

CHM1311 E

Name : _____

TWO STAGE DGD QUIZ

October 2019

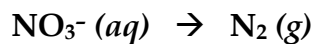
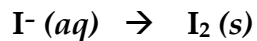
STAGE 1 : INDIVIDUAL RESPONSES (30 min)

1. (6 pts) Magnesium-aluminum alloys are commonly used in aircraft construction. When treated with acid, both metals react to form hydrogen gas, as shown in the unbalanced chemical equations below. A 1.000 g sample of alloy produces 0.107 g of H_2 (g) when reacted with excess HCl (aq). What is the percent composition by mass of Al in the alloy?



Mass Percent of Al in the alloy = _____

2. In an environmental test for dissolved iodide ion in saltwater, the iodide undergoes redox chemistry in acidic solution, according to the following half-reactions:



- a) (2.5 pts) Derive a balanced redox reaction. Underline the oxidizing agent.

b) (0.5 pt) The name of the NO_3^- ion is: _____

- c) (3 pts) A 50.0 mL sample of seawater was found to react with 2.277 mL of a 0.0450 M $\text{Mg}(\text{NO}_3)_2$ solution. What was the molarity of iodide ion in the seawater sample?

Molarity = _____

3. (3 pts) Complete the following table:

Element	Mass Number	Number of protons	Number of electrons	Number of neutrons	Charge
Ba	133				+2
		17	18	18	

LAST NAME: _____

FIRST NAME: _____

Student Number: _____

CHM 1311 Midterm #1 Fall 2019

STAGE 1 – 60 min

Please keep your work covered at all times and keep your eyes on your own paper! Cheating or any appearance of cheating will result in an F in the course and possible expulsion from the university.

There are 6 pages in this test. A periodic table, data tables, and a formula sheet are provided separately. Please show your work to receive partial credit.

Cellular phones, unauthorized electronic devices or course notes (unless an open-book exam) are not allowed during this exam. Phones and devices must be turned off and put away in your bag. Do not keep them in your possession, such as in your pockets. If caught with such a device or document, the following may occur: academic fraud allegations may be filed which may result in you obtaining a 0 (zero) for the exam.

By signing below, you acknowledge that you have ensured that you are complying with the above statement.

Signature: _____

1. Short Answer Questions

- a) (0.5 pt) Four balloons are filled to the same volume with the following gases and a small hole is made in each balloon. Circle the one which will deflate the fastest and underline the one that will deflate the slowest.

Xe SO₃ O₂ CH₄

- b) (1.5 pts) The standard heat of formation of solid sodium carbonate is -1131 kJ. Write the chemical equation for the reaction to which this value applies.

- c) (0.5 pt) Which of the following corresponds to the correct chemical names for KClO₃ and H₂SO₃?

- potassium chlorate and sulfuric acid
- potassium chlorite and sulfurous acid
- potassium chlorate and sulfurous acid
- potassium chlorite and sulfuric acid

- d) (0.5 pt) A sample of a gas is slowly compressed from 8.0 L to 4.0 L. In order for the internal energy of the gas to remain constant, the gas must also be simultaneously heated.

TRUE FALSE

- e) (1 pt) The number of ions present in 250 mL of 0.00100 M CaCl₂ (aq) is:

4.52 x 10²⁰ 2.50 x 10⁻⁴ 6.02 x 10²³ 1.51 x 10²⁰

- f) (1 pt) When the power was turned off to a 125 L water heater, the temperature of the water dropped from 75.0°C to 22.5°C. The amount of heat, in kilojoules, transferred to the surroundings was: _____.

(1 pt) BONUS:

In the environment, nitrogen atoms undergo a multi-step redox process. First, bacteria transform atmospheric nitrogen gas to aqueous ammonium cation, which is then converted to nitrite. Finally, the nitrite is turned into nitrate, which is the form of nitrogen that is directly absorbed by plants.

By how many units does the oxidation state of the nitrogen atom change in this process, from start to finish? *Circle one:*

-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5

2. Complete combustion of a 1.119 g sample of an unknown gaseous compound (consisting of C, H, and S) yields 2.020 g of CO_2 , 0.689 g of H_2O , and some SO_2 .

a) (6 pts) Find the number of moles of each element in the sample.

C = _____ H = _____ S = _____

b) (0.5 pt) What is the empirical formula of the compound?

c) (3 pts) A 0.234 g sample of the gas in a 40.0 mL container has a pressure of 0.9986 bar at 300.0 K. What is the molar mass of the unknown compound?

Answer: _____

d) (0.5 pt) What is the molecular formula of the compound?

3. Your lab partner combined chloroform, CHCl_3 , and acetone, $(\text{CH}_3)_2\text{CO}$, to create a solution where the mole fraction of chloroform is 0.203. The densities of chloroform and acetone are 1.48 g/mL and 0.791 g/mL, respectively.

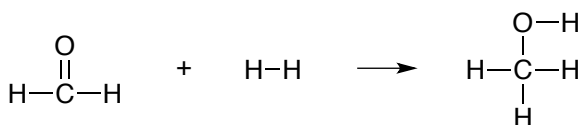
- a) (3 pts) You are given a 1.000 mol sample of the mixture. Complete the following table. You may use the space below for any needed calculations.

	CHCl_3	$(\text{CH}_3)_2\text{CO}$	Mixture
Moles			1.000
Molar mass (g/mol)	119.4	58.08	-
Mass (g)			
Density (g/mL)	1.48	0.791	-
Volume (mL)			

- b) (1 pt) Calculate the molarity of the solution.

- c) (1 pt) Calculate the molality of the solution.

4. Consider the following hydrogenation reaction, which takes place entirely in the gas phase at 600 K:



Bond	Energy (kJ)	Bond	Energy (kJ)
C-C	345	C=C	615
C-H	415	O=O	495
O-H	460	C=O	750
C-O	360	H-H	435

- a) (5 pts) Estimate the total internal energy change, in kJ, using bond energies.
- b) (2 pts) Find the quantity of work associated with this reaction at 600 K, in kJ.
- c) (1 pt) Find the enthalpy change associated with this reaction at 600 K, in kJ.
- d) (2 pts) At right, draw a representative energy diagram for this reaction. Fully label your diagram, including: ΔU , U_1 , U_2 , q , and W .

5. There are two naturally-occurring isotopes of chlorine, chlorine-35 and chlorine-37.

- a) (2 pts) Write the atomic symbols for both isotopes in the form A_ZX : _____
- b) (3 pts) If the relative natural abundance and atomic mass of chlorine-35 is 75.53% and 34.968 u respectively, what are the natural abundance and atomic mass of the other isotope, chlorine-37?

Percent Abundance: _____ Atomic Mass: _____

Question	Points Possible	Points Earned	TA Initial
1	5		
2	10		
3	5		
4	10		
5	5		
TOTAL	35		

LAST NAME: _____

FIRST NAME: _____

Student Number: _____

CHM 1311 Midterm #2 Fall 2019

STAGE 1 – 60 min

Please keep your work covered at all times and keep your eyes on your own paper! Cheating or any appearance of cheating will result in an F in the course and possible expulsion from the university.

There are 6 pages in this test. A periodic table, data tables, and a formula sheet are provided separately. Please show your work to receive partial credit.

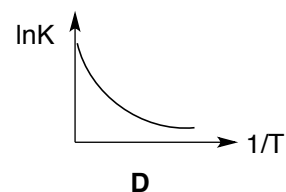
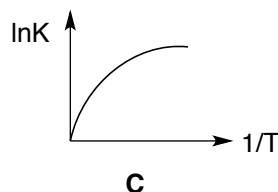
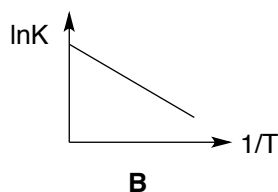
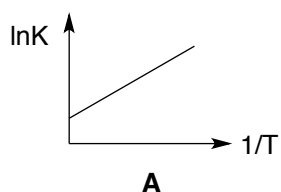
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Signature: _____

1. Short Answer Questions

- a. (1 pt) The conjugate acid and conjugate base of H_2PO_4^- are _____ and _____ respectively.
- b. (0.5 pt) Which of the following would be the correct van't Hoff plot for an endothermic reaction?



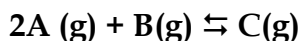
- c. (0.5 pt) Which of the following ions is the strongest base? N_3^- NO_2^- F^- HO_2^-
- d. (1 pt) Circle the two 'ingredients' you would use to prepare a buffer of pH = 7.80.



- e. (1 pt) The solubility of $\text{Co}(\text{OH})_2$ will decrease in the presence of (circle all that apply):



- f. (1 pt) Exactly 2.00 mol of A, 2.00 mol of B, and 2.00 mol of C are placed in a sealed 1.00 L flask at 600K.



$K_C = 645$ at 600 K

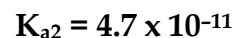
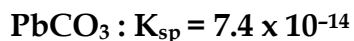
The reaction will proceed towards (circle one)

REACTANTS

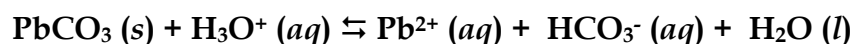
PRODUCTS

because _____

BONUS:



Calculate the equilibrium constant for the following reaction, given the data above.



2. Consider the following reaction: $2A(g) + B(g) \rightleftharpoons C(g)$

To a 2.50 L flask, A and B are added at initial pressures of 0.200 bar each. The mixture was allowed to equilibrate at 1000 K and the flask was found to contain 0.00289 mol of C.

a) (4 pts) What is the value of K_P for the reaction?

b) (1 pt) If the equilibrated gas mixture was then transferred to a container of larger volume, what would be the resulting effect on the equilibrium?

SHIFT TOWARDS REACTANTS

SHIFT TOWARDS PRODUCTS

NO EFFECT

3. A student mixes 31.0 mL of 2.74 M $\text{Pb}(\text{NO}_3)_2$ (aq) with 20.0 mL of 0.00163 M NaI (aq).

- a) (1 pt) Identify the expected precipitate: _____
- b) (8 pts) What are the values of $[\text{Pb}^{2+}]$, $[\text{Na}^+]$, $[\text{NO}_3^-]$ and $[\text{I}^-]$ after the solution has reached equilibrium at 25°C ? You may assume volumes are additive.

