

LAST NAME: _____

FIRST NAME: _____

Student Number: _____

CHM 1311 A Midterm #1 A Fall 2015

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 12 pages (printed both sides) in this test. A periodic table and data sheets are provided at the end. You may GENTLY remove these pages from the exam and use them to cover your work during the test. Any scratch work should be done on the back of last page.

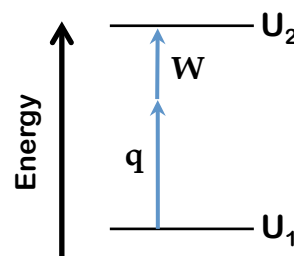
Please show your work to receive partial credit.

You have 80 minutes to complete the test.

#1. (10 points) Short Answer Questions

a) The energy change shown in the diagram at right corresponds to a(n):

- EXOTHERMIC CONTRACTION
 ENDOTHERMIC CONTRACTION
 EXOTHERMIC EXPANSION
 ENDOTHERMIC EXPANSION



b) Name the following compounds:

CuClO_3 _____

$\text{CaSO}_4 \cdot 7 \text{H}_2\text{O}$ _____

c) Starting with an atom of copper-63, we remove three protons, add one neutron, and remove 6 electrons from the atom. Fill in the blanks for our new species:

Number of protons	Number of neutrons	Number of electrons	Chemical Symbol

d) 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. SO_3 Kr O_2 CO_2

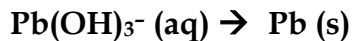
e) When the power was turned off to a 125 L water heater, the temperature of the water dropped from 75.0°C to 22.5°C . The amount of heat, in kilojoules, transferred to/from the surroundings was: _____.

f) A solution of CH_3Cl and H_2O is 45% H_2O by mass; H_2O is the solvent. TRUE FALSE

g) Toothpaste contains 0.21% m/v sodium fluoride. This concentration expressed in mol/L is: _____

BONUS: The standard heat of formation of solid ammonium chloride is -314.4 kJ . Write the chemical equation for the reaction to which this value applies (include phases).

#2. Elemental lead can be isolated from basic solutions using the following half reactions:



a) (4 pts) Determine the balanced chemical equation for the overall redox reaction.

b) (1 pt) Identify the oxidizing agent and the reducing agent in your reaction above.

c) (5 pts) 2.045 g of Fe(OH)_2 is added to 127.0 mL of a 0.0671 M aqueous basic solution of Pb(OH)_3^- and 0.813 g of solid lead is obtained. What was the yield of the redox reaction?

Answer: _____

#3. You are trying to identify an unknown gas. A 100.0 mL glass vessel weighs 45.1066 g when evacuated and 45.1267 g when filled with the gas.

- a) (5 pts) If the pressure and temperature of the gas are 49.19 mmHg and 21.05°C respectively, what is the molar mass of the gas, in g/mol?

Answer: _____

- b) (2 pts) The empirical formula of the gas is found to be CH_3 . What is the molecular formula of the gas?

Answer: _____

- c) (3 pts) The temperature of the vessel in part (a) is raised to 505.4K. In order to maintain a constant pressure, some of the gas is allowed to escape. What is the mass, in mg, of gas that escapes?

Answer: _____

#4. Dr. Fox decides to demonstrate Boyle's law while scuba diving. She takes a syringe filled with 16.0 mL of air from the surface (which is at an atmospheric pressure of 1.033 bar and a temperature of 26.78°C) with her on a dive to an unknown depth.

- a) (3 pts) During the dive, the volume of the air in the syringe drops to 7.50 mL. What is the pressure at this unknown depth, in bars?

Answer = _____

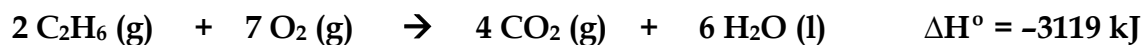
- b) (3 pts) Scuba divers are taught that pressure increases by exactly 1 bar for every 10 m of depth. What was the depth of Dr. Fox's dive, in metres?

Answer = _____

- c) (4 pts) If the mol fraction of oxygen in air is 0.218, calculate the number of moles of oxygen in the syringe.

Answer = _____

#5. For the following reaction:



a) (3 pts) How much heat, in kJ, is associated with the combustion of 10.0 g of ethane?

Answer: _____

b) (3 pts) What is the quantity of work, in kJ, evolved in the combustion of 10.0 g of ethane at 25.00°C ? (Assume an exact stoichiometric quantity of oxygen is present).

Answer: _____

c) (2 pts) Explain the significance of the *sign* of your answer in part (a) in one or two sentences.

d) (2 pts) Calculate the change in internal energy for the combustion of 10.0 g of ethane.

Answer: _____

LAST NAME: _____

FIRST NAME: _____

Student Number: _____

CHM 1311 A Midterm #2 A Fall 2015

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 12 pages in this test. A periodic table, data tables, and a formula sheet are provided at the end. You may GENTLY remove these pages and use them to cover your work. Any scratch work should be done on the back of the last page.

Please show all work to receive partial credit.

You have 80 minutes to complete the exam.

1. (10 pts) Short Answer Questions

a) For the majority of reactions, reaction rate is fastest when:

 E_a high, T low E_a high, T high E_a low, T low E_a low, T high

b) In the reaction: $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2 \text{NO}_2(\text{g})$ ($\Delta H = 57.2 \text{ kJ/mol}$), the reactant is a colourless gas and the product is a brown gas. A flask contains a mixture of these gases at equilibrium. In the box, write the equilibrium constant and choose the best means which would lead to a decrease in the observed colour.

- remove NO_2 and add heat
 add NO_2 and decrease volume
 remove N_2O_4 and add heat
 add N_2O_4 and increase volume

K =

c) For the equilibrium $\text{A}(\text{g}) \rightleftharpoons \text{B}(\text{g})$, $K_C = 10$ at 300 K. If 11 moles of A are added to a 1 L flask and it is allowed to equilibrate, at 300 K it will contain _____ mol of A and _____ mol of B.

d) For the reaction in part (c), we observe that the rate decreases as the reaction progresses and the half-life depends on the initial concentration of A. Therefore, for the reaction:

- the graph of _____ versus time will be a linear plot
- the half-life will INCREASE DECREASE as $[\text{A}]_0$ increases
- if $[\text{A}]_0$ is doubled, the initial reaction rate will change by a factor of: 2 $\frac{1}{2}$ 4 $\frac{1}{4}$

e) Predict the products of the following acid-base reaction. Is $K >$ or < 1 ?



f) 100 mL of 0.100 M acetic acid and 50 mL of 0.100 M NaOH are added together. The resulting pH of the solution would be equal to (provide value) _____.

g) For the following three hydrofluoric acid solutions, circle the one with the highest percent ionization and underline the one with the lowest pH.

