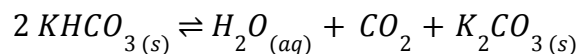


MEDIUM PACKET 1

Team ID: _____

1. $KHCO_3$ decomposes according the following equilibrium:



5 g of $KHCO_3$ were placed into a sealed, 3 L reaction vessel and held at 90°C . At the point at which no macroscopic change was evident, 4 g of $KHCO_3$ were present in the vessel. Unreacted $KHCO_3$ was also present along with gaseous H_2O and CO_2 . Calculate the unitless equilibrium constant of partial pressures, K_p , for this reaction at 90°C . Show all work to support your answer. Given: MW ($KHCO_3$): 84.007 g/mol ; MW (K_2CO_3): 105.99 g/mol. Assume all gases are ideal.

2. The heat of dissolution of ammonium chloride is +14.8 kJ/mol. How many grams of ammonium chloride must be dissolved to raise 20 mL of water by 5°C ? The molar mass of ammonium chloride is 53.49 g/mol.
3. 100 mL of a 0.10 M solution of $NaOH_{(aq)}$ is added to 25 mL of a 0.30 M solution of $HClO_{3(aq)}$ with the temperature maintained at 25°C . After the reaction is complete, what is the concentration (in M) of $OH^-_{(aq)}$ in the solution? What is the pH of this final solution? Is the resulting solution acidic or basic?

MEDIUM PACKET 2

Team ID: _____

- In the lab, you need to synthesize a buffer solution with a pH of 9.45. You need to use NH_4Cl , which has a $K_a = 5.6 \times 10^{-10}$. What ratio of conjugate base to conjugate acid will need to be used?

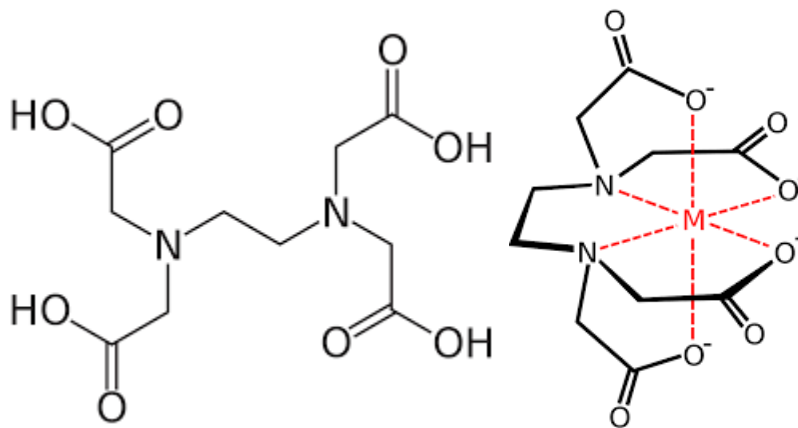
- Propionic acid (CH_3CH_2COOH) is a weak acid, with $K_a = 1.34 \times 10^{-5}$ at $25^\circ C$. It reacts with water as follows: $CH_3CH_2COOH + H_2O \rightleftharpoons CH_3CH_2COO^- + H_3O^+$.
 - Calculate the pH at equilibrium of a 0.35 M aqueous solution of propionic acid at $25^\circ C$.

 - Calculate the percent dissociation of propionic acid in this solution.

MEDIUM PACKET 3

Team ID: _____

1. A solution of sulfuric acid is prepared by dissolving 0.51 g of 98% (by mass) sulfuric acid in 30 mL of H_2O . How many grams of $NaOH$ are required to fully neutralize this solution? The molar mass of sulfuric acid is 98.07 g/mol, and the molar mass of $NaOH$ is 40.0 g/mol.
2. The energy required to excite thiophene to its first excited state is approximately 5.3 eV. Determine the wavelength (in nm) of the photon required to excite thiophene to its first excited state.
3. EDTA is a commonly used chelator. In which environment do you think it works the best?

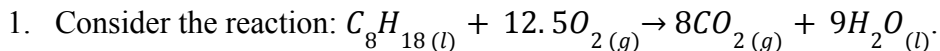


Left: EDTA. Right: EDTA binding to a metal ion.

- a. Acidic
- b. Neutral
- c. Basic

MEDIUM PACKET 4

Team ID: _____



$\Delta H^\circ = -5461 \text{ kJ/mol}$. Which of the following will make its enthalpy change increase (i.e. ΔH° becomes more negative)?