$[\text{Pb}^{2+}] =$ _____

$[\text{Na}^+] =$ _____

$[\text{NO}_3^-] =$ _____

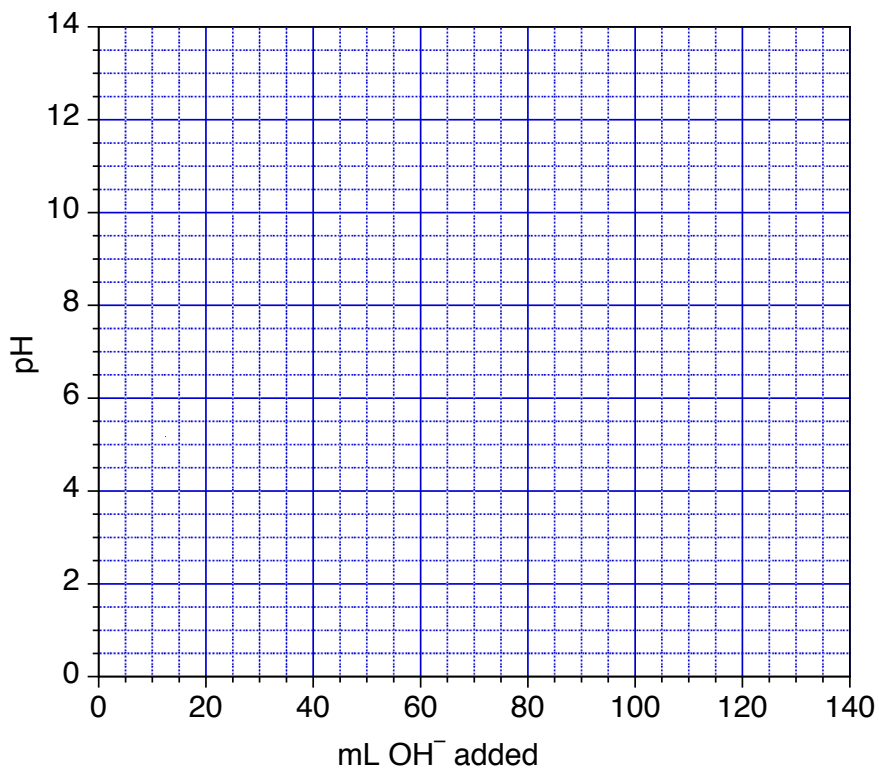
$[\text{I}^-] =$ _____

- c) (3 pts) What mass (in mg) of solid precipitate is obtained?

Answer: _____

4. You are performing a titration of 100.0 mL of 0.110 M benzoic acid with 0.110 M NaOH. Determine the pH of the solution:

- d) (3 pts) initially
- e) (1 pt) at the half-equivalence point
- f) (4 pts) at the equivalence point
- g) (1 pt) Use these values to sketch a titration curve on the graph provided.



5. (4 pts) Smudge the Cat (*see photo at right*) is displeased with his salad, because he prefers balsamic vinegar for his salad dressing. Balsamic vinegar is an aqueous solution of acetic acid. The legal minimum acetic acid content of true balsamic vinegar is 6.00% by mass. Dr. Fox takes a 5.00 mL sample of *Modeleno* brand vinegar ($d = 1.01 \text{ g/mL}$) and titrates it to completion with 39.55 mL of 0.1000 M NaOH. Does the sample exceed the legal minimum content?



Circle one: YES NO

Question	Points Possible	Points Earned	TA Initial
1	5		
2	5		
3	12		
4	9		
5	4		
TOTAL	35		

LAST name (IN CAPITAL LETTERS): _____

FIRST name: _____

Student Number: _____

Seat Number: _____

Please INITIAL HERE when you have verified that there are 17 pages in your exam copy:

CHM 1311 E

Final Exam

December 2019

Attention: If you didn't have **Dr. Focsaneanu (Fox)** as your Instructor, you shouldn't be writing this exam!

INSTRUCTIONS:

- This is a closed book exam with no notes allowed.
- Non-graphing, non-programmable calculators are allowed.
- Please show all work to receive partial credit.
- A periodic table, data tables, and a formula sheet are provided at the end. You may remove these pages off of the exam and use them to cover your work.

There are 17 pages in this exam. You have 3h to complete the exam.

Cellular phones, unauthorized electronic devices or course notes are not allowed during this exam. Phones and devices must be turned off and put away in your bag. Do not keep them in your possession, such as in your pockets. If caught with such a device or document, the following may occur: academic fraud allegations may be filed which may result in you obtaining a 0 (zero) for the exam.

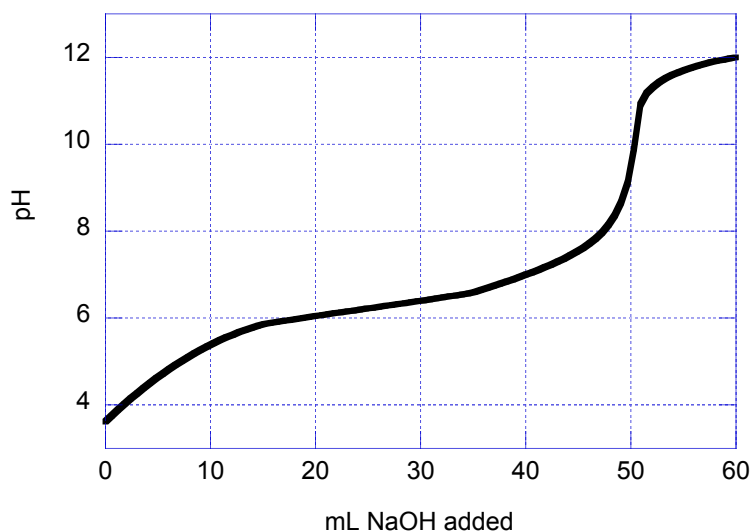
By signing below, you acknowledge that you have ensured that you are complying with the above statement.

Signature: _____

Question	Points Possible	Points Earned	TA Initial
1	20		
2	10		
3	10		
4	10		
5	10		
6	10		
7	10		
8	10		
9	10		
TOTAL	100		

h) 50.0 mL of a 0.100 M solution of a weak acid is titrated with NaOH (aq). Use the resulting titration curve shown below to answer the following:

- (1 pt) On the curve, identify the half-equivalence and equivalence points.
- (1 pt) The molarity of the NaOH (aq) used in the titration is: _____
- (1 pt) The approximate K_a of the acid is: _____
- (1 pt) Choose an appropriate indicator for the titration.



Indicator	pKa
Thymol Blue	8.9
Phenol Red	7.9
Bromocresol Green	4.7

i) (1 pt) For the compounds listed below, how many will be *more* soluble in a pH = 4.5 buffer than in pure water? NONE 1 2 3 ALL OF THEM



j) (2 pts) Give the maximum number of electrons that can have the following quantum numbers:

$$n = 2 \text{ and } l = 1$$

number of electrons = _____

$$n = 5, l = 5 \text{ and } m_l = 0$$

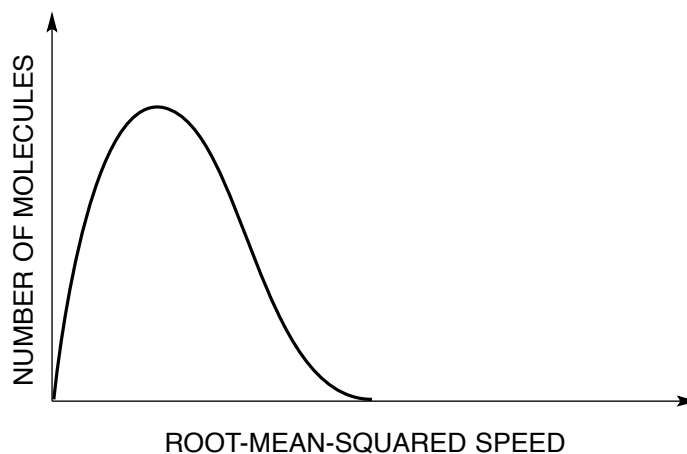
number of electrons = _____

k) (0.5 pt) Buffer capacity is the maximum amount of acid or base that can be added to a buffer without significantly changing the pH. TRUE FALSE

l) (1 pt) Decreasing the temperature of an exothermic reaction will:

- increase the yield and the rate
- increase the yield and decrease the rate
- decrease the yield and increase the rate
- decrease the yield and rate

- m) (1 pt) Below is the distribution of molecular speeds for nitrogen gas at room temperature. On the graph, sketch the expected outcome if the temperature is raised.



- n) (1 pt) An aqueous solution of sulphuric acid has a concentration of 2.45 mol/kg. The mole fraction of H_2SO_4 in this mixture is : _____.
- o) (1 pt) For an ideal gas, a graph of PV versus T will be a linear relationship with a slope that is directly proportional to the gas's:

KINETIC ENERGY

MOLAR MASS

ENTHALPY

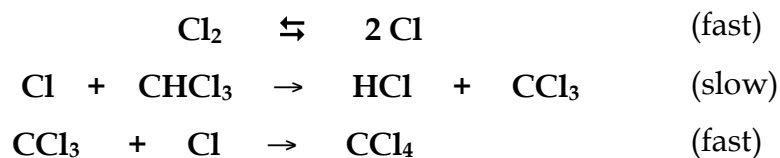
MASS

- p) (0.5 pt) Which of the following is/are a state function? ΔU ΔH q W

BONUS

In the face of so many challenging issues today (climate change, the opioid crisis, *etc.*), it is becoming increasingly apparent that society needs to place more emphasis on evidence-based decision-making, and that all scientists must play a greater role in helping to inform the public. Name a scientist you admire, and describe in one sentence how this person has inspired you.