0.100 M HF

0.500 M HF

0.050 M HF

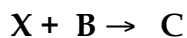
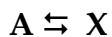
0.010 M HF

h) A buffer made from HA ($\text{pK}_a = 4.82$) and NaA has a pH of 4.25. The buffer therefore contains: $[\text{HA}] > [\text{A}^-]$ $[\text{HA}] < [\text{A}^-]$ $[\text{HA}] = [\text{A}^-]$

2. The mechanism for the gas-phase reaction described by the equation



is suggested to be:



a) (4 pts) Assuming that $[X]$ is governed by steady-state conditions, derive the rate law for the production of C in terms of $[A]$ and $[B]$, and any appropriate k values.

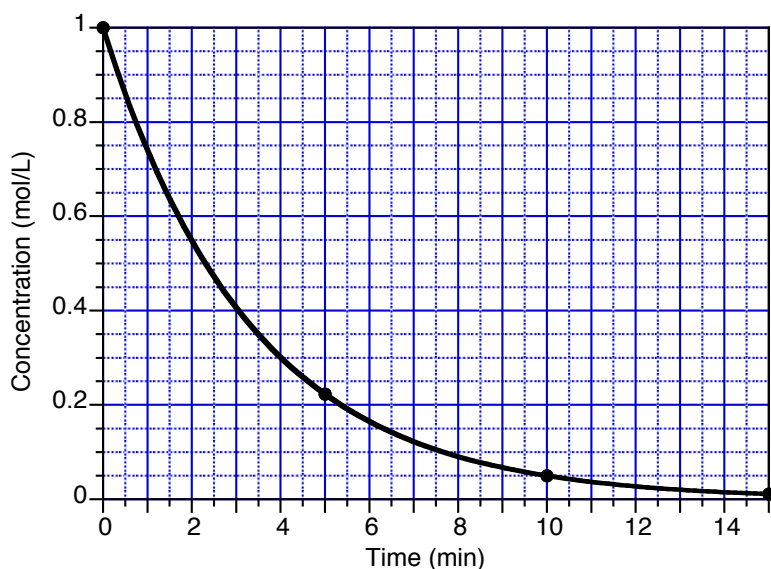
b) (1 pt) What is the expected overall order of the rate law at *very low* gas pressures?

ZERO ORDER FIRST ORDER SECOND ORDER THIRD ORDER

c) (1 pt) What is the expected overall order of the rate law at *very high* gas pressures?

ZERO ORDER FIRST ORDER SECOND ORDER THIRD ORDER

d) (4 pts) Using the graph below, calculate the initial rate *and* average rate (both in M/s) for the reaction.



3. 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) (2 pts) What is the value of K_c for the reaction?

c) (3 pts) What is the percent yield of C?

d) (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

4. Two FBI agents, Mulder and Scully, are investigating a series of strange murders. In each case, the victim was found suspended in a solution of ammonium benzoate, $\text{NH}_4\text{C}_7\text{H}_5\text{O}_2$.

a) (4 pts) Will these salt solutions be acidic, basic, or neutral? Show your reasoning to earn full points. (K_b of ammonia is 1.8×10^{-5}).

b) (6 pts) Agent Scully determines that the solution concentration is 0.166 M. What is the exact pH of the solution?

5. A buffer that contains 0.150 M HA and 0.640 M A⁻ has a pH of 8.17.

a) (4 pts) What is the pK_a of the buffer?

b) (6 pts) What is the change in pH after 0.0015 mol of Ba(OH)₂ is added to 0.500 L of this buffer solution?

BONUS - 2 pts

What are HA and A⁻? (Give their formulas). Show your reasoning to obtain the points.

Last Name: _____

First name: _____

Student Number: _____ Seat Number: _____

CHM 1311 A Final Exam December 2015

Professor: Dr. Fox

There are 16 pages in this test. A periodic table, data tables, and a formula sheet are provided at the end. You may GENTLY remove these pages and use them to cover your work. Any scratch work should be done on these pages.

Please show all work to receive part marks.

You have 180 minutes to complete the exam.

Cellular phones, unauthorized electronic devices and 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: you will be asked to leave immediately the exam, academic fraud allegations will be filed which may result in you obtaining a 0 (zero) for the exam.

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

Signature: _____

#1. (20 pts) Short Answer Questions.

a) The pK_a of fulvic acid is 5.6. This acid will be mostly

PROTONATED

DEPROTONATED

if placed in a $pH = 9$ buffer solution.

b) For the compounds listed below, how many will be *more* soluble in a $pH = 4.5$ buffer than in pure water?

PbS

CaCO₃

BaF₂

Zn(OH)₂

NONE

1

2

3

ALL OF THEM

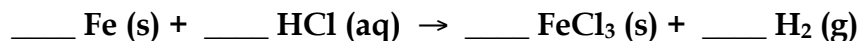
c) Name the following compounds.

NH₄NO₃

P₂O₄

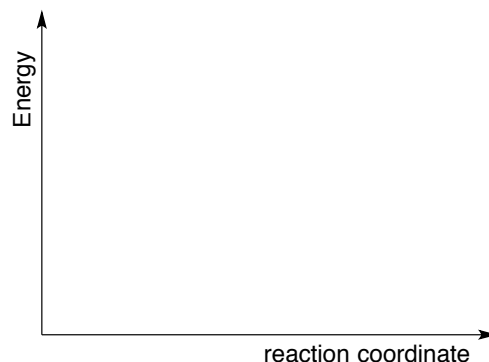
d) Which of the following ions is the strongest base? F⁻ IO₃⁻ N₃⁻ CN⁻

e) Balance the following reaction:



When 4.55 g of Fe (s) was reacted with HCl (aq), 0.101 g of H₂ (g) was formed. The percent yield of the reaction is _____.

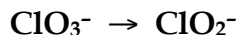
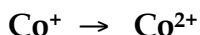
f) A chemical reaction $A + B \rightarrow C$ was determined to be a very slow reaction and slightly endothermic. On the axes provided a right, draw a representative reaction profile for this process.



g) The standard heat of formation of solid barium hydroxide is -945 kJ. Write the chemical equation for the reaction to which this value applies.

