbol{1.12\ M}}$$

2 pts

27) The following experimental data was collected for this reaction:

$2\ NH_3(g) \leftrightarrow 3\ H_2(g) + N_2(g)$

What is the rate law, including rate constant, for this reaction and what is the overall order? Circle your final answers. (8 points)

Experiment	Rate (M/s)	$[NH_3]$ (M)
1	3.25×10^{-2}	0.0500
2	6.47×10^{-2}	0.100
3	9.78×10^{-2}	0.150

As Concentration doubled, Rate also doubled → therefore 1st order 3 pts

$Rate = k[NH_3]^1$ → use any trial to solve for k

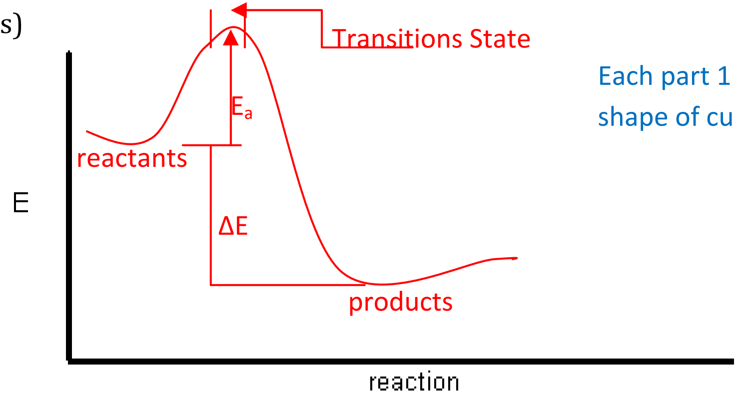
$$3.25 \times 10^{-2} M/s = k[0.0500\ M]$$

$$k = \frac{3.25 \times 10^{-2} M/s}{0.0500\ M}$$

$$k = 0.650\ s^{-1}$$ 3pts

$$\boxed{\boldsymbol{Rate = 0.650\ s^{-1}[NH_3]^1}}$$ 2 pts

28) Draw an activation energy diagram on the axis below and label the transition state, the activation energy, the reactants, the products, and the change in energy for an **Exothermic** reaction. (6 points)



Each part 1 pt, including shape of curve

29) The rate law for a reaction is rate = $k[H_2]^1[F_2]^1$. If the rate is 3.15×10^{-4} M/s when $[H_2]$ = 0.084 M and $[F_2]$ = 0.25 M, calculate the rate when $[H_2]$ = 0.039 M and $[F_2]$ = 0.099 M. (Hint: find k) (6 points)

$Rate = k[H_2][F_2]$

$3.15 \times 10^{-4}\frac{M}{s} = k[0.084\ M][0.25\ M]$

$$k = \frac{3.15\times10^{-4}\frac{M}{s}}{[0.084\ M][0.25\ M]} = 0.015\ M^{-1}s^{-1}$$ 3 pts

$Rate = 0.015\ M^{-1}s^{-1}[0.039\ M][0.099\ M]$

$$\boxed{\boldsymbol{Rate = 5.8 \times 10^{-5}\ m/s}}$$ **3 pts**

Bonus: What is the dissociation equation for nitrous acid? (5 points)

$HNO_2 + H_2O_{(l)} \leftrightarrow NO_2^{-}{}_{(aq)} + H_3O^{+}{}_{(aq)}$