2. Consider the following three-step mechanism:



- a) (2 pts) What is the overall reaction? Identify any reaction intermediates.
- b) (3 pts) The rate law is determined experimentally to be: $\text{rate} = k[\text{CHCl}_3][\text{Cl}_2]^{1/2}$. Is the proposed mechanism valid? Why or why not?
- c) (2 pts) When $[\text{CHCl}_3]_i = 1.05 \times 10^{-4} \text{ M}$ and $[\text{Cl}_2]_i = 2.64 \text{ M}$, the initial rate of reaction is $2.4 \times 10^{-6} \text{ M/s}$. Find the value of the rate constant, with the appropriate units.
- d) (3 pts) What will be $[\text{CHCl}_3]$ after 8.0 s using the conditions from part c)? HINT: note the relative reactant concentrations!

3. Electrons in Atoms.

- a) (3 pts) The following sets of quantum numbers are incorrect. Identify the error and give a possible set of correct quantum numbers.

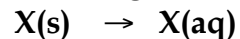
$$n = 3, \ell = 3, m_\ell = 0, m_s = +1/2$$

$$n = 4, \ell = 3, m_\ell = -4, m_s = +1/2$$

- b) (4 pts) Draw the orbital energy diagram (including labels) for Cu^+ in the space below. What is the expected magnetism of this species?

- c) (3 pts) Neils Bohr won the Nobel Prize for his development of the Bohr Model of the atom. Describe one way his model differs from the current quantum mechanical model of the atom. Why did his model only work for hydrogen?

4. A calorimeter contains 24.0 mL of water at 13.0°C. When 2.20 g of X (molar mass 47.0 g/mol) is added, it dissolves via the reaction:



and the temperature of the solution increases to 28.0°C.

a) (4 pts) Calculate the enthalpy change for the dissolution, in kJ/mol. You may assume the specific heat capacity and density of the solution are equal to those of pure water; however, you may NOT assume that the mass of the solution is equal to the mass of the water.

b) (2 pts) Calculate the internal energy change for the dissolution, in kJ/mol.

c) (4 pts) Determine the enthalpy change for the following reaction, using the provided data.



$Y(s) \rightarrow Y(aq)$	$\Delta H^\circ = +24.7 \text{ kJ}$
$2 Y(aq) \rightarrow X(aq)$	$\Delta H^\circ = -1.44 \text{ kJ}$

6. Chlorine gas can be generated by the following redox process: $\text{MnO}_2 (s) \rightarrow \text{Mn}^{2+} (aq)$
 $\text{HCl} (aq) \rightarrow \text{Cl}_2 (g)$

a) (3 pts) Find the overall balanced redox reaction, under acidic conditions.

b) (4 pts) 100.0 g of MnO_2 is allowed to react with an aqueous solution of HCl that is 45.2% HCl by mass. What is the expected amount, in moles, of chlorine gas produced in the reaction?

Answer: _____

c) (3 pts) The chlorine gas produced in part (b) is collected over water at 26.0°C , at a total gas pressure of 0.984 bar. If 18.7 L of gas is obtained, what is the percent yield of the reaction in part (b)? The vapour pressure of water at 26.0°C is 3.3639 kPa.

Answer: _____

7. You wish to determine the pH of a 0.0200 M solution of NH_4NO_2 .

a) (2 pts) The K_b of ammonia is 1.8×10^{-5} . What is the K_a value of its conjugate acid?

Answer = _____

b) (6 pts) Determine the $[\text{H}_3\text{O}^+]$ and $[\text{OH}^-]$ produced by the hydrolysis (if any) of 0.0200 M NH_4NO_2 .

$[\text{H}_3\text{O}^+] =$ _____ $[\text{OH}^-] =$ _____

c) (2 pts) Calculate the expected pH of the solution.

Answer = _____

8. Acids & Bases

- a) (5 pts) The pH of an aqueous solution of HOCl is measured to be 4.61. What was the initial concentration of HOCl, in mol/L?

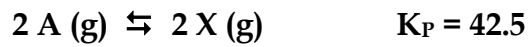
Answer: _____

For the acid-base reaction below:

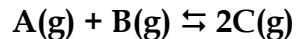


- b) (3 pts) Add the expected products and label the acid, base, conjugate acid, and conjugate base.
- c) (2 pts) Does the equilibrium favour the reactants or products? Justify your answer.

9. With the data measured at 298 K provided below,



a) (4 pts) What is the value of the equilibrium constant at 298 K for the following reaction?



Answer: _____

b) (6 pts) For the reaction in part (a), 0.500 mol each of gases A and B are added to a 2.00 L flask at 298 K. What will be the partial pressure of gas C at equilibrium?

Answer: _____

CHM1311 E

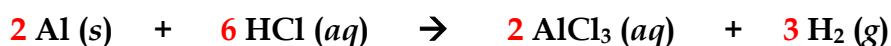
Name : _____

TWO STAGE DGD QUIZ

October 2019

STAGE 1 : INDIVIDUAL RESPONSES (30 min)

1. (6 pts) Magnesium-aluminum alloys are commonly used in aircraft construction. When treated with acid, both metals react to form hydrogen gas, as shown in the unbalanced chemical equations below. A 1.000 g sample of alloy produces 0.107 g of H_2 (g) when reacted with excess HCl (aq). What is the percent composition by mass of Al in the alloy?



Let x represent the mass of Al in the alloy.

$$m_{\text{Al}} + m_{\text{Mg}} = 1.000 \text{ g}$$

$$\therefore m_{\text{Mg}} = 1.000 - x$$

$$? \text{ g H}_2 \text{ from Al} = x \text{ g Al} \times \frac{\text{mol Al}}{26.98 \text{ g}} \times \frac{3 \text{ mol H}_2}{2 \text{ mol Al}} \times \frac{2.016 \text{ g H}_2}{\text{mol H}_2} = 0.1121x$$

$$? \text{ g H}_2 \text{ from Mg} = (1.000 - x) \text{ g Mg} \times \frac{\text{mol Mg}}{24.30 \text{ g}} \times \frac{1 \text{ mol H}_2}{1 \text{ mol Mg}} \times \frac{2.016 \text{ g H}_2}{\text{mol H}_2} = 0.0830 - 0.0830x$$

$$m_{\text{H}_2 \text{ from Al}} + m_{\text{H}_2 \text{ from Mg}} = 0.107 \text{ g}$$

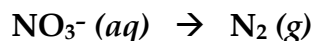
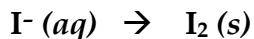
$$0.1121x + 0.0830 - 0.0830x = 0.107 \text{ g}$$

$$x = m_{\text{Al}} = 0.825 \text{ g}$$

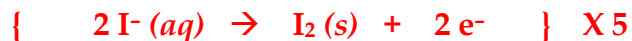
$$\therefore \% \text{Al} = \frac{0.825 \text{ g}}{1.000 \text{ g}} \times 100\% = 82.5\%$$

Mass Percent of Al in the alloy = 82.5%

2. In an environmental test for dissolved iodide ion in saltwater, the iodide undergoes redox chemistry in acidic solution, according to the following half-reactions:



- a) (2.5 pts) Derive a balanced redox reaction. Underline the oxidizing agent.



- b) (0.5 pt) The name of the NO_3^- ion is: nitrate
- c) (3 pts) A 50.0 mL sample of seawater was found to react with 2.277 mL of a 0.0450 M $\text{Mg}(\text{NO}_3)_2$ solution. What was the molarity of iodide ion in the seawater sample?

$$\begin{aligned} ? \text{ mol I}^- &= 0.002277 \text{ L} \times \frac{0.0450 \text{ mol Mg}(\text{NO}_3)_2}{\text{L}} \times \frac{2 \text{ mol NO}_3^-}{1 \text{ mol Mg}(\text{NO}_3)_2} \times \frac{10 \text{ mol I}^-}{2 \text{ mol NO}_3^-} \\ &= 0.00102 \text{ mol I}^- \\ ? \frac{\text{mol I}^-}{\text{L}} &= \frac{0.00102 \text{ mol}}{0.0500 \text{ L}} \\ &= 0.0205 \text{ M} \end{aligned}$$

$$\text{Molarity} = \underline{0.0205 \text{ mol/L}}$$

3. (3 pts) Complete the following table:

Element	Mass Number	Number of protons	Number of electrons	Number of neutrons	Charge
Ba	133	56	54	77	+2
Cl	35	17	18	18	-1

1. Short Answer Questions

- a) (0.5 pt) Four balloons are filled to the same volume with the following gases and a small hole is made in each balloon. Circle the one which will deflate the fastest and underline the one that will deflate the slowest.

Xe SO₃ O₂ CH₄

- b) (1.5 pts) The standard heat of formation of solid sodium carbonate is -1131 kJ. Write the chemical equation for the reaction to which this value applies.



- c) (0.5 pt) Which of the following corresponds to the correct chemical names for KClO₃ and H₂SO₃?

- potassium chlorate and sulfuric acid
 potassium chlorite and sulfurous acid
 potassium chlorate and sulfurous acid
 potassium chlorite and sulfuric acid

- d) (0.5 pt) A sample of a gas is slowly compressed from 8.0 L to 4.0 L. In order for the internal energy of the gas to remain constant, the gas must also be simultaneously heated.

TRUE FALSE

- e) (1 pt) The number of ions present in 250 mL of 0.00100 M CaCl₂ (aq) is:

4.52 x 10²⁰

2.50 x 10⁻⁴

6.02 x 10²³

1.51 x 10²⁰

- f) (1 pt) When the power was turned off to a 125 L water heater, the temperature of the water dropped from 75.0°C to 22.5°C. The amount of heat, in kilojoules, transferred to the surroundings was: 2.75x10⁴ kJ

(1 pt) BONUS:

In the environment, nitrogen atoms undergo a multi-step redox process. First, bacteria transform atmospheric nitrogen gas to aqueous ammonium cation, which is then converted to nitrite. Finally, the nitrite is turned into nitrate, which is the form of nitrogen that is directly absorbed by plants.

By how many units does the oxidation state of the nitrogen atom change in this process, from start to finish? Circle one:

-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5



OX STATE OF N:

0 -3 +3 +5

2. Complete combustion of a 1.119 g sample of an unknown gaseous compound (consisting of C, H, and S) yields 2.020 g of CO₂, 0.689 g of H₂O, and some SO₂.

