

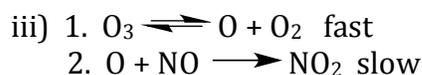
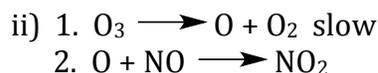
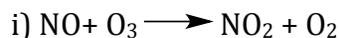
### November 2021 Problem Set

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



The reaction was determined experimentally to be first order in NO and O<sub>3</sub>. The rate constant of the reaction is 80 M<sup>-1</sup>s<sup>-1</sup> at 25 °C and 3000 M<sup>-1</sup>s<sup>-1</sup> at 75 °C.

21. Which is a possible mechanism for the reaction?



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<sub>3</sub> 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 x 10<sup>-5</sup> M and O<sub>3</sub> is 2.5 x 10<sup>-9</sup> M?

a) 1.8 x 10<sup>-14</sup> M/s   b) 2.0 x 10<sup>-12</sup> M/s   c) 9.6 x 10<sup>-10</sup> M/s   d) 3.9 x 10<sup>-7</sup> M/s  
e) 1.9 x 10<sup>-5</sup> 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  $A(aq) + B(aq) \rightarrow C(aq)$ , 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

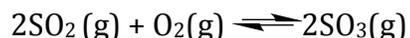
26. What is the rate law for the reaction?

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

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  $\text{H}_2\text{SO}_4$  is the reaction shown below:



Which of the following will not result in an increase in net production of  $\text{SO}_3$ ?

- a) Adding more  $\text{O}_2$
- b) Increasing the pressure of the vessel
- c) Decreasing the volume of the vessel
- d) Removing  $\text{SO}_3$  as it is produced
- e) Removing  $\text{SO}_2$

29.  $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g}) \quad \Delta H = -99 \text{ kJ/mol}$   
 Given a reaction vessel containing  $\text{SO}_2$ ,  $\text{O}_2$  and  $\text{SO}_3$  at equilibrium, which of the following statements is true?
- Adding a catalyst will increase the amount of  $\text{SO}_3$  produced.
  - Increasing temperature will increase the amount of  $\text{SO}_3$  present when equilibrium is re-established.
  - Adding argon to the vessel will change the equilibrium position.
  - Adding  $\text{SO}_3$  will result in less moles of  $\text{SO}_3$  present when equilibrium is re-established than are present before the addition of  $\text{SO}_3$ .
  - None of these statements are true.
30. Which one of the following salts, when dissolved in water, produces the solution with the *lowest* pH?
- KOCl
  - KBr
  - $\text{KNO}_2$
  - KF
  - All of the salts will produce a solution with the same pH.
31. Consider the following gas-phase reaction:  
 $2\text{A}(\text{g}) + \text{B}(\text{g}) \rightleftharpoons 2\text{C}(\text{g}) \quad K_p = 15$   
 If 1.10 atm of A, 0.0100 atm of B and 12 atm of C are put in a sealed vessel,
- the partial pressure of C increases as the reaction proceeds to equilibrium.
  - the total pressure increases as the reaction proceeds to equilibrium.
  - the reaction is at equilibrium.
  - the concentration of A increases and the concentration of B decreases as the reaction proceeds to equilibrium.
  - the partial pressures of the three gases decrease.
32. What is the pH of a saturated solution of  $\text{Mg}(\text{OH})_2$ ?  $K_{sp}$  of  $\text{Mg}(\text{OH})_2$  is  $5.6 \times 10^{-12}$
- 3.64
  - 8.37
  - 10.05
  - 10.35
  - 11.82
33. What is the pH of a 1.0 M sodium acetate,  $\text{CH}_3\text{COONa}$ , solution, given that  $K_a(\text{CH}_3\text{COOH}) = 1.8 \times 10^{-5}$  and  $K_w = 1.0 \times 10^{-14}$ ?
- 10.08
  - 2.43
  - 4.82
  - 7.00
  - 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?
- 3.24
  - 0.0324
  - $1.08 \times 10^{-4}$
  - $1.08 \times 10^{-5}$
  - $8.73 \times 10^{-6}$

35. The  $K_{sp}$  for silver chloride, AgCl (used in photography) is  $2.8 \times 10^{-10}$  at a given temperature. What is the solubility of AgCl in 0.010 M HCl solution at this temperature?
- a)  $2.8 \times 10^{-12}$  M   b)  $2.8 \times 10^{-8}$  M   c)  $5.6 \times 10^{-8}$  M   d)  $2.8 \times 10^{-4}$  M   e)  $5.6 \times 10^{-4}$  M

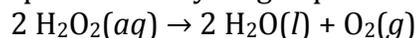
36. Consider equal volumes of the following acid solutions with equal concentrations:

HCl	pH = 1.1
CH <sub>3</sub> COOH	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<sub>3</sub>COOH   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)<sub>2</sub> with water to give a 250.0 mL solution?
- a) 1.80   b) 2.10   c) 11.90   d) 12.20   e) 13.40

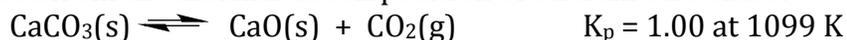
38. The first-order decomposition of hydrogen peroxide occurs according to the equation:



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

- a) [H<sub>2</sub>O<sub>2</sub>] vs time   b) [H<sub>2</sub>O<sub>2</sub>]<sup>2</sup> vs time   c) 1/[H<sub>2</sub>O<sub>2</sub>] vs time  
d) ln[H<sub>2</sub>O<sub>2</sub>] versus time   e) 2[H<sub>2</sub>O<sub>2</sub>] 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<sup>-1</sup>) for the reaction?
- a)  $1.0 \times 10^{-4}$  s<sup>-1</sup>  
b)  $4.8 \times 10^{-4}$  s<sup>-1</sup>  
c)  $6.0 \times 10^{-3}$  s<sup>-1</sup>  
d)  $2.9 \times 10^{-2}$  s<sup>-1</sup>  
e)  $5.2 \times 10^{-2}$  s<sup>-1</sup>

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



When 2.00 g of CaCO<sub>3</sub> are placed in a 1.00 L evacuated flask at 1099 K, how much CaCO<sub>3</sub> 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