- Replace $C_8H_{18(l)}$ with $C_8H_{18(g)}$
 - Replace $H_2O_{(l)}$ with $H_2O_{(g)}$
 - Replace $C_8H_{18(l)}$ with $C_8H_{18(s)}$
 - Replace $O_{2(g)}$ with $O_{2(l)}$
2. Excess $BaCO_3$ and $BaSO_4$ solids are soaked in 1L pure water, and equilibrium is established. Calculate $[Ba^{2+}]$. Assume zero volume change, and ignore the effect of any ions on the ionization of water. Given: $K_{sp}(BaCO_3) = 8.1 \times 10^{-9}$;
 $K_{sp}(BaSO_4) = 1.1 \times 10^{-10}$.

3. If 54 g argon at 400 K is compressed isothermally and reversibly from a pressure of 1.5 atm to 4 atm, calculate the work done on the gas (w) and the heat absorbed by gas (q) in the process.

MEDIUM PACKET 5

Team ID: _____

1. The table below contains weak acid/conjugate base pairs.

a. Fill in the blanks of the table shown below where information is missing.

Acid Name	Acid Formula	K_a	pK_a	Conjugate Base
Formic acid	$HCOOH$	1.77×10^{-4}		$HCOO^-$
Acetic acid	CH_3COOH		4.75	CH_3COO^-
Carbonic acid	H_2CO_3	4.3×10^{-7}	6.37	
Oxalic acid		5.9×10^{-2}	1.23	$H_2C_2O_4^-$

b. Choose the most appropriate pair to make a buffer with a desired pH of 3.5.

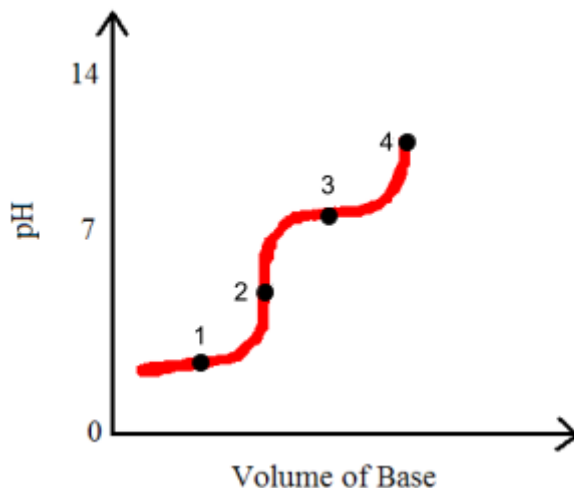
c. Determine the ratio of acid to conjugate base needed in your buffer.

MEDIUM PACKET 6

Team ID: _____

1. A solution of $Ba(OH)_2$ is standardized with potassium acid phthalate (abbreviated *KHP*), $KHC_8H_8O_4$ (MM = 204). If 1.530 g of KHP is titrated with 34.50 mL of the $Ba(OH)_2$ solution, what is the molarity of $Ba(OH)_2$?

2. A solution of sulfurous acid, H_2SO_3 , is titrated with a solution of sodium hydroxide to produce a curve similar to the one shown.



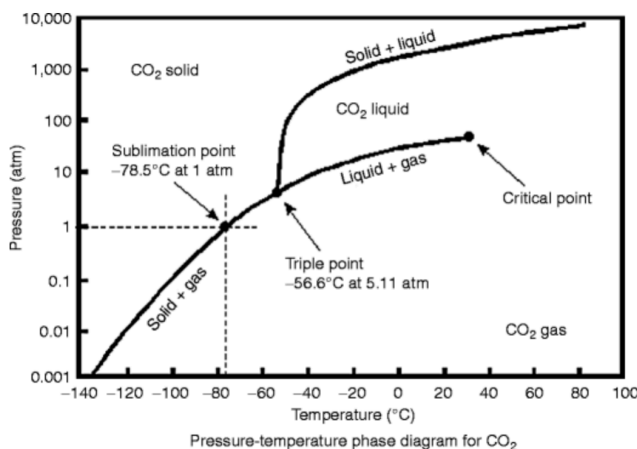
Give the formulas of the major species present at points 1-4 on the titration curve.

3. Solutions of 100 mL of 0.200 M $NaCl_{(aq)}$ and 75 mL of 0.100 M $MgCl_{2(aq)}$ are mixed together in a flask. Calculate the molarity of the chloride ion (Cl^-) in the final solution.

- For the following elements, give the orbital from which the second ionization energy will remove the outermost electron from.

Mg: _____ Al: _____ Na: _____ P: _____

- Given the phase diagram for CO_2 below, what are the phase changes in order as CO_2 is cooled from $40^\circ C$ to $-70^\circ C$, at 200 atm pressure?