THIS QUESTION IS FROM MIDTERM 1 2016 and 2017

a) (6 pts) Find the number of moles of each element in the sample.

$$\begin{aligned} ? \text{ mol C} &= 2.020 \text{ g CO}_2 \times \frac{\text{mol CO}_2}{44.01 \text{ g CO}_2} \times \frac{1 \text{ mol C}}{1 \text{ mol CO}_2} = 0.0460 \text{ mol C} \\ ? \text{ mol H} &= 0.689 \text{ g H}_2\text{O} \times \frac{\text{mol H}_2\text{O}}{18.02 \text{ g H}_2\text{O}} \times \frac{2 \text{ mol H}}{1 \text{ mol H}_2\text{O}} = 0.0765 \text{ mol H} \\ ? \text{ g C} &= 0.0460 \text{ mol C} \times \frac{12.011 \text{ g C}}{1 \text{ mol C}} = 0.552 \text{ g C} \\ ? \text{ g H} &= 0.0765 \text{ mol H} \times \frac{1.008 \text{ g H}}{1 \text{ mol H}} = 0.0771 \text{ g H} \\ \therefore ? \text{ g S} &= 1.119 \text{ g sample} - 0.552 \text{ g C} - 0.0771 \text{ g H} = 0.490 \text{ g S} \\ ? \text{ mol S} &= 0.490 \text{ g S} \times \frac{1 \text{ mol S}}{32.066 \text{ g S}} = 0.0153 \text{ mol S} \end{aligned}$$

$$\text{C} = \underline{0.0460 \text{ mol}} \quad \text{H} = \underline{0.0765 \text{ mol}} \quad \text{S} = \underline{0.0153 \text{ mol}}$$

b) (1 pt) What is the empirical formula of the compound?

$$\text{C}_{\frac{0.0460}{0.0153}} \text{H}_{\frac{0.0765}{0.0153}} \text{S}_{\frac{0.0153}{0.0153}} = \text{C}_3\text{H}_5\text{S}$$

c) (3 pts) A 0.234 g sample of the gas in a 40.0 mL container has a pressure of 0.9986 bar at 300.0 K. What is the molar mass of the unknown compound?

$$\begin{aligned} n &= \frac{PV}{RT} = \frac{0.9986 \text{ bar} \times 0.0400 \text{ L}}{0.083145 \text{ L} \cdot \text{atm} \cdot \text{mol}^{-1} \cdot \text{K}^{-1} \times 300.0 \text{ K}} = 0.00160 \text{ mol} \\ \therefore \text{MM} &= \frac{0.231 \text{ g}}{0.00160 \text{ mol}} = 146 \text{ g/mol} \end{aligned}$$

Answer: 146 g/mol

d) (1 pt) What is the molecular formula of the compound?

$$n = \frac{\text{MF mass}}{\text{EF mass}} = \frac{146}{73} = 2 \quad \therefore \text{C}_3\text{H}_5\text{S} \times 2 = \text{C}_6\text{H}_{10}\text{S}_2$$

3. Your lab partner combined chloroform, CHCl_3 , and acetone, $(\text{CH}_3)_2\text{CO}$, to create a solution where the mole fraction of chloroform is 0.203. The densities of chloroform and acetone are 1.48 g/mL and 0.791 g/mL, respectively.

THIS QUESTION IS FROM SAPLING ASSIGNMENT #2

a) (3 pts) You are given a 1.000 mol sample of the mixture. Complete the following table. You may use the space below for any needed calculations.

	CHCl_3	$(\text{CH}_3)_2\text{CO}$	Mixture
Moles	0.203	0.797	1.000
Molar mass (g/mol)	119.4	58.08	-
Mass (g)	24.2	46.3	70.5
Density (g/mL)	1.48	0.791	-
Volume (mL)	16.4	58.5	74.9

$$? \text{ mol CHCl}_3 = 1.000 \text{ mol mixture} \times \frac{0.203 \text{ mol CHCl}_3}{1 \text{ mol mixture}} = 0.203 \text{ mol CHCl}_3$$

$$? \text{ g CHCl}_3 = 0.203 \text{ mol CHCl}_3 \times \frac{119.4 \text{ g CHCl}_3}{\text{mol CHCl}_3} = 24.2 \text{ g CHCl}_3$$

$$? \text{ mL CHCl}_3 = 24.2 \text{ g CHCl}_3 \times \frac{\text{mL CHCl}_3}{1.48 \text{ g CHCl}_3} = 16.4 \text{ mL CHCl}_3$$

Repeat the above calculations for $(\text{CH}_3)_2\text{CO}$.

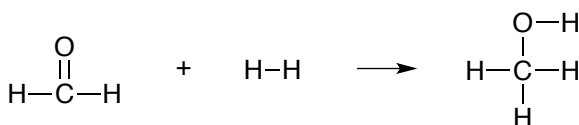
b) (1 pt) Calculate the molarity of the solution.

$$? \frac{\text{mol CHCl}_3}{\text{L solution}} = \frac{0.203 \text{ mol CHCl}_3}{74.9 \text{ mL solution}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 2.71 \text{ mol/L}$$

c) (1 pt) Calculate the molality of the solution.

$$? \frac{\text{mol CHCl}_3}{\text{kg } (\text{CH}_3)_2\text{CO}} = \frac{0.203 \text{ mol CHCl}_3}{46.3 \text{ g } (\text{CH}_3)_2\text{CO}} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 4.38 \text{ mol/kg}$$

4. Consider the following hydrogenation reaction, which takes place entirely in the gas phase at 600 K:



Bond	Energy (kJ)	Bond	Energy (kJ)
C-C	345	C=C	615
C-H	415	O=O	495
O-H	460	C=O	750
C-O	360	H-H	435

THIS QUESTION IS FROM MIDTERM 2 2016, BASED ON AN IN-CLASS QUESTION

a) (5 pts) Estimate the total internal energy change, in kJ, using bond energies.

BROKEN:

1 x C=O	1 x 750 kJ	750 kJ
1 x H-H	1 x 435 kJ	435 kJ
<hr/>		
TOTAL		+ 1185 kJ

FORMED:

1 x C-O	1 x 360 kJ	360 kJ
1 x C-H	1 x 415 kJ	415 kJ
1 x O-H	1 x 460 kJ	460 kJ
<hr/>		
TOTAL		-1235 kJ

$$\Delta U = +1185 \text{ kJ} + (-1235 \text{ kJ}) = -50 \text{ kJ}$$

b) (2 pts) Find the quantity of work associated with this reaction at 600 K, in kJ.

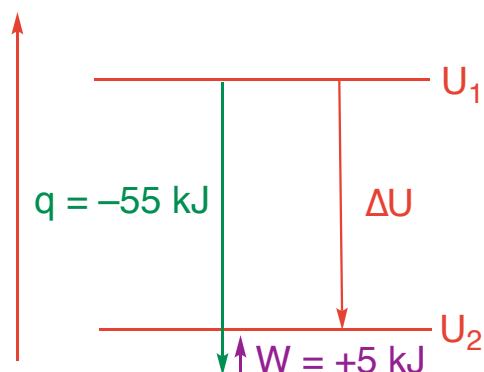
$$W = -\Delta nRT = -(-1 \text{ mol})(8.3145 \text{ J/mol} \cdot \text{K})(600 \text{ K}) = +4573 \text{ J} = +4.6 \text{ kJ}$$

c) (1 pt) Find the enthalpy change associated with this reaction at 600 K, in kJ.

$$\Delta U = q + w = \Delta H + W$$

$$\Delta H = \Delta U - W = -50 \text{ kJ} - (4.6 \text{ kJ}) = -55 \text{ kJ}$$

d) (2 pts) At right, draw a representative energy diagram for this reaction. Fully label your diagram, including: ΔU , U_1 , U_2 , q , and W .



5. There are two naturally-occurring isotopes of chlorine, chlorine-35 and chlorine-37.

THIS QUESTION IS FROM MIDTERM 1 2009, SIMILAR TO SAPLING ASSIGNMENT 1

- a) (2 pts) Write the atomic symbols for both isotopes in the form ${}^A_Z X$: ${}^{35}_{17}\text{Cl}$ ${}^{37}_{17}\text{Cl}$
- b) (3 pts) If the relative natural abundance and atomic mass of chlorine-35 is 75.53% and 34.968 u respectively, what are the natural abundance and atomic mass of the other isotope, chlorine-37?

If chlorine-35 is 75.53%, then chlorine-37 is $[100\% - 75.53\%] = 24.47\%$

Average atomic mass of chlorine is 35.4527 u (from the periodic table).

$$\begin{aligned} \text{Average atomic mass of Cl} &= [m(^{35}\text{Cl}) \times f(^{35}\text{Cl})] + [m(^{37}\text{Cl}) \times f(^{37}\text{Cl})] \\ 35.4527 \text{ u} &= [34.968 \text{ u} \times 0.7553] + [m(^{37}\text{Cl}) \times 0.2447] \\ m(^{37}\text{Cl}) &= 36.95 \text{ u} \end{aligned}$$

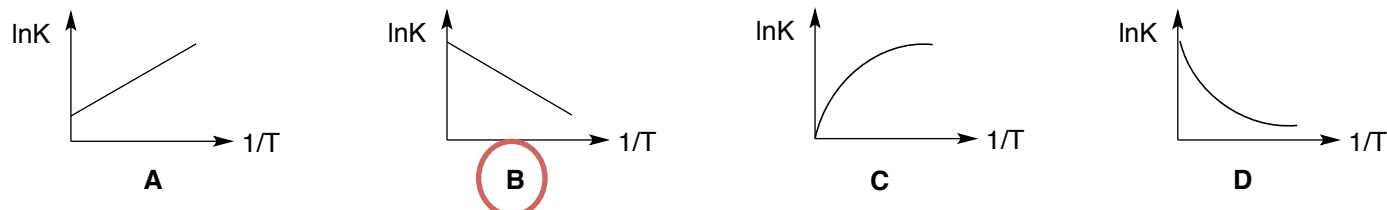
Percent Abundance: 24.47% Atomic Mass: 36.95 u

Question	Points Possible	Points Earned	TA Initial
1	5		
2	10		
3	5		
4	10		
5	5		
TOTAL	35		

1. Short Answer Questions

a. (1 pt) The conjugate acid and conjugate base of H_2PO_4^- are H_3PO_4 and HPO_4^{2-} respectively.

b. (0.5 pt) Which of the following would be the correct van't Hoff plot for an endothermic reaction?

