

Problem Set #2, November 2020

21. The reaction of ozone with oxygen atoms to give oxygen (O_2) has an activation energy of 17.1 kJ/mol with a rate constant (k) at 298 K of $4.8 \times 10^6 \text{ M}^{-1} \text{ s}^{-1}$. What is the rate constant for this reaction at 311 K?
- $3.6 \times 10^{12} \text{ M}^{-1} \text{ s}^{-1}$
 - $4.6 \times 10^6 \text{ M}^{-1} \text{ s}^{-1}$
 - $5.3 \times 10^{12} \text{ M}^{-1} \text{ s}^{-1}$
 - $6.4 \times 10^6 \text{ M}^{-1} \text{ s}^{-1}$
 - $7.1 \times 10^6 \text{ M}^{-1} \text{ s}^{-1}$
22. 200 mL of 0.1 M acetic acid ($K_a = 1.74 \times 10^{-5}$) is titrated with 0.4 M of NaOH. What is the initial pH of the acid, and what volume of base is required to titrate the acid to the equivalence point?
- pH = 1, volume = 1 mL
 - pH = 1, volume = 400 mL
 - pH = 2.9, volume = 50 mL
 - pH = 2.9, volume = 0.01 mL
 - pH = 1.5, volume = 250 mL
23. The heat of fusion of ammonia is 5.65 kJ/mol, and its freezing point is -77.73°C . What is the entropy change in the surroundings when ammonia freezes?
- the entropy of the surroundings is always constant
 - $+28.91 \text{ J mol}^{-1} \text{ K}^{-1}$
 - $-28.91 \text{ J mol}^{-1} \text{ K}^{-1}$
 - $+72.69 \text{ J mol}^{-1} \text{ K}^{-1}$
 - $-72.69 \text{ J mol}^{-1} \text{ K}^{-1}$
24. A 300 mL aqueous solution contains 0.03 M of a strong acid, HA. What is the pH after the addition of 200 mL of a pH 12.6 solution?
- 2.41
 - 1.52
 - 2.98
 - 2.68
 - 3.12
25. What is the concentration of Ag^+ in a saturated solution of the slightly soluble salt Ag_3AsO_4 (silver arsenate, $K_{sp} = 1.0 \times 10^{-22}$ at 25°C)?
- $5.2 \times 10^{-6} \text{ M}$
 - $4.2 \times 10^{-6} \text{ M}$
 - $3.2 \times 10^{-6} \text{ M}$
 - $2.2 \times 10^{-6} \text{ M}$
 - $1.2 \times 10^{-6} \text{ M}$

26. The solubility of silver chromate (Ag_2CrO_4) in 500 mL of water at 25 °C is 0.0129g. What is its solubility product constant at this temperature?

- a. 2.36×10^{-13}
- b. 4.74×10^{-13}
- c. 1.89×10^{-12}
- d. 2.36×10^{-13}
- e. 6.87×10^{-12}

27. Predict the sign of the entropy change (ΔS) for the following processes:

- i. $\text{SF}_4(\text{g}) + \text{F}_2(\text{g}) \rightarrow \text{SF}_6(\text{g})$
- ii. $\text{H}_2\text{S}(\text{g}) + \text{NH}_3(\text{g}) \rightarrow \text{NH}_4\text{HS}(\text{s})$
- iii. $\text{O}_2(\text{g})$ (at 400 K) \rightarrow $\text{O}_2(\text{g})$ (at 800 K)
- iv. $\text{CH}_3\text{OH}(\text{l}) \rightarrow \text{CH}_3\text{OH}(\text{g})$

- a. i: $\Delta S < 0$, ii: $\Delta S > 0$, iii: $\Delta S > 0$; iv: $\Delta S > 0$
- b. i: $\Delta S > 0$, ii: $\Delta S > 0$, iii: $\Delta S < 0$; iv: $\Delta S < 0$
- c. i: $\Delta S < 0$, ii: $\Delta S > 0$, iii: $\Delta S < 0$; iv: $\Delta S > 0$
- d. i: $\Delta S < 0$, ii: $\Delta S < 0$, iii: $\Delta S < 0$; iv: $\Delta S > 0$
- e. i: $\Delta S < 0$, ii: $\Delta S < 0$, iii: $\Delta S > 0$; iv: $\Delta S > 0$

28. For a Haber process taking place in an enclosed vessel,
$$\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g}) \quad \Delta H = -92.4 \text{ kJ}\cdot\text{mol}^{-1}$$

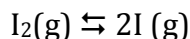
Which of the following is true about this process?