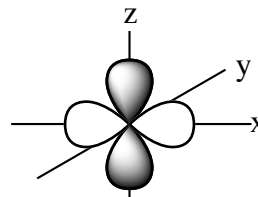
h) For a first order reaction, the half-life _____ with increasing reactant concentration. For a second order reaction, the half-life _____ with increasing reactant concentration.

i) Find the overall balanced redox reaction (acidic conditions) from these half-reactions:



OVERALL: _____

j) For the orbital shown on the 3D axes provided at right, a possible set of quantum numbers would be $n = 3$, $l = \underline{\hspace{2cm}}$, $m_l = -2$.



k) 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) Classify each of the following reaction conditions as *possible* or *impossible*.

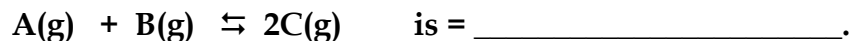
$$\Delta H < 0 < E_a$$

$$0 < \Delta H < E_a$$

$$0 < E_a < \Delta H$$

$$0 = \Delta H < E_a$$

m) Given the information below, the value of the equilibrium constant for the reaction



n) The root-mean-square-speed of xenon is 237 m/s. Which of the following gases would lose to a molecule of xenon gas in race?

O₂

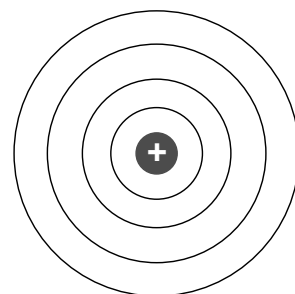
N₂

Kr

Rn

Br₂

o) On the Bohr Atom shown at right, draw an electronic transition that would correspond to the absorption of a photon with the shortest wavelength.



BONUS - Draw the full Lewis structures of the following species:



#2. Quantum Numbers

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

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

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

b) (4 pts) Draw the orbital energy diagram for Ti^{2+} 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?

#3. A 125 g stainless steel ball ($s = 0.50 \text{ J/g}^\circ\text{C}$) at 525°C is dropped into 75.0 mL of water at 28.5°C in an open Styrofoam cup. You observe the release of some steam.

a) (7 pts) Using the data on page 14, calculate the mass of the steam that escaped.

Answer: _____

b) (3 pts) A second identically-sized ball, made from a metal with a higher specific heat capacity than stainless steel, is subjected to the same conditions as part (a). Do you expect the mass of produced steam to be greater or smaller? Explain.

#4. Dr. Fox's favourite single malt scotch whisky is *Lagavulin*, which is 43% ethanol ($\text{C}_2\text{H}_5\text{OH}$) by volume. While marking exams, Dr. Fox drinks 35 mL of the scotch, of which 22% of the ethanol by mass is absorbed into her blood.

- a) (5 pts) If Dr. Fox has 6.6 L of blood, what concentration (in g/mL) of ethanol is in her blood? (d of ethanol = 0.789 g/mL)

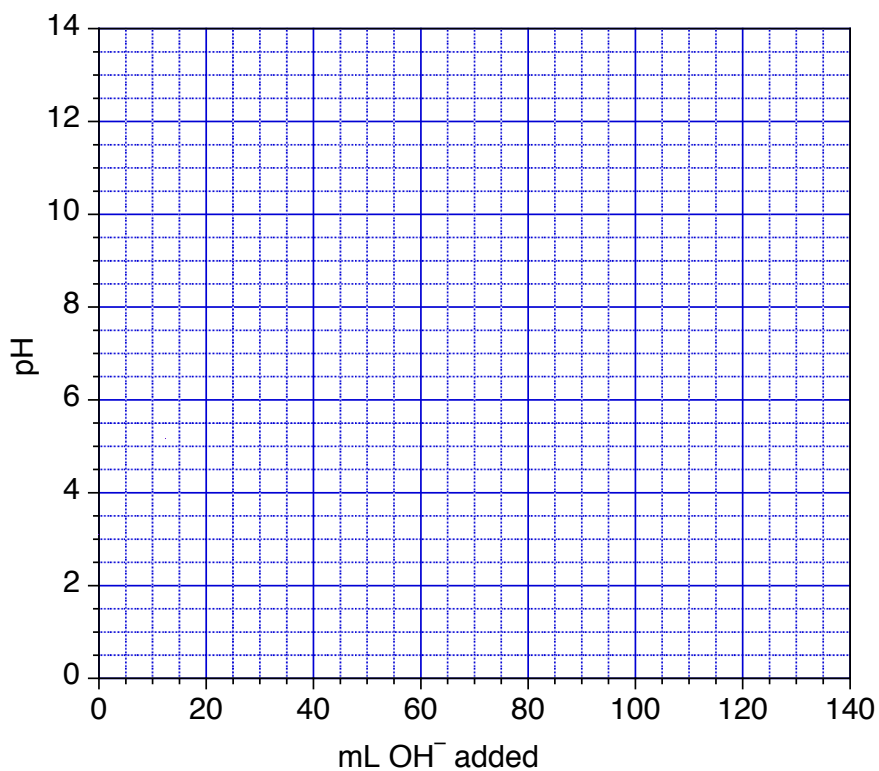
Answer: _____

- b) (5 pts) What volume (in mL) of scotch would raise Dr. Fox's blood alcohol level to 8.0×10^{-4} g/mL, the level at which she would be considered intoxicated and no longer able to mark exams?

Answer: _____

#5. You are performing a titration of 80.0 mL of 0.120 M HN_3 with 0.120 M NaOH. Determine the pH of the solution:

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



#6. A hydrocarbon fuel containing only H and C is being considered as a possible energy source.

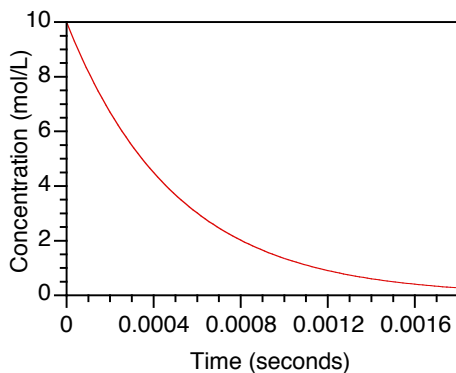
a) (4 pts) What is the molar mass of the gas if a 1.000 L flask containing 2.33 g of the gas at 25.0°C has a pressure of 600 mmHg?

Answer: _____

b) (3 pts) Elemental analysis of the fuel indicates that each molecule contains exactly 5 carbon atoms. What is the molecular formula of the fuel?

Answer: _____

c) (3 pts) The combustion of this hydrocarbon, in the presence of excess oxygen, follows *first order* kinetics, as shown in the graph below. What is the rate constant for the combustion?



Answer: _____

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

To a 2.50 L flask, A and B are added at initial pressures of 0.500 bar each. The mixture was allowed to equilibrate at 1000 K and the flask was found to contain 0.0147 mol of C.

