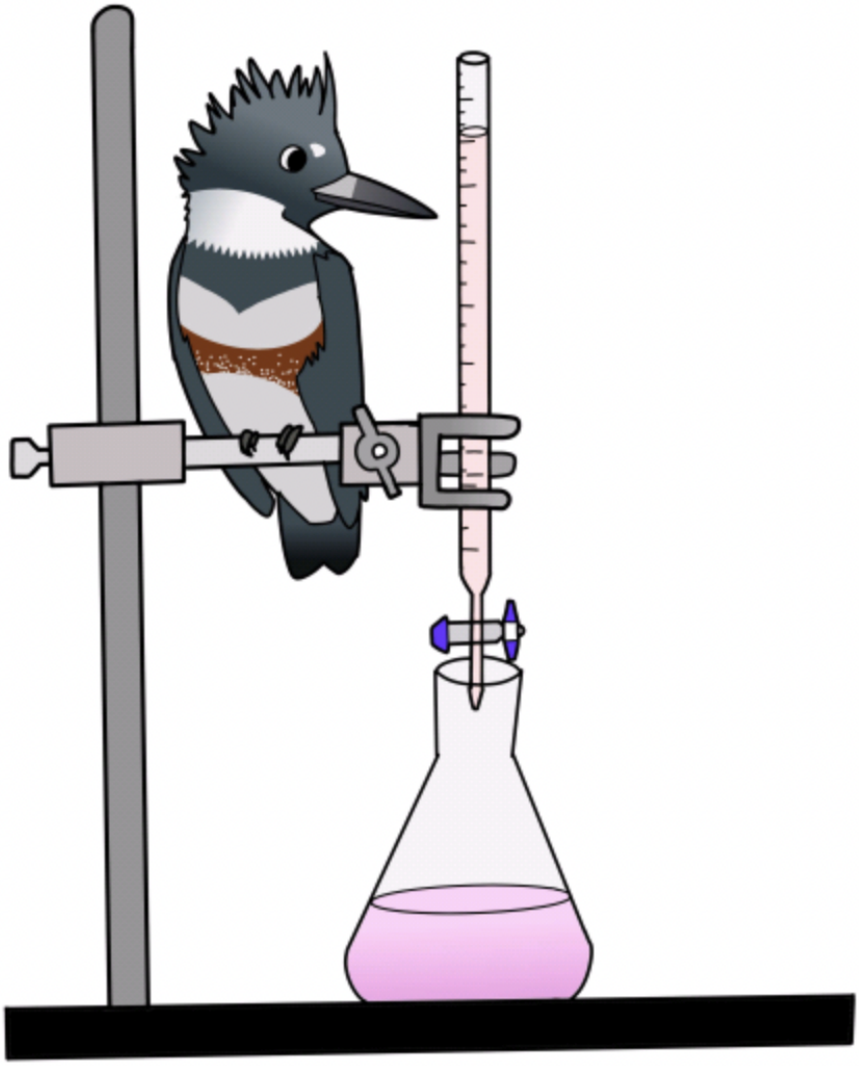


BirdSO Mini Invitational 12/11/2021

Chemistry Lab C

Event Supervisors: Daniel Ye and Dave Jiang

EXAM

Welcome to Chem Lab!

We are Daniel and Dave, and we are excited to be your supervisors for this event!

Some key reminders:

1. This is a 50 minute exam
2. Your reference sheets must be printed out. Your time spent out of the browser WILL be recorded.
3. You may call your teammate through a phone call/Zoom/Discord etc. Make sure you don't accidentally click on that application/tab.
4. Make sure you have a working stand-alone calculator
5. Please read all instructions before starting the test!
6. This exam may test chemical principles beyond Solutions and Electrochem. It's impossible to be good at one area of general chemistry without knowledge of other areas (ex: Electrochem and equilibrium, acids/bases and solutions). Therefore, do expect a somewhat "comprehensive" treatment of general chemistry.
7. There is no wet-lab component to this exam.
8. There are 120 questions
9. Good luck!

Part I - Redox Titration Experiment [15]

Everyone loves a laboratory experiment (so much cap! - your other ES). In this experiment, you will be performing a guided redox titration experiment to determine the mass percent of Fe^{2+} in the original compound.

$$Fe^{3+}\ (aq) + e^- \rightarrow Fe^{2+}\ (aq);\ E^o = 0.770\ V$$

$$MnO_4^-\ (aq) + H^+\ (aq) + e^- \rightarrow Mn^{2+}\ (aq) + H_2O\ (l);\ E^o = 1.507\ V$$

Note: Be sure to balance the half-reactions.