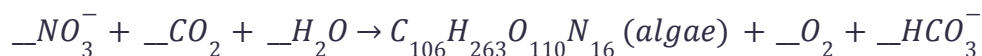
- Consider the balanced chemical reaction: $N_2O_{4(g)} \rightleftharpoons 2 NO_{2(g)}$

The equilibrium constant, K_p , for this reaction at 500 K is equal to 5.9×10^{-3} . If 0.660 atm of N_2O_4 and 0.330 atm of NO_2 are sealed in a reaction vessel at 500 K, determine the equilibrium partial pressures (in atm) of the two gases.

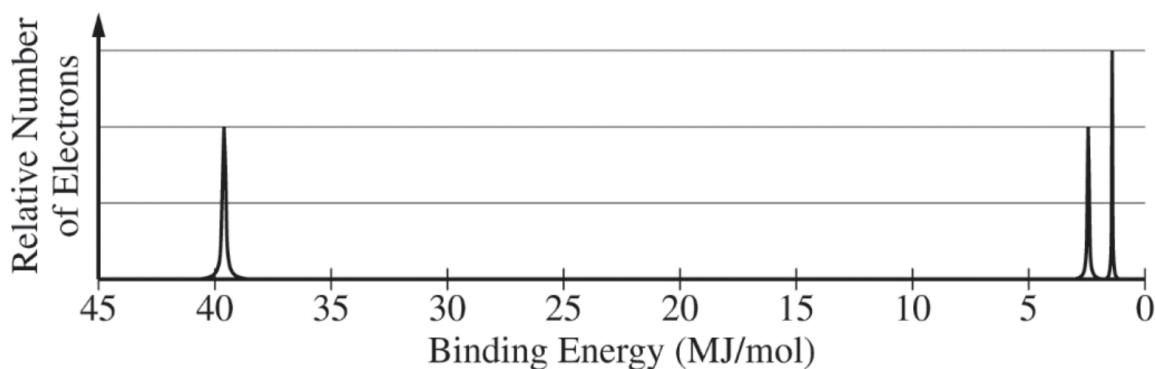
MEDIUM PACKET 8

Team ID: _____

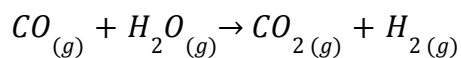
- American oceanographer Alfred C. Redfield proposed the famous Redfield Ratio, which states that in healthy sea areas, the molar ratio of phytoplanktonic carbon, oxygen, nitrogen, and phosphorus remains relatively constant. This discovery drove the development of ecological stoichiometry. Balance the reaction below describing the phytoplanktonic assimilation of nitrate. Note: you may have decimal coefficients because the coefficient of algae is set to be 1.



- Consider the photoelectron spectrum of nitrogen below. If a radioactive isotope decays with a half-life of 8.0 minutes, what is the rate constant, k ?



- Find the ΔH° of the reaction below.

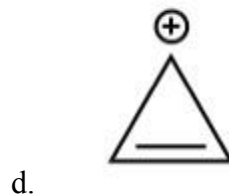
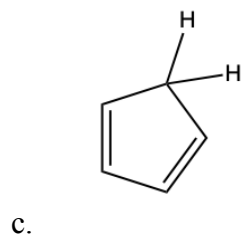
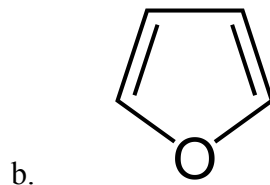
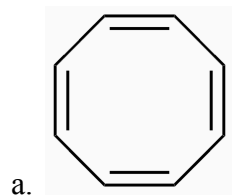


	Bond enthalpy in kJ/mol
C—O in carbon monoxide	+1077
C—O in carbon dioxide	+805
O—H	+464
H—H	+436

MEDIUM PACKET 9

Team ID: _____

1. Given the following molecules, tell if each of them is aromatic, non-aromatic, or antiaromatic. For the aromatic or antiaromatic compounds, please indicate the number of pi-electrons it has.

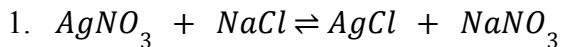


2. Draw out the Lewis-dot structure for CH_3CH_2OH .

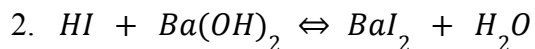
3. Calculate the minimum energy needed to eject a valence electron from a neutral silicon atom in the ground state, given that the Z^* for its outermost valence electron is 5.13. Show all work to support your circled answer.

MEDIUM PACKET 10

Team ID: _____



Given that the K_{sp} of $AgCl$ is 1.6×10^{-10} at room temperature, and assuming the solution contained 0.4 M of Cl^- initially, what is the concentration of silver ions dissolved in the water at equilibrium? Express your answer in molarity.