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

b) (2 pts) What is the value of K_c for the reaction?

c) (3 pts) What is the percent yield of C?

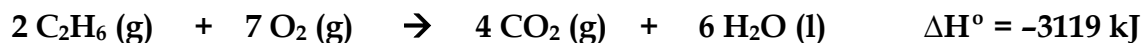
d) (1 pt) If the equilibrated gas mixture was then transferred to a container of smaller volume, what would be the resulting effect on the equilibrium?

SHIFT TOWARDS REACTANTS

SHIFT TOWARDS PRODUCTS

NO EFFECT

#8. For the following reaction:



a) (3 pts) How much heat, in kJ, is associated with the combustion of 8.50 g of ethane?

Answer: _____

b) (3 pts) What is the quantity of work, in kJ, evolved in the combustion of 8.50 g of ethane at 25.00°C ? (Assume an exact stoichiometric quantity of oxygen is present).

Answer: _____

c) (2 pts) Explain the significance of the *sign* of your answer in part (b) in one or two sentences.

d) (2 pts) Calculate the change in internal energy for the combustion of 8.50 g of ethane.

Answer: _____

#9. Wastewater resulting from metal processing is polluted with cadmium ions, Cd^{2+} , which must be removed before the water may be disposed. In one method, the water is treated with solutions of concentrated sodium hydroxide. Suppose 1.00×10^2 L of wastewater containing 1.2×10^{-5} M Cd^{2+} is treated with 1.0 L of 6.0 M NaOH solution.

a) (1 pt) What is the insoluble solid that precipitates out? _____

b) (6 pts) What is the residual concentration of aqueous cadmium ion after treatment?

Answer: _____

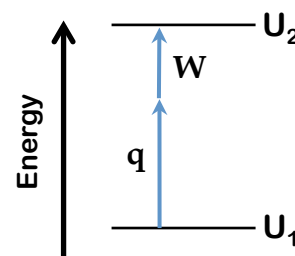
c) (3 pts) What is the mass of the solid that precipitates out?

Answer: _____

#1. (10 points) Short Answer Questions

a) The energy change shown in the diagram at right corresponds to a(n):

- EXOTHERMIC CONTRACTION
 ENDOTHERMIC CONTRACTION
 EXOTHERMIC EXPANSION
 ENDOTHERMIC EXPANSION



b) Name the following compounds:

CuClO_3 copper (I) chlorate

$\text{CaSO}_4 \cdot 7 \text{H}_2\text{O}$ calcium sulphate heptahydrate

c) Starting with an atom of copper-63, we remove three protons, add one neutron, and remove 6 electrons from the atom. Fill in the blanks for our new species:

Number of protons	Number of neutrons	Number of electrons	Chemical Symbol
26	34	23	${}^{60}_{26}\text{Fe}^{3+}$

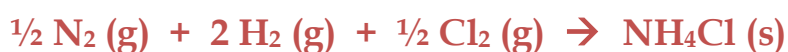
d) Four balloons are filled to the same volume with the following gases and a small hole is made in each balloon. Circle the one which will deflate the fastest and underline the one that will deflate the slowest. SO_3 Kr O_2 CO_2

e) 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/from the surroundings was: $q = mc\Delta T = -2.75 \times 10^4 \text{ kJ}$

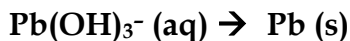
f) A solution of CH_3Cl and H_2O is 45% H_2O by mass; H_2O is the solvent. **TRUE** FALSE

g) Toothpaste contains 0.21% m/v sodium fluoride. This concentration expressed in mol/L is: 0.050 mol/L

BONUS: The standard heat of formation of solid ammonium chloride is -314.4 kJ . Write the chemical equation for the reaction to which this value applies (include phases).



#2. Elemental lead can be isolated from basic solutions using the following half reactions:



a) (4 pts) Determine the balanced chemical equation for the overall redox reaction.

THIS IS SILBERBERG SUGGESTED PROBLEM 19.16c



reducing agent

oxidizing agent

b) (1 pt) Identify the oxidizing agent and the reducing agent in your reaction above.

c) (5 pts) 2.045 g of Fe(OH)_2 is added to 127.0 mL of a 0.0671 M aqueous basic solution of Pb(OH)_3^- and 0.813 g of solid lead is obtained. What was the yield of the redox reaction?

THIS IS VERY SIMILAR TO A LECTURETOOLS QUESTION DONE IN CLASS

$$\begin{aligned} ? \text{ g Pb from Fe(OH)}_2 &= 2.045 \text{ g Fe(OH)}_2 \times \frac{\text{mol Fe(OH)}_2}{89.86 \text{ g Fe(OH)}_2} \times \frac{1 \text{ mol Pb}}{2 \text{ mol Fe(OH)}_2} \times \frac{207.2 \text{ g Pb}}{\text{mol Pb}} \\ &= 2.36 \text{ g} \end{aligned}$$

$$\begin{aligned} ? \text{ g Pb from Pb(OH)}_3^- &= 0.1270 \text{ L solution} \times \frac{0.0671 \text{ mol Pb(OH)}_3^-}{\text{L solution}} \times \frac{1 \text{ mol Pb}}{1 \text{ mol Pb(OH)}_3^-} \times \frac{207.2 \text{ g Pb}}{\text{mol Pb}} \\ &= 1.76 \text{ g} \end{aligned}$$

Therefore, Pb(OH)_3^- is the limiting reagent.

$$\% \text{ yield} = \frac{0.813 \text{ g}}{1.76 \text{ g}} \times 100\% = 46.2\%$$

Answer: _____

#3. You are trying to identify an unknown gas. A 100.0 mL glass vessel weighs 45.1066 g when evacuated and 45.1267 g when filled with the gas.