1. Assuming the reaction is spontaneous, what is the value of E^o in V? [1]
2. Assume the reaction is spontaneous. Provide the balanced overall redox reaction for the titration in acidic medium. You do not need to include the states. [2]

Procedure:

Step 1: An unknown iron sample was obtained from the lab specialist and was measured using a balance. The mass was measured as 15.9 grams.

Step 2: The iron sample was dissolved in 50 mL of 1.00 M sulfuric acid. 2.00 mL of 85% Phosphoric Acid was added to the solution.

Step 3: A permanganate solution is prepared by dissolving 0.20 grams of potassium permanganate in 50 mL of water. It was filled into a buret. The initial volume was recorded at 8.7 mL.

Step 4: The titration was performed: The permanganate solution was dispensed, while the solution was swirled until a pink color was observed. The volume at the endpoint was 41.2 mL.

3. How many moles of permanganate were used? [2]
4. How many moles of iron were required to react with the permanganate? [1]
5. What is the mass of iron present in the initial sample? [1]
6. What is the mass percent of iron in the unknown iron sample? [2]
7. A student performed the experiment and got a higher mass percent than expected. Other than human error or machine malfunctions, briefly explain a source of error from the experiment. [2]

8. What was the purpose of adding phosphoric acid into the solution? [1]
9. In most titrations, an indicator would be used to determine if a solution reached the endpoint. However, in the procedure of this experiment, no external indicator was added to the solution despite a color change. Explain why this is the case. Be specific. [3]

Part II - Nitrogen Compounds [18]

10. Nitrogen dioxide can be formed by reacting NO with oxygen. This reaction has a stepwise mechanism

    $NO + NO \rightleftharpoons N_2O_2$ (fast, reversible)

    $N_2O_2 + O_2 \rightarrow NO_2 + NO_2$ (slow)

    If the first elementary step does not exist, write out the overall rate law for the reaction [1]
11. Write out the overall rate law, taking into account that the first elementary step is fast and reversible (as written). [4]
12. Assume the rate of this reaction to be 0.0087 M/s when the rate constant k is 0.04 [redacted units], and the concentration of O_2 is 0.5 M. What is the concentration of NO? [2]
13. Assume that the partial pressure of NO is 3.5 atm, and this gas is evolved into a closed container. If the Henry's law constant for NO is 0.0019 M·atm, what is the concentration of NO present? [2]
14. Copper and nitric acid can reactor to produce NO:

    $3Cu(s) + 2NO_3^-(aq) + 8H^+(aq) \rightarrow 3Cu^{2+}(aq) + 2NO(g) + 4H_2O(l)$

    What is the oxidation half reaction before balancing? [1]
15. What is the reduction half reaction before balancing? [1]
16. If the standard cell potential for the overall reaction is 0.61 V, what is the standard reduction potential for the reduction reaction, given that the oxidation reaction has a reduction potential of 0.34 V? [1]
17. Calculate the standard free energy change in kJ/mol, and predict whether the value of ΔS° is positive or negative. [2]

18. The formation constant of $[Ag(NH_3)_2^+]$ is 1.6×10^7. Write the reaction that forms this complex ion [1]
19. Calculate the molar solubility of AgCl in 0.1 M NH_3, provided that the K_{sp} of AgCl is 1.8×10^{-10} [3]

Part III - Gasoline [14]

The price of gasoline has been steadily increasing throughout the past few years, and this was met with complaints from all over the United States. Gasoline is generally a mixture of liquid aromatic and aliphatic compounds, with oxygen containing additives to enhance combustion. Even though it's a mixture, for the following questions, assume solution behavior of gasoline.