Write up the net ionic equation for this reaction. Assuming at the end of the reaction, the concentration of OH^- in the solution is 5.2×10^{-8} M. Calculate the pH value for the product mixture.

3. Calculate the wavelength of light (in nm) required to eject the outermost electron from a Cu atom in its ground state with zero kinetic energy, if that electron has a Z^* of 16.40. Show all work to support your circled answer.

1. Find the order of $[S_2O_8^{2-}]$ in the following rate law:

$$\text{Rate} = k [S_2O_8^{2-}]^m [I^-]^n$$

Utilize the following table:

	$[S_2O_8^{2-}]$	$[I^-]$	Rate
Trial 1	$3.657 \times 10^{-2} M$	$4.523 \times 10^{-1} M$	$4.931 \times 10^{-1} \frac{M}{s}$
Trial 2	$7.314 \times 10^{-2} M$	$4.523 \times 10^{-1} M$	$9.861 \times 10^{-1} \frac{M}{s}$

2. NO_2 tends to dimerize: $2NO_2 \rightleftharpoons N_2O_4$. $\alpha = [NO_2]/[N_2O_4]$. Equilibrium is reached in a vessel at some temperature starting with some NO_2 , where the percent concentration of NO_2 is α_1 . If some N_2O_4 is then pumped into this vessel without changing the volume and temperature, after equilibrium is reached again, the percent concentration of NO_2 is α_2 .

Which of the following is true?

- A. $\alpha_1 > \alpha_2$
 B. $\alpha_1 < \alpha_2$
 C. $\alpha_1 = \alpha_2$
 D. The relationship of α_1 and α_2 cannot be determined.
3. Consider a sample of CO_2 gas in a rigid container at 299 K and 0.80 atm that you increase to 414 K. Find the pressure of the gas after the temperature is raised.

1. An electron is confined to a 3-D box with dimensions $L_x = 4.0 \text{ \AA}$, $L_y = 2.0 \text{ \AA}$, and $L_z = 5.0 \text{ \AA}$. Using the particle-in-a-box model, answer the following questions. a. Calculate the zero-point energy (in J) for this electron. Show all work to support your circled answer.

2. A 0.34 M aqueous solution of the monoprotic weak acid acrylic acid, C_2H_3COOH , C_2H_3COOH at 25°C has a percent dissociation of 2.86% after equilibrium is established. Given: 0.34 M is the initial concentration. Using this information, answer the following questions. Determine the pH of the solution after equilibrium is established. Circle your final answer and show all your work.

3. X has a heat of vaporization of 52.3 kJ/mol at its normal boiling point (421°C). Calculate the ΔG (in kJ) of $X(l) \rightarrow X(g)$ at 430 °C and 1 atm. Assume that the heat of vaporization and the entropy of vaporization are constant. (Round to 3 decimal places).

MEDIUM PACKET 13

Team ID: _____

1. CH_3COOH is a monoprotic weak acid with a pK_a of 4.76. Calculate the pH of 0.10 M CH_3COOH aqueous solution at $25^\circ C$.

2. Consider the following radial wavefunction for the H atom:

$$R_{n, \ell} = \frac{1}{2\sqrt{6}} \left[\frac{Z}{a_0} \right] \sigma \text{ where } \sigma = \frac{Zr}{a_0}$$

Sketch the following radial wavefunction for the H atom. Be sure to quantitatively identify nodes (if any) on your sketch.

3. Calculate the entropy change of 1.5 mol of an ideal gas for the following process.

$$T_i = 81 K, V_i = 10 L, P_i = 1 atm$$

$$T_f = 300 K, V_f = 37 L, P_f = 1 atm$$

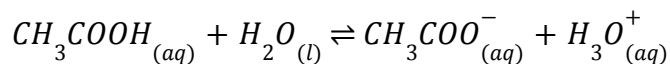
MEDIUM PACKET 14

Team ID: _____

1. What is the mass percent of oxygen in $Al_2(SO_4)_3 \cdot 18H_2O$?

2. Using the thermodynamic data given below:

a. Determine if the reaction is spontaneous in the forward direction at 25°C under standard conditions. Given: $\Delta G_{rxn}^{\circ} = 27.2 \text{ kJ/mol}$ at 298 K.



	ΔH_f° (kJ/mol)
$H_3O^{+}_{(aq)}$	-285.8
$CH_3COO^{-}_{(aq)}$	-486.1
$CH_3COOH_{(aq)}$	-485.8
$H_2O_{(l)}$	-285.8

b. Is there a temperature that would make the forward reaction spontaneous? Hint: calculate ΔS_{rxn}° .