Chemistry Lab

Name: _____ School: _____

_____

Kinetics (46 points total):

Vocabulary. Give the correct word for each of the following definitions (1 pt each):

1. _____ an arrangement of two reactant molecules which can either go on to form products or fall apart again into the unchanged reactants.

2. _____ an empirical factor which takes into account the fact that molecules must collide in a certain orientation in order to react.

3. _____ a reaction in which the reaction rate is independent of reactant concentration.

4. _____ the energy barrier which must be overcome in order for a reaction to occur.

5. _____ the first step in a chain reaction, where chain carriers are formed from a reactant.

6. _____ the assumption that the rate of change of a reaction intermediate is equal to zero.

7. _____ a reaction for which a graph of concentration vs. time yields a straight line.

True/False (0.5 pt each):

8. ____ If a reaction has a very large equilibrium constant, the rate constant for the forward reaction is much larger than the rate constant of the reverse reaction.

9. ____ At equilibrium, the rate constants of the forward and reverse reactions are equal.

10. ____ Increasing the concentration of a reactant increases the rate of a reaction by increasing the rate constant of the forward reaction.

11. ____ In a reaction that is a series of equilibrium steps, the overall equilibrium constant is equal to the product of all the forward rate constants divided by the product of all the reverse rate constants .

Short answer. Show all work if necessary.
12. Give the correct units for the rate constant in each of the following reactions (1 pt each):

a) 0th order _____

b) 1st order _____

c) 3rd order _____

d) 1/2 order_____

13. The decomposition of ozone in the reaction $2\ O_{3\ (g)} \rightarrow 3\ O_{2\ (g)}$ has the following proposed mechanism:

Step 1: $O_3 \rightleftarrows O_2 + O$

Step 2: $O + O_3 \rightleftarrows O_2 + O_2$

a) Determine the rate law for the decomposition of O_3, given that the slow step is the second step and the reverse reaction of step 2 is so slow that it can be ignored (8 pts; TIEBREAKER #1).

b) what is the reaction order of the overall reaction? (1 pt)

14. Use the following data to write the rate law and determine the value of k for the reaction used to produce carbonyl chloride, $COCl_2$:

$$CO_{(g)} + Cl2_{(g)} \rightarrow COCl2_{(g)}$$

Trial	[CO] (mol / L)	[Cl_2] (mol / L)	Initial rate (mol $COCl_2$) / L·s
1	0.12	0.20	0.121
2	0.24	0.20	0.241
3	0.24	0.40	0.682

a) Write the rate law for the reaction used to produce carbonyl chloride. Hint: one of the reaction orders is not an integer. (4 pts)

b) determine the value of k, the rate constant, for the above reaction (2 pt)

15. The rate constant of the second order reaction

$$2\ HI_{(g)} \rightarrow H_{2\ (g)} + I_{2\ (g)}$$

is 2.4×10^{-6} L/mol·s at 272°C and 6.0×10^{-5} L/mol·s at 357°C. Calculate the activation energy of the reaction (5 pts; TIEBREAKER #4).

16. For the elementary, reaction $2\ A \rightleftarrows B + C$, the forward rate constant for the formation of B is 265 L/mol·min and the rate constant for the reverse reaction is 392 L/mol·min. The activation energy for the forward reaction is 39.7 kJ/mol and that of the reverse reaction is 25.4 kJ/mol.

a) Calculate the rate of the forward reaction if [A] = 2.0 M (2 pt)

b) What is the change in enthalpy of this reaction? (1 pt)

c) What will the effect of raising the temperature be on each of the rate constants and the equilibrium constant? Give your answer as "increases", "decreases" or "stays the same" for the three options. (3 pts)

forward reaction rate constant _____

reverse reaction rate constant _____

equilibrium constant _____

17. The contribution to the destruction of the ozone layer caused by the exhaust of high flying aircraft has been attributed to the following mechanism:

Step 1: $O_3 + NO \rightarrow NO_2 + O_2$

Step 2: $NO_2 + O \rightarrow NO + O_2$

a) write the overall reaction (1 pt)

b) write the rate law for each step and give its molecularity (4 pts; TIEBREAKER #3)

c) What is the reaction intermediate? (1 pt)

d) What is the catalyst in the reaction? (1 pt)

Chemical reactions / stoichiometry (46 points total):

Short answer. Show all work if necessary.

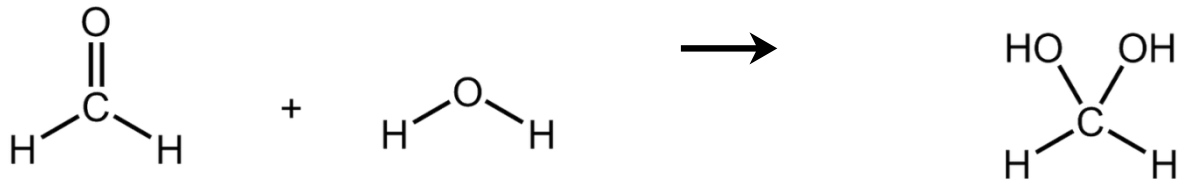
18. Given the following redox reaction:

$$Cl_2O_{7\,(g)} + H_2O_{2\,(aq)} \rightarrow ClO_2^-{}_{(aq)} + O_{2\,(g)}$$

a) identify the oxidizing and reducing agent(s) (2 pts)

b) Balance the reaction, given that it takes place in basic solution (4 pts)