- a. the reaction is favoured at higher temperatures
- b. an increase in volume will favour the formation of ammonia
- c. a decrease in volume will favour the formation of ammonia
- d. adding more N_2 will not affect the production of ammonia
- e. the equilibrium constant will increase with increasing temperature

29. The equilibrium constant of a reaction can be changed by changing:

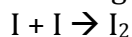
- a. the pressure
- b. the volume
- c. the concentration
- d. the temperature
- e. it is a fixed value and will not change

30. The dissociation of molecular iodine into iodine atoms can be written as



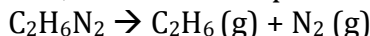
The equilibrium constant for this reaction at 1000 K is 3.8×10^{-5} . If you start with 0.0456 mole of I_2 in a 2.3 L flask at 1000 K, what are the concentrations of the gases at equilibrium?

- $[\text{I}] = 8.58 \times 10^{-4} \text{ M}$, $[\text{I}_2] = 1.94 \times 10^{-2} \text{ M}$
 - $[\text{I}] = 1.31 \times 10^{-3} \text{ M}$, $[\text{I}_2] = 1.92 \times 10^{-2} \text{ M}$
 - $[\text{I}] = 7.52 \times 10^{-7} \text{ M}$, $[\text{I}_2] = 1.98 \times 10^{-2} \text{ M}$
 - $[\text{I}] = 1.70 \times 10^{-3} \text{ M}$, $[\text{I}_2] = 1.90 \times 10^{-2} \text{ M}$
 - $[\text{I}] = 6.34 \times 10^{-4} \text{ M}$, $[\text{I}_2] = 1.96 \times 10^{-2} \text{ M}$
31. At 25 °C and proceeding in carbon tetrachloride, the reaction



is second order in the concentration of the iodine atoms. The rate constant has been measured to be $k = 8.2 \times 10^9 \text{ L mol}^{-1} \text{ s}^{-1}$. Suppose the initial concentration of iodine atoms is $1.00 \times 10^{-4} \text{ M}$; what is their concentration after 2.0×10^{-6} seconds?

- $9.81 \times 10^{-5} \text{ M}$
 - $3.79 \times 10^{-5} \text{ M}$
 - $4.32 \times 10^{-5} \text{ M}$
 - $6.21 \times 10^{-6} \text{ M}$
 - $1.22 \times 10^{-6} \text{ M}$
32. Azomethane, $\text{C}_2\text{H}_6\text{N}_2$ decomposes at 297 °C in the gas phase as follows:



Given the following data, what is the order of the reaction in $[\text{C}_2\text{H}_6\text{N}_2]$, and what is the rate constant?

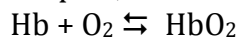
(Hint: recall the equation for a straight line, $y=mx + b$)

Time (min)	$[\text{C}_2\text{H}_6\text{N}_2] (\text{M})$
0	0.36
15	0.30
30	0.25
48	0.19
75	0.13

- second order $k = 6.17 \times 10^{-4} \text{ L mol}^{-1} \text{ s}^{-1}$
- first order, $k = 2.28 \times 10^{-4} \text{ s}^{-1}$
- second order, $k = 4.08 \times 10^{-2} \text{ L mol}^{-1} \text{ s}^{-1}$
- first order, $k = 1.22 \times 10^{-2} \text{ s}^{-1}$
- there is not enough information provided

33. For the azomethane reaction in Question 12, how long will it take for the concentration of $[C_2H_6N_2]$ to decrease from 0.36 M to 0.07 M?
- 200 seconds
 - 2 minutes
 - 20 minutes
 - 2 hours
 - 5 hours

34. Hemoglobin (Hb) is the oxygen binding molecule found in blood, which carries O_2 to the muscle tissues. The equilibrium reaction of O_2 binding to hemoglobin is quite complex, but can be simplified here as:



where oxyhemoglobin (HbO_2) is the oxygen transporting complex.

At sea level, the partial pressure of oxygen is 0.2 atm, compared to about 0.14 atm at an altitude of 3 km. How will the concentrations of oxygen, hemoglobin, and oxyhemoglobin change if a climber ascends over the span of a few hours from sea level to a 3000m peak?

- $[O_2]$ will decrease, $[HbO_2]$ will increase
 - $[O_2]$ will increase
 - $[Hb]$ will decrease, $[HbO_2]$ will increase
 - $[O_2]$ will decrease, $[HbO_2]$ will decrease
 - $[Hb]$ will decrease
35. Consider equal volumes of the following solutions, all of which are of equal concentrations (0.1 M):
- | | |
|----------------------------|----------|
| Hydrofluoric (HF) | pH = 2.1 |
| Acetic acid (CH_3COOH) | pH = 2.9 |
| Lactic acid ($HCOOH$) | pH = 2.4 |
| Hydrocyanic (HCN) | pH = 5.1 |

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

- HF
- Acetic acid
- Lactic acid
- Hydrocyanic
- all the same

36. A solution contains $2 \times 10^{-2} \text{ M}$ each of Cl^- , Br^- and CrO_4^{2-} ions. A 100 % dissociated solution of AgNO_3 is added drop by drop in sufficient amounts to form precipitates. What is the order in which the ions will precipitate?