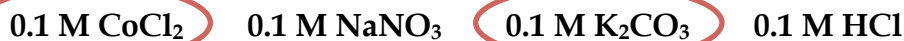


c. (0.5 pt) Which of the following ions is the strongest base? N_3^- NO_2^- F^- HO_2^-

d. (1 pt) Circle the two 'ingredients' you would use to prepare a buffer of pH = 7.80.



e. (1 pt) The solubility of $\text{Co}(\text{OH})_2$ will decrease in the presence of (circle all that apply):



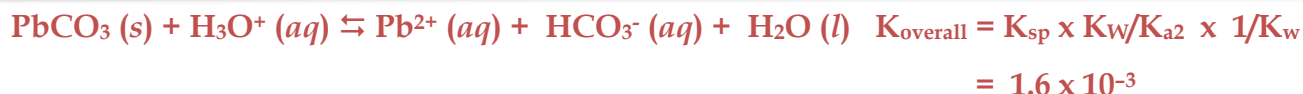
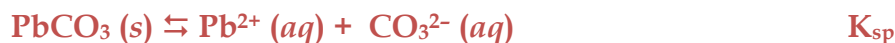
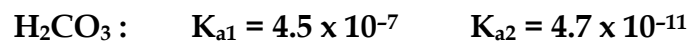
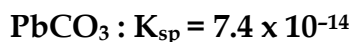
f. (1 pt) Exactly 2.00 mol of A, 2.00 mol of B, and 2.00 mol of C are placed in a sealed 1.00 L flask at 600K.



The reaction will proceed towards (circle one) REACTANTS PRODUCTS

because $Q = 0.25$, which is less than K

BONUS:



2. Consider the following reaction: $2A(g) + B(g) \rightleftharpoons C(g)$

To a 2.50 L flask, A and B are added at initial pressures of 0.200 bar each. The mixture was allowed to equilibrate at 1000 K and the flask was found to contain 0.00289 mol of C.

THIS QUESTION IS FROM MIDTERM 2 2015 AND IS SIMILAR TO AN EXAMPLE FROM CLASS

a) (4 pts) What is the value of K_P for the reaction?

$$P_C \text{ at EQM} = \frac{n_C RT}{V} = \frac{(0.00289 \text{ mol})(0.083145 \text{ L} \cdot \text{bar/mol} \cdot \text{K})(1000 \text{ K})}{2.50 \text{ L}}$$

$$= 0.0961 \text{ bar}$$

	2A(g)	+ B(g)	\rightleftharpoons	C(g)
I	0.200	0.200		0
C	-2(0.0961)	-0.0961		+0.0961
E	0.0078	0.1039		0.0961

$$K_P = \frac{P_C}{(P_A)^2 \times P_B} = \frac{0.0961}{(0.0078)^2 (0.1039)} = 1.52 \times 10^4$$

α

b) (1 pt) If the equilibrated gas mixture was then transferred to a container of larger volume, what would be the on the equilibrium?

SHIFT TOWARDS REACTANTS

SHIFT TOWARDS PRODUCTS

NO EFFECT

3. A student mixes 31.0 mL of 2.74 M $\text{Pb}(\text{NO}_3)_2$ (aq) with 20.0 mL of 0.00163 M NaI (aq).

a) (1 pt) Identify the expected precipitate: PbI_2

b) (8 pts) What are the values of $[\text{Pb}^{2+}]$, $[\text{Na}^+]$, $[\text{NO}_3^-]$ and $[\text{I}^-]$ after the solution has reached equilibrium at 25°C? You may assume volumes are additive.

$$? \text{ mol Pb}^{2+} = \frac{2.74 \text{ mol Pb}(\text{NO}_3)_2}{\text{L}} \times \frac{1 \text{ mol Pb}^{2+}}{1 \text{ mol Pb}(\text{NO}_3)_2} \times 0.0310 \text{ L} = 8.494 \times 10^{-2} \text{ mol}$$

$$? \text{ mol NO}_3^- = \frac{2.74 \text{ mol Pb}(\text{NO}_3)_2}{\text{L}} \times \frac{2 \text{ mol NO}_3^-}{1 \text{ mol Pb}(\text{NO}_3)_2} \times 0.0310 \text{ L} = 0.1699 \text{ mol}$$

$$? \text{ mol Na}^+ = \frac{0.00163 \text{ mol NaI}}{\text{L}} \times \frac{1 \text{ mol Na}^+}{1 \text{ mol NaI}} \times 0.0200 \text{ L} = 3.26 \times 10^{-5} \text{ mol}$$

$$? \text{ mol I}^- = \frac{0.00163 \text{ mol NaI}}{\text{L}} \times \frac{1 \text{ mol I}^-}{1 \text{ mol NaI}} \times 0.0200 \text{ L} = 3.26 \times 10^{-5} \text{ mol}$$

	Pb^{2+}	+	2 I^-	\rightarrow	PbI_2 (s)
B	8.494×10^{-2}				0
A			3.26×10^{-5}		
M	$-\frac{1}{2} \times (3.26 \times 10^{-5})$		-3.26×10^{-5}		$+\frac{1}{2} \times (3.26 \times 10^{-5})$
A	8.492×10^{-2}		0		1.63×10^{-5}

$$? [\text{Pb}^{2+}] = \frac{8.494 \times 10^{-2} \text{ mol}}{0.0510 \text{ L}} = 1.665 \text{ M}$$

$$? [\text{NO}_3^-] = \frac{0.1699 \text{ mol}}{0.0510 \text{ L}} = 3.33 \text{ M}$$

$$? [\text{Na}^+] = \frac{3.26 \times 10^{-5} \text{ mol}}{0.0510 \text{ L}} = 6.39 \times 10^{-4} \text{ M}$$

$$? [\text{I}^-] = \frac{0 \text{ mol}}{0.0510 \text{ L}} = 0 \text{ M}$$

	PbI_2 (s)	\rightleftharpoons	Pb^{2+}	+	2 I^-
I	$(1.63 \times 10^{-5} \text{ mol})$		1.665		0
C	$(-s)$		$+s$		$+2s$
E	$(1.63 \times 10^{-5} \text{ mol} - s)$		$1.665 + s$		$2s$

$$K_{\text{sp}} = [\text{Pb}^{2+}][\text{I}^-]^2$$

$$8.7 \times 10^{-9} = (1.665 + s)(2s)^2$$

$$8.7 \times 10^{-9} \approx (1.665)(2s)^2$$

$$s = 3.61 \times 10^{-5} \text{ mol/L}$$

$$\text{CHECK: } \frac{3.61 \times 10^{-5}}{1.665} \times 100\% = 0.002\%$$

$$[\text{Pb}^{2+}] = 1.665 \text{ M} + s$$

$$= 1.665 + 3.61 \times 10^{-5} \text{ M}$$

$$= 1.66 \text{ M}$$

$$[\text{I}^-] = 2s$$

$$= (2)(3.61 \times 10^{-5}) \text{ M}$$

$$= 7.22 \times 10^{-5} \text{ M}$$

$$[\text{Pb}^{2+}] = \underline{1.66 \text{ M}}$$

$$[\text{Na}^+] = \underline{6.39 \times 10^{-4} \text{ M}}$$

$$[\text{NO}_3^-] = \underline{3.33 \text{ M}}$$

$$[\text{I}^-] = \underline{7.22 \times 10^{-5} \text{ M}}$$

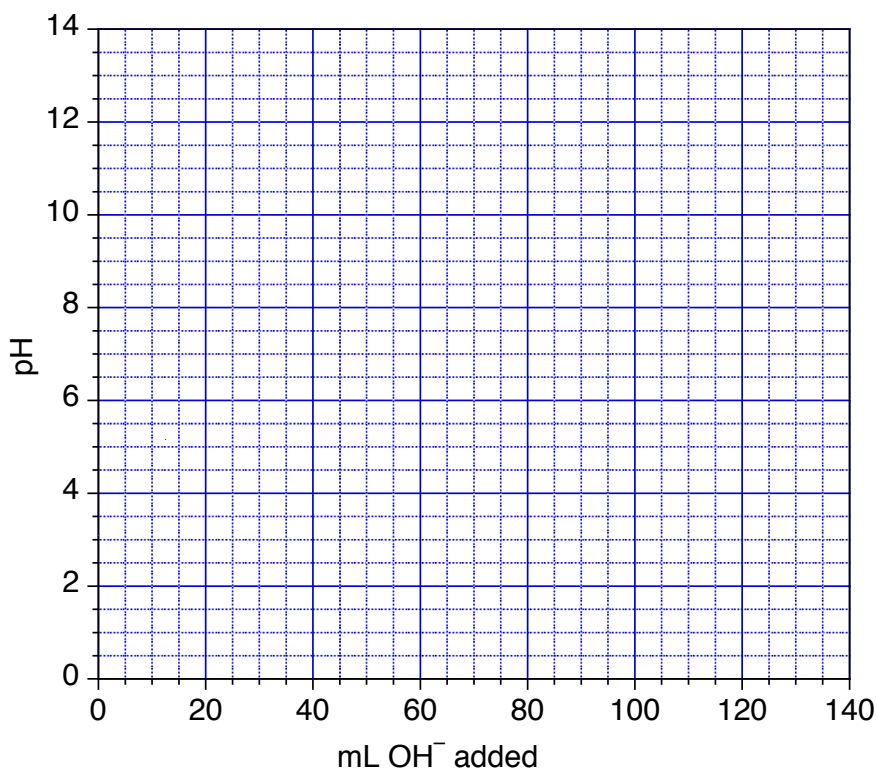
c) (3 pts) What mass (in mg) of solid precipitate is obtained?

$$\begin{aligned}\text{mol PbI}_2 \text{ that dissolves} &= \frac{3.61 \times 10^{-5} \text{ mol}}{\text{L}} \times 0.0510 \text{ L} = 1.84 \times 10^{-6} \text{ mol} \\ \therefore \text{mol PbI}_2 \text{ remaining} &= (1.63 \times 10^{-5} - 1.84 \times 10^{-6}) \text{ mol} = 1.45 \times 10^{-5} \text{ mol} \\ ? \text{ g PbI}_2 &= 1.45 \times 10^{-5} \text{ mol} \times \frac{461 \text{ g}}{\text{mol}} \times \frac{1000 \text{ mg}}{1 \text{ g}} = 6.7 \text{ mg}\end{aligned}$$