19. When dissolved in water, formaldehyde will react with water to yield methylene glycol. The reaction is depicted in the following image:



a) underneath each of the compounds in the above image, write the corresponding name for each compound (1 pts)

b) Write a balanced chemical equation for the above reaction, including phase notation of for each compound. (2 pts)

c) 600 mL of a 2 M formaldehyde solution in water is prepared.

i) identify how many moles of formaldehyde were initially dissolved (1 pts)

ii) Assuming the reaction goes to 99% completion, identify the mass of methylene glycol present in the final solution and the final concentrations of both formaldehyde and methylene glycol (5 pts; TIEBREAKER #5)

20. The water-gas shift reaction is an important reaction in the industrial production of hydrogen. In the reaction, gaseous water and carbon monoxide react to produce carbon dioxide and hydrogen in the presence of an iron (III) oxide catalyst

a) Write a balanced chemical equation for the reaction, giving appropriate phase notation. (2 pts)

b) 200 mL of hydrogen gas and 400 mL of water vapor are reacted in the water-gas shift reaction. Identify the limiting reactant (1 pt)

c) If the gaseous reactants of part (b) are at STP, identify the theoretical yields of carbon dioxide and hydrogen, giving your answer in grams. (3 pts)

d) Identify the percent yield of the reaction if in reality 0.157 grams of carbon dioxide are produced from the reactants in (b). (2 pts)

21. Complete combustion of 5.0 g of an unknown hydrocarbon yields 15.4 g of carbon dioxide and 7.1 g of oxygen.

a) Identify the empirical formula of the hydrocarbon (5 pts)

b) Mass spectrometry reveals that the compound has a molecular mass of 114.23 g/mol. What is the molecular formula of the hydrocarbon? (2 pts)

22. For each of the following reactions, write a balanced chemical equation with phase notation for the reaction that occurs and predict the products. If a reaction occurs, indicate if it is a single displacement (SD), double displacement (DD), decomposition (D), or synthesis (S) reaction. If no reaction occurs, write NR. (2 pts each)

a) calcium bicarbonate is heated

b) gaseous ammonia is bubbled through water

c) copper metal is placed in a zinc nitrate solution

d) water is electrolyzed

e) lithium hydride is dissolved in water

f) gaseous iodine trichloride and fluorine gas are mixed

23. Write and balance the reaction between permaganate ions and hydrogen peroxide in acidic solution (4 pts; TIEBREAKER #2)

ANSWER KEY:

1. transition state OR activated complex
2. steric factor
3. 0th order reaction
4. activation energy
5. initiation
6. steady state approximation
7. 0th order reaction
8. True
9. False
10. False
11. True
12. a) mol / L / s
    b) 1 / s
    c) L^2 / mol^2 / s
    d) $mol^{0.5}$ / $L^{0.5}$ / s
13. After much work, the student should find that
    a) $k[O_3]^2 / [O_2]$
    b) 0.5
14. a) rate = $k[CO][Cl_2]^{1.5}$
    b) k = 11.3 $L^{1.5}$ / $mol^{1.5}$ / s
15. 107.9 kJ
16. a) 1060 mol / L / min
    b) +14.3 kJ/mol
    c) forward rate constant increases, reverse rate constant increases, equilibrium constant increases
17. a) $O_3 + O \rightarrow 2O_2$
    b) Step 1: rate = $k_1[O_3][NO]$ & bimolecular, Step 2: rate = $k_2[NO_2][O]$ & bimolecular
    c) NO_2
    d) NO

18. a) Cl_2O_7 is the oxidizing agent, H_2O_2 is the reducing agent

b) $2OH^-_{(aq)} + Cl_2O_{2\,(aq)} + 4H_2O_{2\,(aq)} \rightarrow 5H_2O_{(l)} + 4O_{2\,(g)} + 2ClO_2^-{}_{(aq)}$

19. a) from left to right, the compounds are formaldehyde, water, and methylene glycol

b) $CH_2O_{(aq)} + H_2O_{(aq)} \rightarrow H_2C(OH)_{2\,(aq)}$

c) i. 1.2 moles

ii. mass of methylene glycol = 57 g, final concentration of formaldehyde = 0.02 M, final concentration of methylene glycol = 1.98 M

20. a) $H_2O_{(g)} + CO_{(g)} \rightarrow CO_{2\,(g)} + H_{2\,(g)}$, with Fe_2O_3 above the reaction arrow

b) hydrogen

c) CO_2 = 0.393 g, H_2 = 0.0179 g

d) 39.9%

21. a) C_4H_9

b) C_8H_{18}

22. a) $2CaHCO_{3\,(g)} + \text{heat} \rightarrow 2CaO_{(s)} + H_2O_{(l)} + 2CO_{2\,(g)}$; decomposition

b) $NH3_{(g)} + H_2O_{(l)} \rightarrow NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$; double displacement

c) No reaction

d) $2H_2O_{(l)} \rightarrow O_{2\,(g)} + 2H_{2\,(g)}$; decomposition

e) $LiH_{(s)} + H_2O \rightarrow H_2 + LiOH_{(aq)}$; double displacement (sorta…)

f) $2ICl_{3\,(g)} + 3F_{2\,(g)} \rightarrow 2IF_{3\,(g)} + 3Cl_{2\,(g)}$; single displacement

23. $2MnO_4^-{}_{(aq)} + 5H_2O_{2\,(aq)} + 6H^+_{(aq)} \rightarrow 2Mn^{2+}_{(aq)} + 5O_{2\,(g)} + 8H_2O_{(l)}$