THESE QUESTIONS ARE BASED ON THE CHAPTER 4 EXAMPLES IN THE NOTES

a) (5 pts) If the pressure and temperature of the gas are 49.19 mmHg and 21.05°C respectively, what is the molar mass of the gas, in g/mol?

$$m_{\text{gas}} = 45.1267 \text{ g} - 45.1066 \text{ g} = 0.0201 \text{ g}$$

$$P = 49.10 \text{ mmHg} \times \frac{1 \text{ atm}}{760 \text{ mmHg}} = 0.06472 \text{ atm}$$

$$T = 21.05 + 273.15 = 294.2 \text{ K}$$

$$n = \frac{PV}{RT} = \frac{0.06472 \text{ atm} \times 0.1000 \text{ L}}{0.08206 \text{ L} \cdot \text{atm} \cdot \text{mol}^{-1} \cdot \text{K}^{-1} \times 294.2 \text{ K}} = 0.0002681 \text{ mol}$$

$$\therefore \text{MM} = \frac{0.0201 \text{ g}}{0.0002681 \text{ mol}} = 74.98 \text{ g/mol}$$

Answer: _____

b) (2 pts) The empirical formula of the gas is found to be CH₃. What is the molecular formula of the gas?

$$n = \frac{\text{MF mass}}{\text{EF mass}} = \frac{74.98}{15.03} = 5$$

$$\therefore \text{CH}_3 \times 5 = \text{C}_5\text{H}_{15}$$

Answer: _____

c) (3 pts) The temperature of the vessel in part (a) is raised to 505.4K. In order to maintain a constant pressure, some of the gas is allowed to escape. What is the mass, in mg, of gas that escapes?

$$m_2 = m_1 \times \frac{T_1}{T_2} = 0.0201 \text{ g} \times \frac{294.2 \text{ K}}{505.4 \text{ K}} = 0.0117 \text{ g}$$

$$\Delta m = m_1 - m_2 = 0.0201 \text{ g} - 0.0117 \text{ g} = 0.0084 \text{ g} \times \frac{1000 \text{ mg}}{1 \text{ g}} = 8.4 \text{ mg}$$

Answer: _____

#4. Dr. Fox decides to demonstrate Boyle's law while scuba diving. She takes a syringe filled with 16.0 mL of air from the surface (which is at an atmospheric pressure of 1.033 bar and a temperature of 26.78°C) with her on a dive to an unknown depth.

THIS IS A NEW QUESTION

- a) (3 pts) During the dive, the volume of the air in the syringe drops to 7.50 mL. What is the pressure at this unknown depth, in bars?

$$P_2 = P_1 \times \frac{V_1}{V_2} = 1.033 \text{ bar} \times \frac{16.0 \text{ mL}}{7.50 \text{ mL}} = 2.204 \text{ bar}$$

Answer = _____

- b) (3 pts) Scuba divers are taught that pressure increases by exactly 1 bar for every 10 m of depth. What was the depth of Dr. Fox's dive, in metres?

The pressure is already 1.033 bar at the surface. Therefore, the *increase* in pressure is:

$$\Delta P = 2.204 \text{ bar} - 1.033 \text{ bar} = 1.170 \text{ bar}$$

$$? \text{ m depth} = 1.170 \text{ bar} \times \frac{10 \text{ m}}{1 \text{ bar}} = 11.70 \text{ m}$$

Answer = _____

- c) (4 pts) If the mol fraction of oxygen in air is 0.218, calculate the number of moles of oxygen in the syringe.

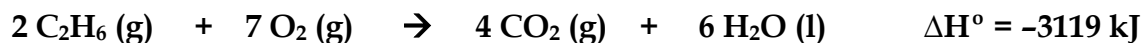
$$P_{O_2} = \chi_{O_2} \times P_T = 0.218 \times 1.033 \text{ bar} = 0.225 \text{ bar}$$

$$T = 26.78 + 273.15 = 299.93 \text{ K}$$

$$? \text{ mol } O_2 = \frac{PV}{RT} = \frac{0.225 \text{ bar} \times 0.0160 \text{ L}}{0.083145 \text{ L} \cdot \text{bar} \cdot \text{mol}^{-1} \cdot \text{K}^{-1} \times 299.93 \text{ K}} = 0.000144 \text{ mol}$$

Answer = _____

#5. For the following reaction:



THIS QUESTION IS VERY SIMILAR TO AN EXAMPLE SHOWN IN THE DGD

a) (3 pts) How much heat, in kJ, is associated with the combustion of 10.0 g of ethane?

$$\begin{aligned} ? \text{ mol C}_2\text{H}_6 &= 10.0 \text{ g} \times \frac{\text{mol}}{30.07 \text{ g}} = 0.3326 \text{ mol} \\ ? \text{ mol kJ heat} &= 0.3326 \text{ mol C}_2\text{H}_6 \times \frac{-3119 \text{ kJ}}{2 \text{ mol C}_2\text{H}_6} = -518 \text{ kJ} \end{aligned}$$

Answer: _____

b) (3 pts) What is the quantity of work, in kJ, evolved in the combustion of 10.0 g of ethane at 25.00°C? (Assume an exact stoichiometric quantity of oxygen is present).

$$\begin{aligned} ? \text{ mol O}_2 &= 0.3326 \text{ mol} \times \frac{7 \text{ mol O}_2}{2 \text{ mol C}_2\text{H}_6} = 1.164 \text{ mol} \\ ? \text{ mol CO}_2 &= 0.3326 \text{ mol} \times \frac{4 \text{ mol CO}_2}{2 \text{ mol C}_2\text{H}_6} = 0.6652 \text{ mol} \\ T &= 25.00 + 273.15 = 298.15 \text{ K} \\ W &= -\Delta n_{\text{gas}} RT = -[0.6652 - (1.164 + 0.3326) \text{ mol}] \times 8.3145 \text{ J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1} \times 298.15 \text{ K} \\ &= +2061 \text{ J} \times \frac{1 \text{ kJ}}{1000 \text{ J}} = +2.06 \text{ kJ} \end{aligned}$$

Answer: _____

c) (2 pts) Explain the significance of the *sign* of your answer in part (a) in one or two sentences.

The sign is **NEGATIVE**, indicating that heat is transferred from the system to the surroundings. This makes sense, because the reaction is **EXOTHERMIC**.

d) (2 pts) Calculate the change in internal energy for the combustion of 10.0 g of ethane.

$$\Delta U = q + W = -518 \text{ kJ} + 2.06 \text{ kJ} = -516 \text{ kJ}$$

Answer: _____

1. (10 pts) Short Answer Questions

a) For the majority of reactions, reaction rate is fastest when:

 E_a high, T low E_a high, T high E_a low, T low E_a low, T highb) In the reaction: $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2 \text{NO}_2(\text{g})$ ($\Delta H = 57.2 \text{ kJ/mol}$), the reactant is a colourless gas and the product is a brown gas. A flask contains a mixture of these gases at equilibrium. In the box, write the equilibrium constant and choose the best means which would lead to a decrease in the observed colour.