20. n-octane is the main active component of gasoline. Write out its full, balanced combustion reaction. [2]
21. The normal boiling point of n-octane is 126°C at 1 atm. The heat of vaporization for octane is 35 kJ/mol. If you store octane in a container pressurized to 4.6 atm, what would the temperature of the surroundings have to be for octane to boil (and cause a disaster for you)? [3]
22. To increase the heat released by combustion of 500 grams of liquid gasoline, you add some liquid ethanol into the octane mix. Octane normally has a vapor pressure of around 60 torr. You want this solution to have a vapor pressure to be at 50 torr because you think by having less gas on top of the liquid you are less at risk of injury by explosion. Therefore, you add some amount of ethanol, which has a vapor pressure of around 45 torr. How many moles of liquid ethanol should you add to achieve the desired pressure? Assume ideal behavior for this hypothetical situation. [4]
23. In another scenario, you mix 45 grams of octane with 12.7 grams of ethanol, assuming ideal behavior. If the measured P_{soln} is 47 torr, do you expect this non-ideal solution to feel warm or cold to the touch? Explain. [2]

24. When the gasoline is combusted, gas evolution occurs (one of the products is a gas). Assume that the Henry's Law constant for this gas is 0.02 mol/L*atm. You also want to make sure that the partial pressure of this gas does not exceed 0.008 atm. What concentration of this gas can be evolved so it's saturated with the air, with saturation dictated by the pressure stated above? [3]

Part IV - Vapor Pressure and Colligative Properties [32]

25. What is the freezing point of water in a solution of 43 grams of glucose, $C_6H_{12}O_6$, in 450 g of water? K_b of H_2O is 1.86 [2]
26. An ideal solution of NaCl has a density of 1.02 g/mL. At STP, the freezing point of this solution is -3.75 °C. Calculate the percent composition by mass of NaCl in this solution. [2]
27. What is the vapor pressure of a solution containing 51 grams of liquid C_2H_5OH (P_{vap}= 6.0 kPa) and 132 grams of water (P_{vap} = 2.3 kPa) at STP? [3]
28. At what temperature, in K, would water boil, if the external pressure is 2.56 atm? Note that ΔH_{vap} for water is 44 kJ/mol. [3]
29. 0.75 g of a molecular compound X is dissolved in 20 grams of benzene. The boiling point increased by 0.83 °C. What is the molar mass of X, given that K_b of benzene is 2.53 °C/m and the freezing point of pure benzene is 5.5 °C? [3]
30. The pressure at a height h above sea level is given by the barometric formula, $P = P_0 e^{-mgh/RT}$, where m is ~0.029 kg/mol for dry air, P_0 is atmospheric pressure at sea level, and g is the acceleration due to gravity, 9.81 m/s^2. If ΔH_{vap} = 44 kJ/mol, estimate the boiling point of water at 3000 meters above sea level, in Kelvin. Assume that at sea level, the current temperature is room temperature. [4]
31. At room temperature, the vapor pressure of water is around 30 mmHg. 90 grams of some solid unknown compound X is added to 400 grams of water. The vapor pressure of the solution is 26 mmHg. What is the molar mass of X? [3]

32. What mass of $C_3H_8O_2$ must be added to 1 kg of water to reduce the vapor pressure by 5 mmHg at 40°C? The vapor pressure of water at 40 °C is 55 torr. [3]
33. The vapor pressure of Hg at 573 K is 33 torr. What mass of Au will have to be dissolved in 5 grams of Hg to lower its vapor pressure to 10 torr? Note that gold at 573 K is still a solid. [3]
34. When you add salt to water, it actually changes two properties of the solution. Explain both of them and describe how they respond when you are cooking. Why doesn't adding salt to water help it cook faster? [2]
35. You dissolve 3 grams of a solid XY_2 to prepare a saturated solution in half a liter of water. Assume that XY_2 dissociates completely. The freezing point of the solution is -0.092 °C. Calculate the K_{sp} of XY_2 [3]
36. What type of deviation solution should hexane (C_6H_{14}) and chloroform ($CHCl_3$) exhibit? [1]

Part V - Acids and Bases [18]

