November 2021 Problem Set

Questions 21- 24 pertain to the following reaction, important for the formation of smog:

$$NO(g) + O_3(g) \longrightarrow NO_2(g) + O_2(g)$$

The reaction was determined experimentally to be first order in NO and O_3. The rate constant of the reaction is 80 $M^{-1}s^{-1}$ at 25 °C and 3000 $M^{-1}s^{-1}$ at 75 °C.

21. Which is a possible mechanism for the reaction?

i) $NO + O_3 \longrightarrow NO_2 + O_2$

ii) 1. $O_3 \longrightarrow O + O_2$ slow
2. $O + NO \longrightarrow NO_2$

iii) 1. $O_3 \rightleftharpoons O + O_2$ fast
2. $O + NO \longrightarrow NO_2$ slow

a) i only b) ii only c) iii only d) i and ii only e) i and iii only

22. What is the activation energy for the reaction?

a) -65 kJ/mol b) -25 kJ/mol c) 25 kJ/mol d) 62 kJ/mol e) 125 kJ/mol

23. If the concentration of NO is doubled and the concentration of O_3 is halved, the reaction rate:

a) would decrease by a factor of 4.
b) would decrease by a factor of 2.
c) would remain the same.
d) would increase by a factor of 2.
e) would increase by a factor of 4.

24. What is the rate of reaction at 25 °C when the initial concentration of NO is 1.0×10^{-5} M and O_3 is 2.5×10^{-9} M?

a) 1.8×10^{-14} M/s b) 2.0×10^{-12} M/s c) 9.6×10^{-10} M/s d) 3.9×10^{-7} M/s
e) 1.9×10^{-5} M/s

25. Which of the following statements is TRUE?

a) Increasing temperature increases the rate of the forward reaction by lowering the activation energy for the forward reaction.
b) Increasing temperature increases the rates of both the forward and reverse reactions.
c) A catalyst affects the rate of the forward reaction only by providing a new reaction pathway.
d) A catalyst affects both the rate of reaction and equilibrium position of a reaction (i.e. the amount of reactants and products present when the reaction reaches equilibrium.)
e) None of the statements are true.

Use the data below for questions 26 and 27. For the reaction $A(aq) + B(aq) \longrightarrow C(aq)$, the following data was collected:

Experiment	[A] (M)	[B] (M)	Initial rate (M/s)
1	0.200	0.100	0.630
2	0.200	0.300	5.67
3	0.800	0.100	2.52

26. What is the rate law for the reaction?

a) rate = $k[A]^2[B]$ b) rate = $k[A][B]$ c) rate = $k[A][B]^3$ d) rate = $k[A][B]^2$
e) rate = $k[A]^2[B]^3$

27. What is the value and units of k?

a) 31.5 $M^{-1}s^{-1}$ b) 158 $M^{-2}s^{-1}$ c) 315 $M^{-2}s^{-1}$ d) 3150 $M^{-3}s^{-1}$ e) 231 $M^{-1}s^{-1}$

28. Sulfuric acid is an important chemical used in mineral processing, production of fertilizer, oil refining and chemical synthesis. One step in the production of H_2SO_4 is the reaction shown below:

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

Which of the following will not result in an increase in net production of SO_3?

a) Adding more O_2
b) Increasing the pressure of the vessel
c) Decreasing the volume of the vessel
d) Removing SO_3 as it is produced
e) Removing SO_2

29. $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ $\Delta H = -99$ kJ/mol
Given a reaction vessel containing SO_2, O_2 and SO_3 at equilibrium, which of the following statements is true?

a) Adding a catalyst will increase the amount of SO_3 produced.
b) Increasing temperature will increase the amount of SO_3 present when equilibrium is re-established.
c) Adding argon to the vessel will change the equilibrium position.
d) Adding SO_3 will result in less moles of SO_3 present when equilibrium is re-established than are present before the addition of SO_3.
e) None of these statements are true.