- remove NO_2 and add heat
 add NO_2 and decrease volume
 remove N_2O_4 and add heat
 add N_2O_4 and increase volume

$$K = \frac{(P_{\text{NO}_2})^2}{P_{\text{N}_2\text{O}_4}}$$

c) For the equilibrium $\text{A}(\text{g}) \rightleftharpoons \text{B}(\text{g})$, $K_C = 10$ at 300 K. If 11 moles of A are added to a 1 L flask and it is allowed to equilibrate, at 300 K it will contain 1 mol of A and 10 mol of B.

d) For the reaction in part (c), we observe that the rate decreases as the reaction progresses and the half-life depends on the initial concentration of A. Therefore, for the reaction:

Since the rate is NOT constant, we know it CAN'T be zero order – that leaves 1st or 2nd order
 1st order half life is INDEPENDENT of $[\text{A}]_0$ – therefore, this must be 2nd order

- the graph of $1/[\text{A}]$ versus time will be a linear plot
- the half-life will INCREASE DECREASE as $[\text{A}]_0$ increases $\text{half-life} = 1/(k[\text{A}]_0)$
- if $[\text{A}]_0$ is doubled, the initial reaction rate will change by a factor of: 2 $1/2$ 4 $1/4$

e) Predict the products of the following acid-base reaction. Is $K >$ or < 1 ?f) 100 mL of 0.100 M acetic acid and 50 mL of 0.100 M NaOH are added together. The resulting pH of the solution would be equal to (provide value) 4.74.

g) For the following three hydrofluoric acid solutions, circle the one with the highest percent ionization and underline the one with the lowest pH.

0.100 M HF

0.500 M HF

0.050 M HF

0.010 M HF

h) A buffer made from HA ($\text{pK}_a = 4.82$) and NaA has a pH of 4.25. The buffer therefore contains: $[\text{HA}] > [\text{A}^-]$ $[\text{HA}] < [\text{A}^-]$ $[\text{HA}] = [\text{A}^-]$

2. The mechanism for the gas-phase reaction described by the equation



is suggested to be:



THIS QUESTION WAS TAKEN FROM THE 2014 FINAL EXAM

a) (4 pts) Assuming that [X] is governed by steady-state conditions, derive the rate law for the production of C in terms of [A] and [B], and any appropriate k values.

$$\text{rate } \textcircled{2} = k_2[X][B]$$

SSA for X: rates of reactions that form X = rates of reactions that consume X

$$\text{rate } \textcircled{1} \text{ forward} = \text{rate } \textcircled{1} \text{ reverse} + \text{rate } \textcircled{2}$$

$$k_1[A] = k_{-1}[X] + k_2[X][B]$$

$$\therefore [X] = \frac{k_1[A]}{k_{-1} + k_2[B]}$$

$$\begin{aligned} \text{rate} &= k_2 \left(\frac{k_1[A]}{k_{-1} + k_2[B]} \right) [B] \\ &= \frac{k_1 k_2 [A][B]}{k_{-1} + k_2[B]} \end{aligned}$$

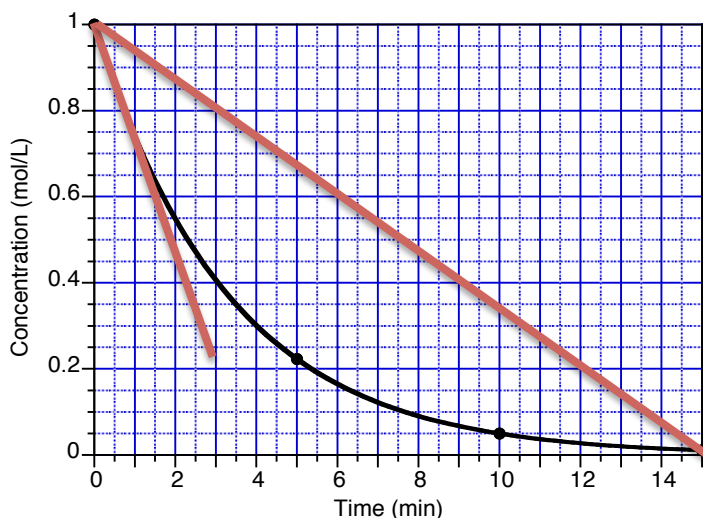
b) (1 pt) What is the expected overall order of the rate law at *very low* gas pressures?

ZERO ORDER FIRST ORDER **SECOND ORDER** THIRD ORDER

c) (1 pt) What is the expected overall order of the rate law at *very high* gas pressures?

ZERO ORDER **FIRST ORDER** SECOND ORDER THIRD ORDER

d) (4 pts) Using the graph below, calculate the initial rate *and* average rate (both in M/s) for the reaction.



Initial Rate = - slope of tangent

$$-\frac{\Delta y}{\Delta x} = -\frac{(0.65 - 1.0) \text{ M}}{(1.5 - 0) \text{ min}} \times \frac{1 \text{ min}}{60 \text{ s}} = 3.9 \times 10^{-3} \text{ M/s}$$

Average Rate = - slope of diagonal

$$-\frac{\Delta y}{\Delta x} = -\frac{(0 - 1.0) \text{ M}}{(15 - 0) \text{ min}} \times \frac{1 \text{ min}}{60 \text{ s}} = 1.1 \times 10^{-3} \text{ M/s}$$

3. 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 VERY SIMILAR TO ONE ON THE 2009 MIDTERM#2

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

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

b) (2 pts) What is the value of K_C for the reaction?

$$K_P = K_C (RT)^{\Delta n_{\text{gas}}}$$

$$K_C = \frac{K_P}{(RT)^{\Delta n_{\text{gas}}}} = \frac{1.52 \times 10^4}{(0.083145 \times 1000)^{1-3}} = 1.05 \times 10^8$$

c) (3 pts) What is the percent yield of C?

$$? \text{ theoretical } P_C \text{ from A} = 0.200 \text{ bar A} \times \frac{1 \text{ bar C}}{2 \text{ bar A}} = 0.100 \text{ bar}$$

$$? \text{ theoretical } P_C \text{ from B} = 0.200 \text{ bar B} \times \frac{1 \text{ bar C}}{1 \text{ bar B}} = 0.200 \text{ bar}$$

Therefore, A is the LIMITING REAGENT.

$$\% \text{ yield} = \frac{0.0961 \text{ bar}}{0.100 \text{ bar}} \times 100\% = 96.1\%$$

d) (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

4. Two FBI agents, Mulder and Scully, are investigating a series of strange murders. In each case, the victim was found suspended in a solution of ammonium benzoate, $\text{NH}_4\text{C}_7\text{H}_5\text{O}_2$.

THIS QUESTION IS NEARLY IDENTICAL TO A QUESTION FROM THE 2014 MIDTERM#2

a) (4 pts) Will these salt solutions be acidic, basic, or neutral? Show your reasoning to earn full points. (K_b of ammonia is 1.8×10^{-5}).

Dissolution of the salt: $\text{NH}_4\text{C}_7\text{H}_5\text{O}_2 (\text{s}) \rightarrow \text{NH}_4^+ (\text{aq}) + \text{C}_7\text{H}_5\text{O}_2^- (\text{aq})$

Both ions will hydrolyze, so which one hydrolyzes more?