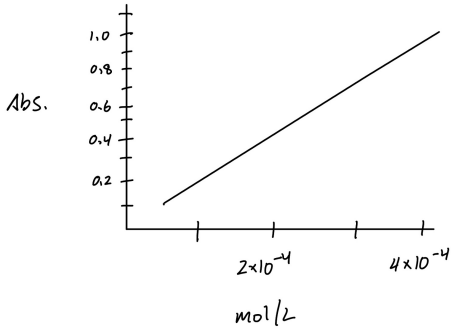
37. Calculate the pH of 0.75 M HF, given that K_a of HF is 0.00072 [1]
38. What concentration of an HCl solution has the same pH as 1.0 M HF? [3]
39. 100 mL of 1.0 M HA is mixed with 100 mL of 0.50 M NaOH. The pK_a of HA is 6. What is the pH of this solution? [2]
40. K_w at 25 °C is 10^{-14}, while K_w at 50 °C is 5×10^{-14}. Based on this, is the autoionization of water endothermic or exothermic? Explain. [2]
41. What is the pH of 1.0 M $AlCl_3$? (K_a of $Al(H_2O)_6^{3+}$ is 1.5×10^{-5}) [2]
42. 40 mL of 0.25 M NaOH is added 100 mL of 0.25 M HA. The resulting pH is 4.80. What is the K_a of HA? [2]
43. What volume of 0.050 M HBr must be added to 100.0 mL of 0.010 M KOH to achieve a pH of 10? [3]
44. What is the pH of a solution made by mixing 100 mL of 0.10 M acetic acid with 100 mL of 0.20 M NaCN? K_a of acetic acid is 1.8×10^{-5}, K_a of HCN is 6.2×10^{-10} [3]

Part VI - Transition Metal Complexes [11]

45. If the dissociation constant K_d of $Cd(CN)_4^-$ is 8.0×10^{-18}, what is the equilibrium concentration of Cd^{2+} in a 1.0 M solution of $Cd(CN)_4^-$? [3]
46. Would you expect $[Fe(CN)_4]^{2-}$ to be high spin or low spin? Why? [2]
47. Consider $[Cr(CN)_6]^{3-}$. It has three unpaired electrons. Which of the following are true? [3]
48. $[CrCl_6]^{3-}$ has a maximum absorbance spectrum at 740 nm. Calculate the crystal field splitting energy in kJ/mol. Show your work. [3]

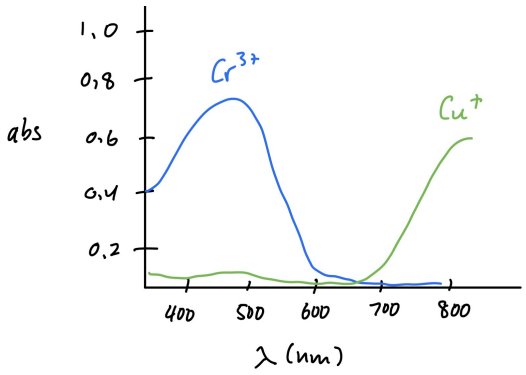
Part VII - General Solutions Problems [27]

49. An aqueous solution of a compound with a molar mass of 68.9 g/mol is 35% by mass. The solution has a density of 1.24 g/mL. What is the molarity of this solution? [2]
50. A 5% w/w aqueous solution of NH_3 has a density of 0.96 g/mL. Calculate the molarity of NH_3 [2]
51. Calculate the molar solubility of $Cu(OH)_2$ in a solution with pH=13. The K_{sp} of $Cu(OH)_2$ is 8×10^{-16} [2]
52. Hydroxyapatite, $Ca_5(PO_4)_3OH$, has a K_{sp} of 6.9×10^{-37}. Calculate the molar solubility of hydroxyapatite in water. [2]
53. If a strong acid is added to hydroxyapatite, how does it affect its solubility? [1]
54. Calculate the pH of a saturated solution of $Mg(OH)_2$ at room temperature, given that its solubility is 6.5 grams per liter. [3]
55. The molar solubility of $BaSO_4$ in water is 10^{-5} M, while the molar solubility of BaF_2 in water is 3.6×10^{-3}. If a solution of $Ba(NO_3)_2$ is added to 1 L of a solution with 0.05 mol F^- and 0.075 mol SO_4^{2-}, which salt precipitates first? What's the $[Ba^{2+}]$ required for the precipitation? [3]
56. The following is a graph of absorbance vs concentration. 150 mL of a MnO_4^- solution was prepared and put under



the spectrophotometer. If the absorbance is 0.75, how many moles of MnO_4^- were present? [2]

57. We want to know the concentration of Cu^+ in a solution. However, the solution also has a small amount of Cr^{3+}. The hypothetical absorbance curves of Cu^+ and Cr^{3+} are given. What is the lowest wavelength the student should use to most accurately determine the concentration? Note that the spectrophotometer can really only detect up to 750 nm. [2]