Data: $K_{\text{sp}}(\text{AgCl}) = 1.5 \times 10^{-10}$; $K_{\text{sp}}(\text{Ag}_2\text{CrO}_4) = 1.9 \times 10^{-12}$; $K_{\text{sp}}(\text{AgBr}) = 5.0 \times 10^{-13}$

- AgCl , Ag_2CrO_4 , AgBr
 - AgBr , Ag_2CrO_4 , AgCl
 - AgCl , AgBr , Ag_2CrO_4
 - AgBr , AgCl , Ag_2CrO_4
 - Ag_2CrO_4 , AgCl , AgBr
37. Which of the following statements are true for buffer solutions:
- they contain a strong acid and its conjugate base
 - they contain a weak acid and weak base that are conjugate to each other
 - a buffer system should be chosen so that the pK_a is close to the desired pH
 - buffer solutions with lower concentrations of buffer resist pH changes more effectively
- (i) only
 - (ii) and (iii)
 - (ii) and (iv)
 - (ii) (iii) and (iv)
 - (i), (iii) and (iv)

38. The rate of the elementary reaction between argon and oxygen
- $$\text{Ar} + \text{O}_2 \rightarrow \text{Ar} + \text{O} + \text{O}$$
- was studied as a function of temperature, and the following data was collected for the rate constant k :

Temp (K)	k ($\text{L mol}^{-1} \text{s}^{-1}$)
5000	5.60×10^6
10000	9.28×10^8
15000	5.15×10^9
18000	8.99×10^9

What is the activation energy E_a and prefactor A in the Arrhenius equation for the temperature dependence of the rate constant?

(Hint: recall the equation for a straight line, $y = mx + b$)

- $E_a = 1.16 \times 10^5 \text{ J/mol}$, $A = 5.59 \times 10^6 \text{ L mol}^{-1} \text{ s}^{-1}$
- $E_a = 3.12 \times 10^3 \text{ kJ/mol}$, $A = 7.02 \times 10^8 \text{ L mol}^{-1} \text{ s}^{-1}$
- $E_a = 3.12 \times 10^3 \text{ kJ/mol}$, $A = 1.54 \times 10^{11} \text{ L mol}^{-1} \text{ s}^{-1}$
- $E_a = 4.25 \times 10^2 \text{ kJ/mol}$, $A = 5.59 \times 10^6 \text{ L mol}^{-1} \text{ s}^{-1}$
- $E_a = 4.25 \times 10^2 \text{ kJ/mol}$, $A = 1.54 \times 10^{11} \text{ L mol}^{-1} \text{ s}^{-1}$

39. A solution contains the following ions: Ag^+ , Ca^{2+} , Cd^{2+} , Mg^{2+} , Ni^{2+} and Pb^{2+} . The solution is treated using the following steps and filtered after each: (i) addition of 6M HCl, (ii) adjustment of filtrate to pH = 9 and addition of H_2S , and (iii) addition of $(\text{NH}_4)_2\text{CO}_3$ to filtrate. What will be observed after each step, and which ions remain in solution after the last step (if any)?
- (i) no precipitate; (ii) precipitate; (iii) precipitate; no ions remain in solution
 - (i) precipitate; (ii) no precipitate; (iii) precipitate; remaining in solution - Ca^{2+} and Mg^{2+}
 - (i) precipitate; (ii) precipitate; (iii) precipitate; remaining in solution - Mg^{2+}
 - (i) no precipitate; (ii) precipitate; (iii) no precipitate; remaining in solution - Cd^{2+} , Ni^{2+} and Ca^{2+}
 - (i) precipitate; (ii) precipitate; (iii) no precipitate; remaining in solution Ca^{2+} and Mg^{2+}
40. A weak acid is titrated with a strong base. Which of the following statements is true?
- The initial pH is high
 - At the equivalence point, the pH is low
 - The region of the titration near the equivalence point shows the buffering action of a mixture of a weak acid with its conjugate base
 - When half of the weak acid has been titrated with a strong base, the pH is equal to the pKa
 - For this titration, the pH changes more dramatically near the half-equivalence point than near the equivalence point