$\text{NH}_4^+ + \text{H}_2\text{O} \rightleftharpoons \text{NH}_3 + \text{H}_3\text{O}^+$	$K_a = \frac{K_w}{K_b} = \frac{1.0 \times 10^{-14}}{1.8 \times 10^{-5}} = 5.56 \times 10^{-10}$
$\text{C}_7\text{H}_5\text{O}_2^- + \text{H}_2\text{O} \rightleftharpoons \text{HC}_7\text{H}_5\text{O}_2 + \text{OH}^-$	$K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{6.3 \times 10^{-5}} = 1.59 \times 10^{-10}$

Since $K_a > K_b$, we know that the first equilibrium favours the products more. Therefore, the solution should be ACIDIC.

b) (6 pts) Agent Scully determines that the solution concentration is 0.166 M. What is the exact pH of the solution?

	NH_4^+	H_2O	\rightleftharpoons	H_3O^+	$+$	NH_3
I	0.166	-		0		0
C	-x	-		+x		+x
E	0.166 - x	-		x		x

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

$$5.56 \times 10^{-10} = \frac{x^2}{0.166 - x} \approx \frac{x^2}{0.166}$$

$$\therefore x \approx 9.61 \times 10^{-6} \text{ M} = [\text{H}_3\text{O}^+]$$

$$\text{Check: } \frac{9.61 \times 10^{-6}}{0.166} \times 100\% = 0.006\% \longrightarrow \text{PASSES}$$

	$\text{C}_7\text{H}_5\text{O}_2^-$	H_2O	\rightleftharpoons	$\text{HC}_7\text{H}_5\text{O}_2$	$+$	OH^-
I	0.166	-		0		0
C	-x	-		+x		+x
E	0.166 - x	-		x		x

$$K_b = \frac{K_w}{K_a} = \frac{[\text{OH}^-][\text{HC}_7\text{H}_5\text{O}_2]}{[\text{C}_7\text{H}_5\text{O}_2^-]}$$

$$1.59 \times 10^{-10} = \frac{x^2}{0.166 - x} \approx \frac{x^2}{0.166}$$

$$\therefore x \approx 5.14 \times 10^{-6} \text{ M} = [\text{OH}^-]$$

$$\text{Check: } \frac{5.14 \times 10^{-6}}{0.166} \times 100\% = 0.003\% \longrightarrow \text{PASSES}$$

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

$$\text{leftover } [\text{H}_3\text{O}^+] = 9.61 \times 10^{-6} - 5.14 \times 10^{-6} = 4.47 \times 10^{-6} \text{ M}$$

$$\text{pH} = -\log(2.80 \times 10^{-6}) = 5.35$$

5. A buffer that contains 0.150 M HA and 0.640 M A⁻ has a pH of 8.17.

THIS IS A NEW QUESTION, BUT SIMILAR TO MANY EXAMPLES SEEN ALREADY

a) (4 pts) What is the pK_a of the buffer?

$$\text{pH} = \text{pK}_a + \log\left(\frac{[\text{A}^-]}{[\text{HA}]}\right)$$

$$8.17 = \text{pK}_a + \log\left(\frac{0.640}{0.150}\right)$$

$$\text{pK}_a = 7.54$$

b) (6 pts) What is the change in pH after 0.0015 mol of Ba(OH)₂ is added to 0.500 L of this buffer solution?

$$? \frac{\text{mol OH}^-}{\text{L}} \text{ added} = \frac{0.0015 \text{ mol Ba(OH)}_2}{0.500 \text{ L}} \times \frac{2 \text{ mol OH}^-}{1 \text{ mol Ba(OH)}_2} = 0.0060 \text{ M}$$

	HA	+ OH ⁻	⇌	A ⁻	+ H ₂ O
B	0.150			0.640	-
A		0.0060			-
M	-0.0060	-0.0060		+0.0060	-
A	0.144	0		0.646	-

$$\text{pH} = \text{pK}_a + \log\left(\frac{[\text{A}^-]}{[\text{HA}]}\right) = 7.54 + \log\left(\frac{0.646}{0.144}\right) = 8.19$$

$$\therefore \Delta\text{pH} = \text{pH}_2 - \text{pH}_1 = 8.19 - 8.17 = +0.02$$

BONUS - 2 pts

What are HA and A⁻? (Give their formulas). Show your reasoning to obtain the points.

Since pK_a = 7.54, K_a = 10^{-7.54} = 2.9 × 10⁻⁸

From the K_a table in the data sheets, we see that this corresponds to HOCl.

Therefore, HA and A⁻ are HOCl and OCl⁻, respectively.

#1. (20 pts) Short Answer Questions.

a) The pK_a of fulvic acid is 5.6. This acid will be mostly

PROTONATED

DEPROTONATED

if placed in a $pH = 4$ buffer solution.

b) For the compounds listed below, how many will be *less* soluble in a $pH = 4.5$ buffer than in pure water?

NONE

1

2

3

ALL OF THEM

PbS

CaCO₃

BaF₂

Zn(OH)₂

c) Name the following compounds.

NH₄NO₃

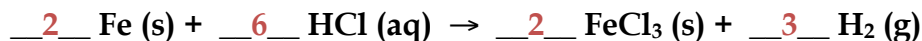
ammonium nitrate

P₂O₄

diphosphorus tetroxide

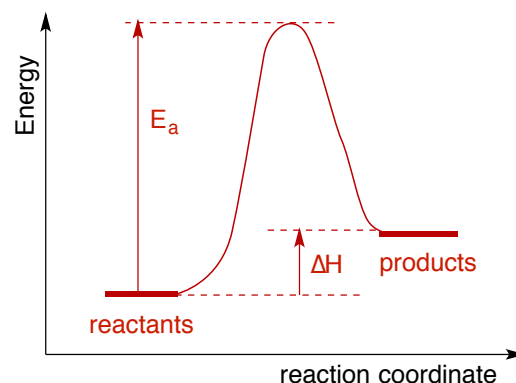
d) Which of the following ions is the strongest base? F⁻ IO₃⁻ N₃⁻ CN⁻

e) Balance the following reaction:



When 4.55 g of Fe (s) was reacted with HCl (aq), 0.101 g of H₂ (g) was formed. The percent yield of the reaction is 41.6%.

f) A chemical reaction $A + B \rightarrow C$ was determined to be a very slow reaction and slightly endothermic. On the axes provided a right, draw a representative reaction profile for this process.