58. A solution of the amino acid Trp at 280 nm has an absorbance of 0.06 when the path length is 1 cm. Given that ε=6400, what is the concentration of Trp, in M? [2]
59. A 5.5 x 10^{-6} M solution of pigment has an absorbance of 0.726 at 450 nm in a 1 cm cuvette. Calculate ε at 450 nm, to 3 sig figs. [2]
60. Calculate the molar solubility of $Ca_3(PO_4)_2$ in a 0.3 M Na_3PO_4 solution. The K_{sp} of calcium phosphate is 10^{-32}. You may make reasonable assumptions. [2]
61. X_2Y_3 has a molar mass of 472 g/mol. Its molar solubility is 10^{-6} g/L. Calculate its K_{sp}. [2]

Part VIII - General Electrochemistry Problems [55]

Use the following information to answer the following three questions. Assume the reaction takes place at 1 atm and 25 °C.

Reaction	E^o_{red}
Cu^{2+} (aq) + $2e^-$ -> Cu (s)	0.3419 V
O_2(g) + $4H^+$ (aq) + $4e^-$ -> $2H_2O$	1.229 V

62. Determine the expected standard voltage for the following two reactions. [1]
63. Determine the value of ΔG^{o} in kJ. [2]
64. If the concentration of Cu^{2+} is 0.10 M and the concentration of H^{+} is 0.20 M, what is the cell potential? [3]
65. How many grams of Cr can be electroplated using a current of 5.2 A through a solution of $Cr(NO_3)_3$ for 45 minutes? [2]
66. Calculate E_{cell} for the half cell MnO_4^- (0.01 M) + $8H^+$ (0.2 M) + $5e^- \rightarrow Mn^{2+}$ (0.02 M) + $4H_2O$ [3]
67. Calculate E_{cell} for the following at room temperature: Ga | Ga^{3+} (10^{-6} M) || Ag^+ (10^{-4} M) | Ag [3]
68. Use the cell notation in the above question as reference. What does the single vertical line "|" represent? [1]
69. Calculate the equilibrium constant for $Cu^{2+} + 2Ag \rightarrow 2Ag^+ + Cu$ at room temperature [2]
70. Calculate the equilibrium constant for ½ $Cu + Ag^+ \rightarrow$ ½ $Cu^{2+} + Ag$ at room temperature [2]
71. A hypothetical compound $X(NO_3)_3$ is electrolyzed. When a current of 6.7 A is applied for 12 minutes, 5.60 grams of metal X is deposited. What is the molar mass of X? [3]

For the next five questions: In an electrolytic cell, a current of 0.875 A runs through a solution of a fluoride of some metal Y, producing solid Y and fluorine gas.

72. What reaction occurs at the anode? [1]
73. The cell runs for 1.5 hours. At one electrode, it is measured that 1.469 grams of Y has been deposited. The molar mass of Y is 125.7 grams. Determine the full chemical formula of the metal fluoride. [3]
74. Write the overall, balanced equation for the reaction that occurs in this voltaic cell. [1]
75. Under the conditions assumed two questions before this one, how many liters of fluorine gas are produced at room temperature and at a pressure of 800 torr? [2]
76. What current would produce fluorine gas from this cell at a rate of 10 grams per hour? [2]

77. Given the following half reactions, calculate the equilibrium constant K of the reaction at 298 K [2]

    $S_4O_6^{2-} + 2e^- \rightarrow 2S_2O_3^{2-}$ $E^o = 0.17$ V

    $Cr^{3+} + e^- \rightarrow Cr^{2+}$ $E^o = -0.50$ V

78. A current of 5.0 A is passed through a solution of $CrCl_2$ for 20 minutes. How many grams of Cr is deposited at the cathode? [2]
79. Regarding the previous question, calculate the volume of Cl_2 collected at the anode, at STP. [2]
80. When Au is reduced from $AuCl_4^-$ during electrolysis, the solution must be stirred. Explain why this stirring is needed. [1]
81. 5 C of charge is passed through fused anhydrous $MgCl_2$. The Mg obtained is completely converted into a Grignard. How many moles of the Grignard were formed? [2]
82. When a rod of solid Pb was added to a 0.01 M solution of $Co(en)_3^{3+}$, 68% of the complex ion was reduced to $Co(en)_3^{2+}$ by the lead. Write out the balanced equation for this equilibrium. [1]
83. Referring to the question above, calculate the equilibrium constant K [3]
84. Calculate $E^o(Co(en)_3^{3+})/(Co(en)_3^{2+})$ [2]
85. Calculate the potential of an indicator electrode against the standard hydrogen electrode with 0..1 M MnO_4^- and 0.8 M H^+. It has been treated with 90% of Fe^{2+} necessary to reduce all MnO_4^- to Mn^{2+}. Note that the E^o for the manganese reduction is 1.51 V, and a hint that Iron is not present in Q. [3]
86. Calculate reduction potential of a half cell consisting of Pt immersed in 2.0 M Fe^{2+} and 0.02 M Fe^{3+} solution. [2]
87. What is the potential of an electrode consisting of Zn (s) in a solution in which $[Zn^{2+}]=0.0100$ M? [2]
88. Why are Co^{3+} salts unstable in water? (Hint: think about all the redox reactions that are happening here) [2]