Answer: 6.7 mg

4. You are performing a titration of 100.0 mL of 0.110 M benzoic acid with 0.110 M NaOH. Determine the pH of the solution:

- d) (3 pts) initially
- e) (1 pt) at the half-equivalence point
- f) (4 pts) at the equivalence point
- g) (1 pt) Use these values to sketch a titration curve on the graph provided.



a) initial pH:

	HA	+ H ₂ O	⇌	H ₃ O ⁺	+ A ⁻
I	0.110	-		0	0
C	-x	-		+x	+x
E	0.110 - x	-		x	x

$$\text{pH} = -\log(0.0026) = 2.58$$

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{A}^-]}{[\text{HA}]}$$

$$6.3 \times 10^{-5} = \frac{x^2}{0.110 - x} \approx \frac{x^2}{0.110}$$

$$\therefore x \approx 0.0026 \text{ M} = [\text{H}_3\text{O}^+]$$

$$\text{Check: } \frac{0.0026}{0.110} \times 100\% = 2.4\% \longrightarrow \text{PASSES}$$

b) At the 1/2 equivalence point: $\text{pH} = \text{p}K_a = -\log(6.3 \times 10^{-5}) = 4.20$ (after 50 mL added)

c) At the equivalence point:

mol HA = mol OH⁻ added = 0.0110 mol (this corresponds to adding 100.0 mL of base)
 new [A⁻] = 0.0110 mol / (0.100 L + 0.100 L) = 0.0550 M

Benzoate (C₇H₅O₂⁻) is the conjugate base of a weak acid, so it hydrolyzes:

	A ⁻	+ H ₂ O	⇌	HA	+ OH ⁻
I	0.0550	-		0	0
C	-x	-		+x	+x
E	0.055 - x	-		x	x

$$\text{pOH} = -\log(5.6 \times 10^{-6}) = 5.53$$

$$\text{pH} = 14 - 5.53 = 8.47$$

$$K_b = \frac{K_w}{K_a} = \frac{[\text{HA}][\text{OH}^-]}{[\text{A}^-]}$$

$$\frac{1.0 \times 10^{-14}}{6.3 \times 10^{-5}} = 1.6 \times 10^{-10} = \frac{x^2}{0.055 - x} \approx \frac{x^2}{0.055}$$

$$\therefore x \approx 2.9 \times 10^{-6} \text{ M} = [\text{OH}^-]$$

$$\text{Check: } \frac{2.9 \times 10^{-6}}{0.055} \times 100\% = 0.005\% \longrightarrow \text{PASSES}$$

5. (4 pts) Smudge the Cat (see photo at right) is displeased with his salad, because he prefers balsamic vinegar for his salad dressing. Balsamic vinegar is an aqueous solution of acetic acid. The legal minimum acetic acid content of true balsamic vinegar is 6.00% by mass. Dr. Fox takes a 5.00 mL sample of *Modeleno* brand vinegar ($d = 1.01 \text{ g/mL}$) and titrates it to completion with 39.55 mL of 0.1000 M NaOH. Does the sample exceed the legal minimum content?



$$\text{mol CH}_3\text{COOH} = 0.03955 \text{ L NaOH} \times \frac{0.1000 \text{ mol NaOH}}{\text{L}} \times \frac{1 \text{ mol CH}_3\text{COOH}}{1 \text{ mol NaOH}} = 0.003955 \text{ mol}$$

$$? \text{ g CH}_3\text{COOH} = 0.003955 \text{ mol CH}_3\text{COOH} \times \frac{60.0 \text{ g CH}_3\text{COOH}}{\text{mol CH}_3\text{COOH}} = 0.2373 \text{ g}$$

$$? \text{ g vinegar} = 5.00 \text{ mL} \times \frac{1.01 \text{ g}}{\text{mL}} = 5.05 \text{ g}$$

$$\therefore \% \text{CH}_3\text{COOH} = \frac{0.2373 \text{ g}}{5.05 \text{ g}} \times 100\% = 4.7\%$$

Circle one: YES

NO

Question	Points Possible	Points Earned	TA Initial
1	5		
2	5		
3	12		
4	9		
5	4		
TOTAL	35		

1. Short Answer Questions.

a) (0.5 pt) 1.0 mol of oxygen gas at 300 K will have a lower root-mean-squared molecular speed than 1.0 mol of hydrogen gas at 350 K. **TRUE** FALSE

b) (2 pts) Name the following compounds:

NH_4Cl **ammonium chloride**

$\text{CuSO}_4 \cdot 2\text{H}_2\text{O}$ **copper (II) sulfate dihydrate**

c) (2 pts) Classify each of the following reaction conditions as *possible* or *impossible*.

$0 < E_a < \Delta H$

$0 = \Delta H < E_a$

$0 < \Delta H < E_a$

$\Delta H < 0 < E_a$

impossible

possible

possible

possible

d) (0.5 pt) Below is a hypothetical configuration for the ground state of a scandium atom. This configuration is incorrect because: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2$

it contains one or more orbitals that do not exist

it contains too few electrons

it contains too many electrons

it contains electrons in incorrect orbitals

it contains orbitals listed in incorrect order

e) (1 pt) You wish to recover some platinum metal that has been used as a catalyst in the lab. To be separated and purified, the solid platinum must be converted its molten form at 2041 K. Calculate, in kJ, the amount of energy required to melt 1.00 g of Pt. (ΔH_{fus} of Pt = 22.17 kJ/mol at 2041 K)

$$? \text{ kJ} = 1.00 \text{ g Pt} \times \frac{\text{mol Pt}}{195.08 \text{ g Pt}} \times \frac{22.17 \text{ kJ}}{\text{mol Pt}} = 0.114 \text{ kJ}$$

f) (1 pt) A chemist is measuring the kinetics of a reaction. In the first trial, she finds that 50% of the reactant is consumed in 164 seconds. In a second trial, the chemist doubles the concentration of the reactant and again finds 50% completion after 164 s. This indicates that the reaction is:

ZERO ORDER

FIRST ORDER

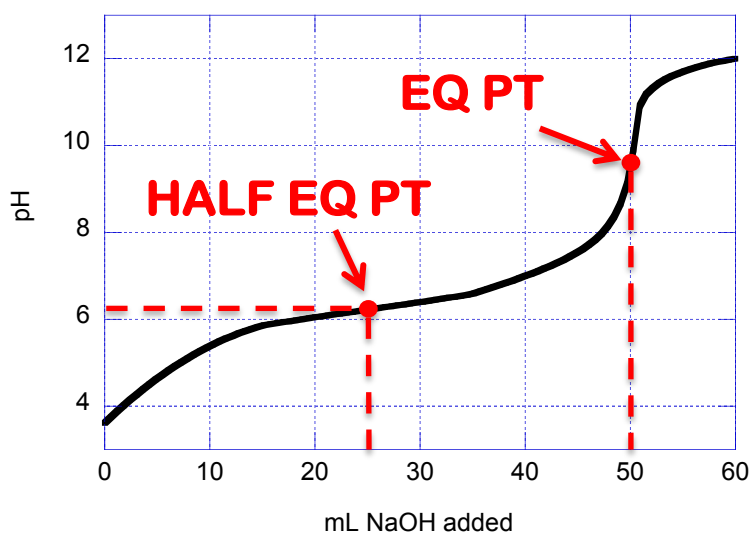
SECOND ORDER

PSEUDO-1ST ORDER

g) (1 pt) Two sets of successive reactions, $A \rightarrow B$ and $B \rightarrow C$, have respective percent yields of 48% and 73%. The overall percent yield for the conversion of A to C is: 35%.

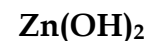
h) 50.0 mL of a 0.100 M solution of a weak acid is titrated with NaOH (aq). Use the resulting titration curve shown below to answer the following:

- (1 pt) On the curve, identify the half-equivalence and equivalence points.
- (1 pt) The molarity of the NaOH (aq) used in the titration is: 0.100 M
- (1 pt) The approximate K_a of the acid is: $10^{-6.2} = 6.3 \times 10^{-7}$
- (1 pt) Choose an appropriate indicator for the titration.



Indicator	pKa
Thymol Blue	8.9
Phenol Red	7.9
Bromocresol Green	4.7

i) (1 pt) For the compounds listed below, how many will be *more* soluble in a pH = 4.5 buffer than in pure water? NONE 1 2 **3** ALL OF THEM



j) (2 pts) Give the maximum number of electrons that can have the following quantum numbers:

$n = 2 \text{ and } l = 1$

number of electrons = 6

$n = 5, l = 5 \text{ and } m_l = 0$

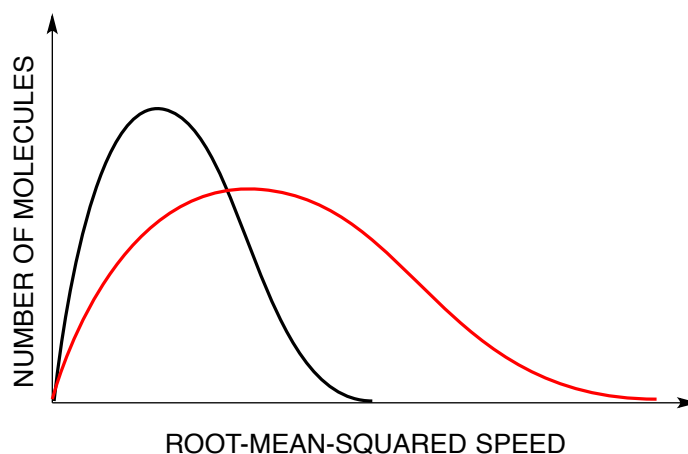
number of electrons = 0

k) (0.5 pt) Buffer capacity is the maximum amount of acid or base that can be added to a buffer without significantly changing the pH. **TRUE** FALSE

l) (1 pt) Decreasing the temperature of an exothermic reaction will:

- increase the yield and the rate
 increase the yield and decrease the rate
 decrease the yield and increase the rate
 decrease the yield and rate

m) (1 pt) Below is the distribution of molecular speeds for nitrogen gas at room temperature. On the graph, sketch the expected outcome if the temperature is raised.



n) (1 pt) An aqueous solution of sulphuric acid has a concentration of 2.45 mol/kg. The mole fraction of H_2SO_4 in this mixture is : 0.042.

o) (1 pt) For an ideal gas, a graph of PV versus T will be a linear relationship with a slope that is directly proportional to the gas's:

KINETIC ENERGY

MOLAR MASS

ENTHALPY

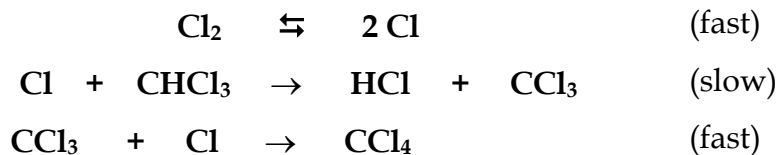
MASS

p) (0.5 pt) Which of the following is/are a state function? ΔU ΔH q W

BONUS

In the face of so many challenging issues today (climate change, the opioid crisis, *etc.*), it is becoming increasingly apparent that society needs to place more emphasis on evidence-based decision-making, and that all scientists must play a greater role in helping to inform the public. Name a scientist you admire, and describe in one sentence how this person has inspired you.