30. Which one of the following salts, when dissolved in water, produces the solution with the *lowest* pH?

a) KOCl
b) KBr
c) KNO_2
d) KF
e) All of the salts will produce a solution with the same pH.

31. Consider the following gas-phase reaction:

$$2A(g) + B(g) \rightleftharpoons 2C(g) \quad K_p = 15$$

If 1.10 atm of A, 0.0100 atm of B and 12 atm of C are put in a sealed vessel,

a) the partial pressure of C increases as the reaction proceeds to equilibrium.
b) the total pressure increases as the reaction proceeds to equilibrium.
c) the reaction is at equilibrium.
d) the concentration of A increases and the concentration of B decreases as the reaction proceeds to equilibrium.
e) the partial pressures of the three gases decrease.

32. What is the pH of a saturated solution of $Mg(OH)_2$? K_{sp} of $Mg(OH)_2$ is 5.6×10^{-12}

a) 3.64 b) 8.37 c) 10.05 d) 10.35 e) 11.82

33. What is the pH of a 1.0 M sodium acetate, CH_3COONa, solution, given that $K_a(CH_3COOH) = 1.8 \times 10^{-5}$ and $K_w = 1.0 \times 10^{-14}$?

a) 10.08 b) 2.43 c) 4.82 d) 7.00 e) 9.37

34. A 0.100 M weak acid solution is 3.24% dissociated in solution. What is the K_a value for this acid?

a) 3.24 b) 0.0324 c) 1.08×10^{-4} d) 1.08×10^{-5} e) 8.73×10^{-6}

35. The K_{sp} for silver chloride, AgCl (used in photography) is 2.8×10^{-10} at a given temperature. What is the solubility of AgCl in 0.010 M HCl solution at this temperature?

a) 2.8×10^{-12} M b) 2.8×10^{-8} M c) 5.6×10^{-8} M d) 2.8×10^{-4} M e) 5.6×10^{-4} M

36. Consider equal volumes of the following acid solutions with equal concentrations:

HCl	pH = 1.1
CH_3COOH	pH = 2.9
HCOOH	pH = 2.3
HCN	pH = 5.1

Which solution requires the most base to titrate to the equivalence point?

a) HCl b) CH_3COOH c) HCOOH d) HCN e) all the same

37. What is the pH of a solution prepared by diluting 100.0 mL of 0.020 M $Ba(OH)_2$ with water to give a 250.0 mL solution?

a) 1.80 b) 2.10 c) 11.90 d) 12.20 e) 13.40

38. The first-order decomposition of hydrogen peroxide occurs according to the equation:

$$2\ H_2O_2(aq) \rightarrow 2\ H_2O(l) + O_2(g)$$

Using experimental data from this reaction, which plot will produce a straight line?

a) $[H_2O_2]$ vs time b) $[H_2O_2]^2$ vs time c) $1/[H_2O_2]$ vs time
d) $\ln[H_2O_2]$ versus time e) $2[H_2O_2]$ vs time

39. For a particular first-order reaction, it takes 48 minutes for the concentration of the reactant to decrease to 25% of its initial value. What is the value for rate constant (in s^{-1}) for the reaction?

a) $1.0 \times 10^{-4}\ s^{-1}$
b) $4.8 \times 10^{-4}\ s^{-1}$
c) $6.0 \times 10^{-3}\ s^{-1}$
d) $2.9 \times 10^{-2}\ s^{-1}$
e) $5.2 \times 10^{-2}\ s^{-1}$

40. Lime, used in large quantities in construction and in the production of chemicals, can be produced from the thermal decomposition of calcium carbonate:

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g) \qquad K_p = 1.00 \text{ at } 1099\ K$$

When 2.00 g of $CaCO_3$ are placed in a 1.00 L evacuated flask at 1099 K, how much $CaCO_3$ will be left when equilibrium is reached?

a) 0.00 g b) 0.11 g c) 0.89 g d) 1.56 g e) 1.92 g