Part IX - General Chemistry Problems [32]

For the next four questions, consider the following: $2A + B \rightleftharpoons 2C + 4D$, $K_c = 3.2 \times 10^{-13}$. A solution is prepared by mixing 25.0 mL of 2.0 M A, 25.0 mL of 2.0 M B, 25.0 mL of 2.0 M C, and 25.0 mL of 2.0 M D.

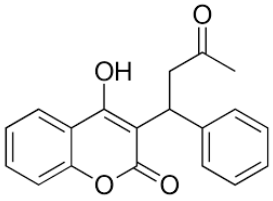
89. What is $[A]_{eq}$ [1]
90. What is $[B]_{eq}$ [1]
91. What is $[C]_{eq.}$ [1]
92. What is $[D]_{eq}$ [1]
93. Of HOCl, HOClO, $HOClO_2$, $HOClO_3$, which is the strongest acid? Provide a valid explanation. [2]
94. I want to make a solution that has $[Ac^-]=3[HAc]$. I start with a 100.0 mL of a 1 M HAc solution. How many mL of 1 M NaOH should I add? [3]
95. The pK_a values of aspartic acid, cysteine, and glutamic acid are 3.9, 8.33, 4.07, respectively. How many of these amino acids would be in their deprotonated form in blood, which has a pH of 7.3? [1]

For the next three questions: Given the following reaction and data in tabular format:

	Mg (s) +	½ CO_2 (g)	→	MgO (s) +	C (graphite)
ΔH°_f (kJ/mol)	0	-393.51		-601.7	0
S° (J/K*mol)	32.68	213.63		26.94	5.74

96. What is ΔH° of the reaction? [1]
97. What is ΔS° of the reaction? [1]
98. Over what temperature range is this reaction spontaneous, if any? [3]
99. What is the noble gas shorthand electron configuration for Zn in the ground state? [2]

Refer to the following organic compound for the next 3 questions.



100. How many pi molecular orbitals are there? [1]

101. How many pi molecular orbitals are filled? [2]

102. A compound contains 40% C, 6.7% H, and 53.3% O. Determine molar mass of the empirical formula. [2]

103. The pK_a of HNO_2 is 3.34. You want to make a buffer solution with pH = 3.6, and $[HNO_2]+[NO_2^-]=1M$. What concentrations of $[HNO_2]$ and $[NO_2^-]$ do you want? [3]

104. For the reaction $C_2H_5I + OH^- \rightarrow C_2H_5OH + I^-$, k = 5.03 x 10^{-2} $M^{-1}s^{-1}$ at 289 K and k = 6.71 $M^{-1}s^{-1}$ at 333 K. What is the activation energy, E_a, of this reaction, in kJ/mol? [3]

105. Pent-2-one reacts with $NaBH_4$, then PBr_3, then NaCN, and finally H_3O^+. What is the product of this reaction sequence? [2]

    a. 2-methyl-1-pentanol

    b. 2-bromo-3-methylpentanoic acid

    c. 2-methylpentanoic acid

    d. 4-hydroxyhexanoic acid

106. Bromocyclohexane reacts with NaO*t*-Bu. Write out the full IUPAC name of the product [2]

Part X - Haber Process & Ostwald Process [29]

The Ostwald process is commonly used for making nitric acid and provides the raw materials for producing fertilizers. It is commonly associated with the Haber process that produces the raw materials for producing ammonia. For this entire portion, assume everything is an ideal gas unless stated otherwise.