2. Consider the following three-step mechanism:



a) (2 pts) What is the overall reaction? Identify any reaction intermediates.



b) (3 pts) The rate law is determined experimentally to be: $\text{rate} = k[\text{CHCl}_3][\text{Cl}_2]^{1/2}$. Is the proposed mechanism valid? Why or why not?

Since the second step is slowest, it must be the RDS. Deriving the expected rate law gives:

$$\begin{aligned} \text{rate} &= k_2[\text{Cl}][\text{CHCl}_3] \\ k_1[\text{Cl}_2] &= k_{-1}[\text{Cl}]^2 \\ \therefore [\text{Cl}] &= \left(\frac{k_1}{k_{-1}}\right)^{1/2} [\text{Cl}_2]^{1/2} \\ \therefore \text{rate} &= \left(\frac{k_1}{k_{-1}}\right)^{1/2} k_2[\text{Cl}_2]^{1/2}[\text{CHCl}_3] = k_{\text{obs}}[\text{CHCl}_3][\text{Cl}_2]^{1/2} \end{aligned}$$

Since this matches the experimentally measured rate law, this is a valid mechanism.

c) (2 pts) When $[\text{CHCl}_3]_i = 1.05 \times 10^{-4} \text{ M}$ and $[\text{Cl}_2]_i = 2.64 \text{ M}$, the initial rate of reaction is $2.4 \times 10^{-6} \text{ M/s}$. Find the value of the rate constant, with the appropriate units.

$$\begin{aligned} \text{rate} &= k[\text{CHCl}_3][\text{Cl}_2]^{1/2} \\ \therefore k &= \frac{\text{rate}}{[\text{CHCl}_3][\text{Cl}_2]^{1/2}} = \frac{2.4 \times 10^{-6} \text{ M} \cdot \text{s}^{-1}}{(1.05 \times 10^{-4} \text{ M})(2.64 \text{ M})^{1/2}} = 0.0141 \text{ M}^{-1/2} \cdot \text{s}^{-1} \end{aligned}$$

d) (3 pts) What will be $[\text{CHCl}_3]$ after 8.0 s using the conditions from part c)? **HINT: note the relative reactant concentrations!**

Since $[\text{CHCl}_3]_i \ll \ll \ll [\text{Cl}_2]_i$, we can assume pseudo-first conditions:

$$\begin{aligned} \text{rate} &= k[\text{CHCl}_3][\text{Cl}_2]^{1/2} \\ k' &= k[\text{Cl}_2]^{1/2} = (0.0141 \text{ M}^{-1/2} \cdot \text{s}^{-1})(2.64 \text{ M})^{1/2} = 0.0229 \text{ s}^{-1} \\ \therefore \ln[\text{CHCl}_3]_t &= \ln[\text{CHCl}_3]_i - k't = \ln(1.05 \times 10^{-4} \text{ M}) - (0.0229 \text{ s}^{-1})(8.00 \text{ s}) = -9.34 \\ \therefore [\text{CHCl}_3]_t &= e^{-9.34} = 8.8 \times 10^{-5} \text{ M} \end{aligned}$$

3. Electrons in Atoms.

- a) (3 pts) The following sets of quantum numbers are incorrect. Identify the error and give a possible set of correct quantum numbers.

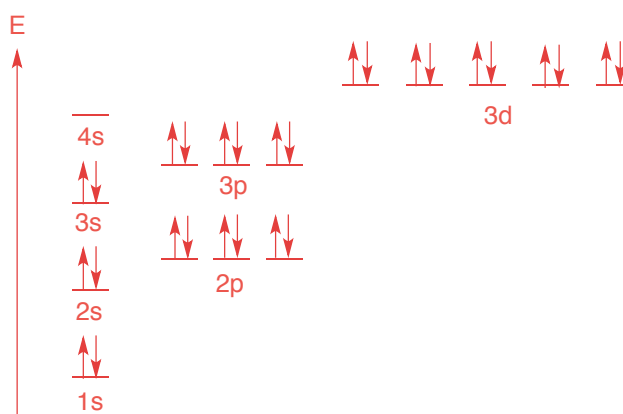
$$n = 3, l = 3, m_l = 0, m_s = +1/2$$

The allowed values of l are 0 up to $(n - 1)$. Therefore, l cannot equal 3 in this case. A possible correct set would be: $n = 3, l = 2, m_l = 0, m_s = +1/2$

$$n = 4, l = 3, m_l = -4, m_s = +1/2$$

The allowed values of m_l are $-l$ up to $+l$. Therefore, m_l cannot equal -4 in this case. A possible correct set would be: $n = 4, l = 3, m_l = -3, m_s = +1/2$

- b) (4 pts) Draw the orbital energy diagram (including labels) for Cu^+ in the space below. What is the expected magnetism of this species?



Cu^+ is DIAMAGNETIC.

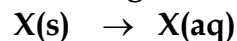
- c) (3 pts) Neils Bohr won the Nobel Prize for his development of the Bohr Model of the atom. Describe one way his model differs from the current quantum mechanical model of the atom. Why did his model only work for hydrogen?

Bohr Model: treats electrons as PARTICLES in well-defined ORBITS

Current Model: treats electrons as WAVES in 3D ORBITALS

The Bohr Model only works for hydrogen because it does not account for the electronic repulsion in polyelectronic species.

4. A calorimeter contains 24.0 mL of water at 13.0°C. When 2.20 g of X (molar mass 47.0 g/mol) is added, it dissolves via the reaction:



and the temperature of the solution increases to 28.0°C.

- a) (4 pts) Calculate the enthalpy change for the dissolution, in kJ/mol. You may assume the specific heat capacity and density of the solution are equal to those of pure water; however, you may NOT assume that the mass of the solution is equal to the mass of the water.

$$\begin{aligned}
 q_{\text{soln}} &= m_{\text{soln}} c_{\text{soln}} \Delta T_{\text{soln}} \\
 &= (2.20\text{g} + 24.0\text{g}) \left(4.184 \frac{\text{J}}{\text{g}^\circ\text{C}}\right) (28.0^\circ\text{C} - 13.0^\circ\text{C}) \\
 &= +1644 \text{ J} \\
 \therefore q_{\text{rxn}} &= -1644 \text{ J} \\
 \Delta H^\circ_{\text{rxn}} &= \frac{? \text{ kJ}}{\text{mol}} = \frac{-1644 \text{ J}}{2.20 \text{ g}} \times \frac{47.0 \text{ g}}{\text{mol}} \times \frac{1 \text{ kJ}}{1000 \text{ J}} = -35.1 \text{ kJ/mol}
 \end{aligned}$$

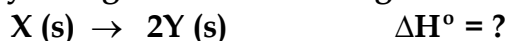
- b) (2 pts) Calculate the internal energy change for the dissolution, in kJ/mol.

$$\Delta U = q + W = \Delta H + W$$

But: there are no gases involved. Therefore $W \sim 0$ and thus:

$$\Delta U \sim \Delta H = -35.1 \text{ kJ/mol}$$

- c) (4 pts) Determine the enthalpy change for the following reaction, using the provided data.



$Y(s) \rightarrow Y(aq)$	$\Delta H^\circ = +24.7 \text{ kJ}$
$2 Y(aq) \rightarrow X(aq)$	$\Delta H^\circ = -1.44 \text{ kJ}$

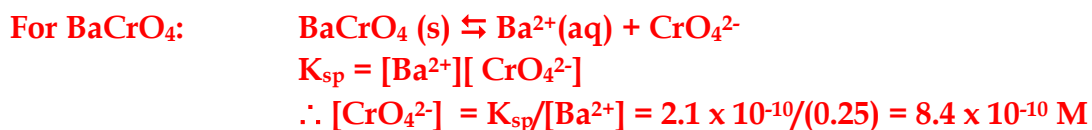
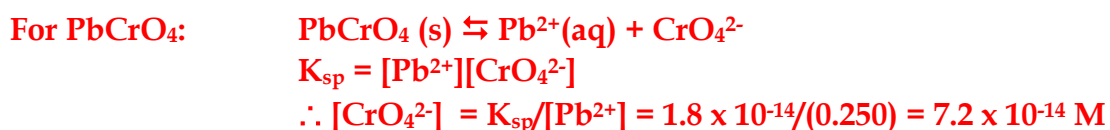
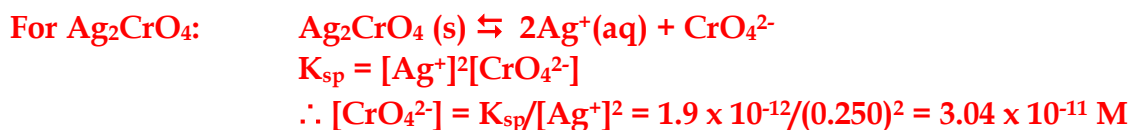
Using the value from part (a):

① (same)	$X(s) \rightarrow X(aq)$	$\Delta H^\circ = -35.1 \text{ kJ}$
③ reversed	$X(aq) \rightarrow 2 Y(aq)$	$\Delta H^\circ = +1.44 \text{ kJ}$
② reversed, x2	$2 Y(aq) \rightarrow 2 Y(s)$	$\Delta H^\circ = -49.4 \text{ kJ}$
SUM	$X(s) \rightarrow 2Y(s)$	$\Delta H^\circ = -83.2 \text{ kJ}$

5. You are given 200.0 mL of an aqueous solution that contains 0.250 M each of Ag^+ , Pb^{2+} , and Ba^{2+} . You wish to precipitate these cations sequentially by adding chromate to the solution.

a) (4 pts) In what order will the solids precipitate as chromate is added to the above solution?