107. The Haber Process is provided as follows

$$N_2\,(g) + 3H_2\,(g) \rightarrow 2NH_3\,(g)$$

Assuming the reaction happens at STP, if 5.00 L of nitrogen gas reacts with excess hydrogen, how many moles of NH_3 will be formed from the reaction? [2]

108. The ammonia from the previous step was transferred from a 20.0 L vessel into a 100.0 L vault. However, the workers were also professional clowns and forgot to remove the liquid water inside the vault. Assuming the temperature of the vault is 25°C, what is the concentration of ammonia in the vault? The Henry's Law constant for ammonia in water is 58.77 $mol \cdot L^{-1} \cdot atm^{-1}$. [2]

109. A dilution was performed to decrease the final molarity of the ammonia solution to 5.00 M. After doing so, like the test writers for this exam, the workers procrastinated and left the apparatus sitting in the vault for an extended period of time. Unfortunately, the ammonia was located near a hot platinum wire and some of the ammonia decomposed into nitrogen and hydrogen gas.

$[NH_3]$ (M)	**time (s)**
5.00	0
4.95	400
4.90	800
4.85	1200
4.80	1600

The concentration of the ammonia decreased over time as shown. Assume the concentration of NH_3 decreases at the same rate, what is the concentration of NH_3 in M when the workers return 4900 seconds later? [2]

110. The workers managed to convert the remaining concentrated ammonia to gaseous form through experimental techniques. How many moles of ammonia gas remained in the vault? [2]

The Ostwald Process is provided as follows.

Rxn 1: $4NH_3\,(g) + 5O_2\,(g) + Pt(s) \rightarrow 4NO\,(g) + 6H_2O\,(g)$; $\Delta H = -905.2$ kJ/mol (slow)

Rxn 2: $2NO\,(g) + O_2(g) \rightarrow 2NO_2\,(g)$; $\Delta H = -114$ kJ/mol (fast)

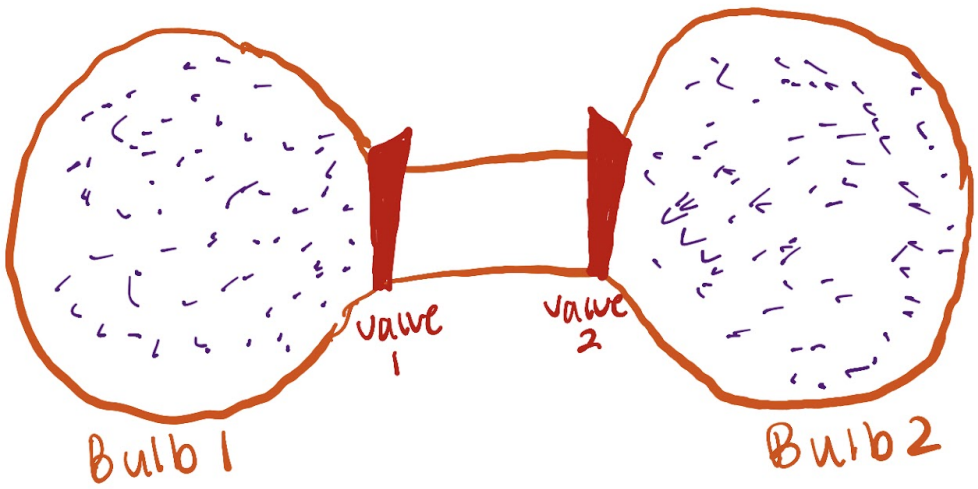
Rxn 3: $3NO_2\,(g) + H_2O\,(l) \rightarrow 2HNO_3\,(aq) + NO\,(g) + Pt(s)$; $\Delta H = -117$ kJ/mol (fast)

The overall reaction for the Ostwald Process is as follows

$$2NH_3\,(g) + 4O_2\,(g) + H_2O\,(l) \rightarrow 3H_2O\,(g) + 2HNO_3\,(aq)$$

Note: The below procedure is not 100% accurate in how the Ostwald actually process works in the real world, but for the sake of simplicity, assume it works as follows.

Step 1: The first reaction occurs in the reaction vessel shown below. The two bulbs have different volumes, and the tube connecting the two bulbs has negligible volume. Two valves were placed at the intersection between the bulbs and the center tube to prevent mixing of the gases. The left bulb contains the amount of ammonia from the vault in a bulb with a volume of 5.00 L at 25°C. The right bulb contains 7.00 L of oxygen gas at a pressure of 1.5 atm and at a temperature of 25°C. Both valves are opened, and the gases are allowed to react at the center of the tube. Unfortunately, the person performing the experiment did not notice a small hole in the center of the tube that resulted in some of the NO and H_2O gas escaping the apparatus. It was later repaired, but the overall reaction could only produce a 70% yield. After the reaction was complete, both valves were closed, so the products remain in the center of the apparatus.

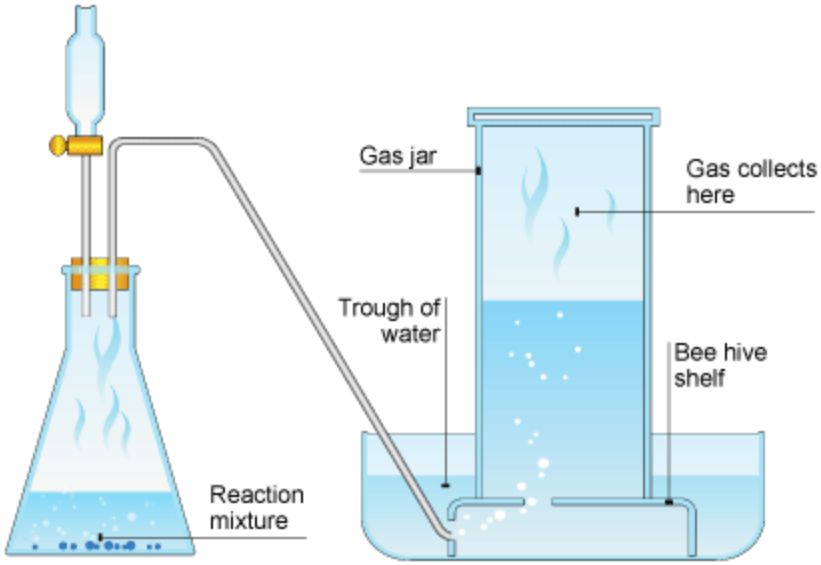


111. Calculate the number of moles of NO produced from the reaction. [3]

Step 2: Since we have a low budget, sodium chloride was used to remove the water vapor waste product from the previous step. A vacuum was connected to Bulb 1 to remove any excess NH_3 gases. Valve 1 was opened, so the remaining NO moved from the center of the tube to bulb 1. Excess O_2 gas from the previous step remained in bulb 2. Valve 1 was closed to prevent any excess gas from mixing. After the gases have settled in their respective bulbs, the valve is opened, allowing the gases to react in the center of the apparatus.

112. Calculate the number of moles of NO_2 produced from the reaction. [3]

Step 3: After the reaction was completed, a vacuum was connected to Bulb 2 to remove any excess O_2 gas that remained in Bulb 2. Only valve 2 was opened to allow the nitrogen dioxide gas product to settle into Bulb 2. The nitrogen dioxide gas is then siphoned (transferred) via a tube from Bulb 2 to a 5 L beaker containing 0.01 L of H_2O at 0 °C. A stopper was placed on top of the beaker, and a tube connects the stopper with a water bath with a gas jar. The reaction occurs at 0°C, and the nitrogen monoxide byproduct was collected over water. The vapor pressure of water at 0 °C is 4.6 mmHg. Assume no water moves backwards from the water bath into the reaction vessel.



113. To the nearest tenth, calculate the pressure, in mmHg, of NO collected over water. Assume the gas jar has the same volume as the beaker. Hint: 1 atm = 760 mmHg. [3]

114. Calculate the molarity of HNO_3 produced in the reaction. [3]

115. Using Hess's Law and the number of moles of HNO_3 found in the previous question, calculate the amount of heat released in the reaction in kJ (Note: conventional signs matter). [3]

116. If the temperature was lowered for the overall reaction, would you expect more or less HNO_3 to be produced? Why or why not? [2]

117. Provide the rate law expression for the overall expression. [2]

118. If the concentration of NH_3 was tripled and the concentration of O_2 was doubled, what would happen to the final rate of the reaction? [2]

Part XI - End Questions [2]

119. There was something on chem lab that you spent last night cramming and it wasn't on this test. Describe and explain what it is. [1]

120. I liked some of the responses from a previous exam we wrote, so I'll ask the same thing again: Write anything you want here for a free point. [1]

Test out of 253 points