What are the concentrations of CrO_4^{2-} needed to precipitate each cation? Whichever requires the least amount will precipitate first...



First = PbCrO_4

Second = Ag_2CrO_4

Third = BaCrO_4

b) (2 pts) What concentration of chromate will cause the first precipitation?

From part (a), the concentration at which precipitation of PbCrO_4 begins is $7.2 \times 10^{-14} \text{ M}$.

Answer: _____ $7.2 \times 10^{-14} \text{ M}$ _____

c) (4 pts) At the point *just before* BaCrO_4 begins to precipitate, what will be the concentration of all of the ions in solution?

BaCrO_4 begins to precipitate when $[\text{CrO}_4^{2-}] = 8.4 \times 10^{-10} \text{ M}$. At this concentration, both Ag_2CrO_4 and PbCrO_4 have precipitated. Therefore, what are the concentrations of each ion when $[\text{CrO}_4^{2-}] = 8.4 \times 10^{-10} \text{ M}$?

$[\text{Ba}^{2+}]$ 0.250 M (still not precipitated)

$[\text{Ag}^+]$ $K_{\text{sp}} = [\text{Ag}^+]^2[\text{CrO}_4^{2-}]$
 $\therefore [\text{Ag}^+] = \{K_{\text{sp}}/[\text{CrO}_4^{2-}]\}^{1/2} = \{1.9 \times 10^{-12}/(8.4 \times 10^{-10})\}^{1/2} = 0.0476 \text{ M}$

$[\text{Pb}^{2+}]$ $K_{\text{sp}} = [\text{Pb}^{2+}][\text{CrO}_4^{2-}]$
 $\therefore [\text{Pb}^{2+}] = K_{\text{sp}}/[\text{CrO}_4^{2-}] = 1.8 \times 10^{-14}/(8.4 \times 10^{-10}) = 2.14 \times 10^{-5} \text{ M}$

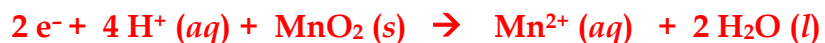
$$[\text{Ag}^+] = 0.0476 \text{ M}$$

$$[\text{Pb}^{2+}] = 2.14 \times 10^{-5} \text{ M}$$

$$[\text{Ba}^{2+}] = 0.250 \text{ M}$$

6. Chlorine gas can be generated by the following redox process: $\text{MnO}_2 (s) \rightarrow \text{Mn}^{2+} (aq)$
 $\text{HCl} (aq) \rightarrow \text{Cl}_2 (g)$

a) (3 pts) Find the overall balanced redox reaction, under acidic conditions.



b) (4 pts) 100.0 g of MnO_2 is allowed to react with an aqueous solution of HCl that is 45.2% HCl by mass. What is the expected amount, in moles, of chlorine gas produced in the reaction?

Answer: _____

c) (3 pts) The chlorine gas produced in part (b) is collected over water at 26.0°C , at a total gas pressure of 0.984 bar. If 18.7 L of gas is obtained, what is the percent yield of the reaction in part (b)? The vapour pressure of water at 26.0°C is 3.3639 kPa.

Answer: _____

7. You wish to determine the pH of a 0.0200 M solution of NH_4NO_2 .

a) (2 pts) The K_b of ammonia is 1.8×10^{-5} . What is the K_a value of its conjugate acid?

$$K_a = \frac{K_w}{K_b} = \frac{1.0 \times 10^{-14}}{1.8 \times 10^{-5}} = 5.56 \times 10^{-10}$$

Answer = _____

b) (6 pts) Determine the $[\text{H}_3\text{O}^+]$ and $[\text{OH}^-]$ produced by the hydrolysis (if any) of 0.0200 M NH_4NO_2 .

	NH_4^+	$+$	H_2O	\rightleftharpoons	H_3O^+	$+$	NH_3
I	0.0200		-		0		0
C	-x		-		+x		+x
E	0.0200 - x		-		x		x

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{NH}_3]}{[\text{NH}_4^+]}$$

$$5.56 \times 10^{-10} = \frac{x^2}{0.0200 - x} \approx \frac{x^2}{0.0200}$$

$$\therefore x \approx 3.33 \times 10^{-6} \text{ M} = [\text{H}_3\text{O}^+]$$

$$\text{Check: } \frac{3.33 \times 10^{-6}}{0.0200} \times 100\% = 0.02\% \longrightarrow \text{PASSES}$$

	NO_2^-	$+$	H_2O	\rightleftharpoons	OH^-	$+$	HNO_2
I	0.0200		-		0		0
C	-x		-		+x		+x
E	0.0200 - x		-		x		x

$$K_b = \frac{K_w}{K_a} = \frac{[\text{OH}^-][\text{HNO}_2]}{[\text{NO}_2^-]}$$

$$\frac{1.0 \times 10^{-14}}{7.2 \times 10^{-4}} = \frac{x^2}{0.0200 - x} \approx \frac{x^2}{0.0200}$$

$$\therefore x \approx 5.27 \times 10^{-7} \text{ M} = [\text{OH}^-]$$

$$\text{Check: } \frac{5.27 \times 10^{-7}}{0.0200} \times 100\% = 0.003\% \longrightarrow \text{PASSES}$$

$$[\text{H}_3\text{O}^+] = \underline{3.33 \times 10^{-6} \text{ M}} \quad [\text{OH}^-] = \underline{5.27 \times 10^{-7} \text{ M}}$$

a) (2 pts) Calculate the expected pH of the solution.

$[\text{H}_3\text{O}^+] > [\text{OH}^-]$, therefore, the excess H_3O^+ will determine the pH of the solution:

$$\text{leftover } [\text{H}_3\text{O}^+] = 3.33 \times 10^{-6} - 5.27 \times 10^{-7} = 2.80 \times 10^{-6} \text{ M}$$

$$\text{pH} = -\log(2.80 \times 10^{-6}) = 5.55$$

Answer = 5.55

8. Acids & Bases

- a) (5 pts) The pH of an aqueous solution of HOCl is measured to be 4.61. What was the initial concentration of HOCl, in mol/L?

	HOCl	+ H ₂ O	⇌	H ₃ O ⁺	+ OCl ⁻
I	[HOCl] ₀	-		0	0
C	-x	-		+x	+x
E	[HOCl] ₀ - x	-		x	x

$$[\text{H}_3\text{O}^+] = 10^{-4.61} = 2.45 \times 10^{-5} \text{ M} = x$$

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{OCl}^-]}{[\text{HOCl}]}$$

$$2.9 \times 10^{-8} = \frac{x^2}{[\text{HOCl}]_0 - x} = \frac{(2.45 \times 10^{-5})^2}{[\text{HOCl}]_0 - 2.45 \times 10^{-5}}$$

$$2.9 \times 10^{-8} [\text{HOCl}]_0 - 7.12 \times 10^{-13} = 6.00 \times 10^{-10}$$

$$\therefore [\text{HOCl}]_0 = 0.0207 \text{ M}$$

(Note: you can also solve this by making the assumption “x is small”; if you did, you’ll have to verify that assumption.)

Answer: _____

For the acid-base reaction below:



ACID

BASE

CONJ. BASE

CONJ. ACID

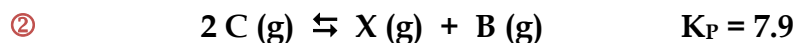
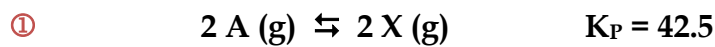
- b) (3 pts) Add the expected products and label the acid, base, conjugate acid, and conjugate base.
 c) (2 pts) Does the equilibrium favour the reactants or products? Justify your answer.

K_a of HNO₂ is 7.2×10^{-4}

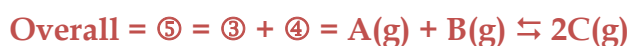
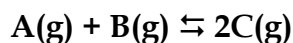
K_a of C₆H₅OH is 1.0×10^{-10}

Therefore, HNO₂ is the stronger acid (better proton donor), and the equilibrium goes LEFT to RIGHT, favouring PRODUCTS.

9. With the data measured at 298 K provided below,



a) (4 pts) What is the value of the equilibrium constant at 298 K for the following reaction?



$$K_P \textcircled{5} = K_P \textcircled{3} \times K_P \textcircled{4} = 6.52 \times 0.126 = 0.822$$

Answer: _____

b) (6 pts) For the reaction in part (a), 0.500 mol each of gases A and B are added to a 2.00 L flask at 298 K. What will be the partial pressure of gas C at equilibrium?

INITIAL PRESSURES:

$$P_A = P_B = \frac{nRT}{V} = \frac{(0.500 \text{ mol})(0.083145 \text{ L} \cdot \text{bar/mol} \cdot \text{K})(298\text{K})}{2.00 \text{ L}} = 6.19 \text{ bar}$$

	A(g)	+	B(g)	\rightleftharpoons	2C(g)
I	6.19		6.19		0
C	-x		-x		+2x
E	6.19 - x		6.19 - x		2x

$$K_P = \frac{(2x)^2}{(6.19 - x)^2}$$

$$\sqrt{K_P} = \frac{2x}{6.19 - x}$$

$$x = 1.93 \text{ bar}$$

$$P_C = 2x = 3.86 \text{ bar}$$

Answer: _____