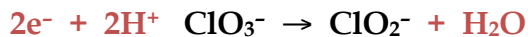


g) The standard heat of formation of solid barium hydroxide is -945 kJ. Write the chemical equation for the reaction to which this value applies.

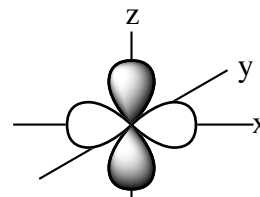


h) For a first order reaction, the half-life does not change with increasing reactant concentration. For a second order reaction, the half-life decreases with increasing reactant concentration.

i) Find the overall balanced redox reaction (acidic conditions) from these half-reactions:



j) For the orbital shown on the 3D axes provided at right, a possible set of quantum numbers would be $n = 3, \ell = \underline{2}, m_\ell = -2$.



k) 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) Classify each of the following reaction conditions as *possible* or *impossible*.

$$\Delta H < 0 < E_a$$

possible

$$0 < \Delta H < E_a$$

possible

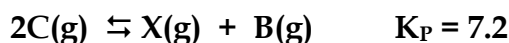
$$0 < E_a < \Delta H$$

impossible

$$0 = \Delta H < E_a$$

possible

m) Given the information below, the value of the equilibrium constant for the reaction



n) The root-mean-square-speed of xenon is 237 m/s. Which of the following gases would lose to a molecule of xenon gas in race?

O_2

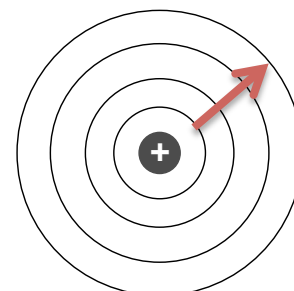
N_2

Kr

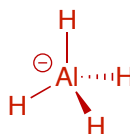
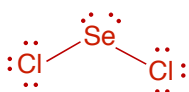
Rn

Br_2

o) On the Bohr Atom shown at right, draw an electronic transition that would correspond to the absorption of a photon with the shortest wavelength.



BONUS - Draw the full Lewis structures of the following species:



#2. Quantum Numbers

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

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

Error: n cannot equal zero (n starts with 1, 2, 3...)

Corrected set: $n = 1, l = 0, m_l = 0, m_s = +1/2$

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

Error: ℓ cannot equal three ($\ell = 0$ to $n - 1$)

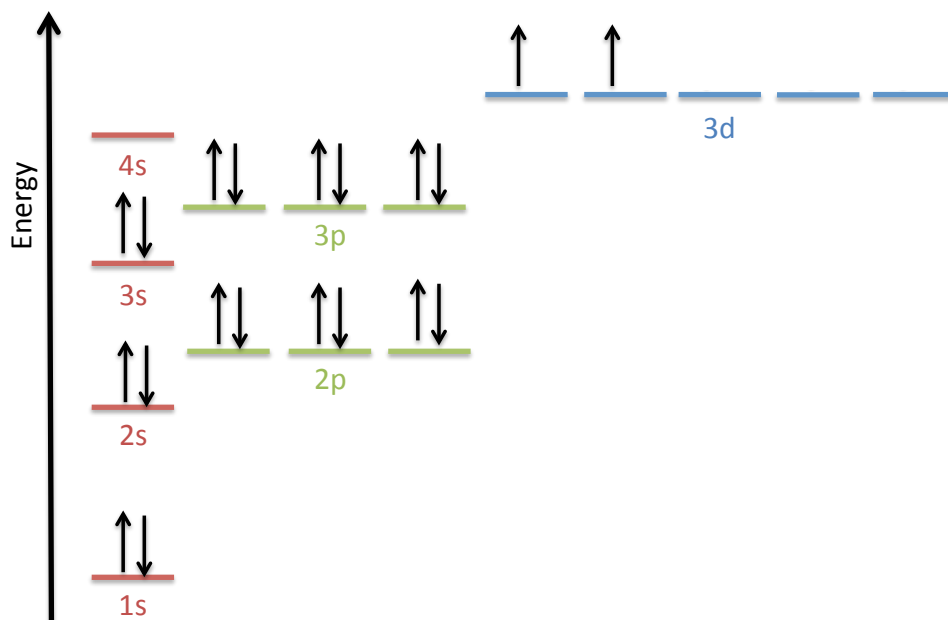
Corrected set: $n = 1, l = 0, m_l = 0, m_s = +1/2$

b) (4 pts) Draw the orbital energy diagram for Ti^{2+} in the space below. What is the expected magnetism of this species?

Ti (neutral atom) = $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2$

Fe^{3+} (ion) = $1s^2 2s^2 2p^6 3s^2 3p^6 4s^0 3d^5$

Since this ion has unpaired electrons, it is PARAMAGNETIC.



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.

#3. A 125 g stainless steel ball ($s = 0.50 \text{ J/g}^\circ\text{C}$) at 525°C is dropped into 75.0 mL of water at 28.5°C in an open Styrofoam cup. You observe the release of some steam.

a) (7 pts) Using the data on page 15, calculate the mass of the steam that escaped.

$$\begin{aligned}
 q_{ball} &= m_{ball} \times s_{ball} \times \Delta T_{ball} \\
 &= (125 \text{ g})(0.50 \text{ J/g}^\circ\text{C})(100^\circ\text{C} - 525^\circ\text{C}) \\
 &= -2.656 \times 10^4 \text{ J} \\
 \therefore \text{heat absorbed by water} &= q_{H_2O} = +2.656 \times 10^4 \text{ J}
 \end{aligned}$$

Let's define: q_1 = heat needed to raise temp of water to 100°C
 q_2 = heat needed to boil water at 100°C

Thus $q_{H_2O} = q_1 + q_2$

$$\begin{aligned}
 q_1 &= m_{H_2O} \times s_{H_2O} \times \Delta T_{H_2O} \\
 &= (75.0 \text{ g})(4.185 \text{ J/g}^\circ\text{C})(100^\circ\text{C} - 28.5^\circ\text{C}) \\
 &= +2.244 \times 10^4 \text{ J} \\
 q_2 &= q_{H_2O} - q_1 = 2.656 \times 10^4 \text{ J} - 2.244 \times 10^4 \text{ J} \\
 &= 4120 \text{ J} \\
 ? \text{ g steam} &= 4120 \text{ J} \times \frac{\text{mol } H_2O}{40.7 \times 10^3 \text{ J}} \times \frac{18.02 \text{ g } H_2O}{\text{mol } H_2O} \\
 &= 1.8 \text{ g}
 \end{aligned}$$

Answer: _____

b) (3 pts) A second identically-sized ball, made from a metal with a higher specific heat capacity than stainless steel, is subjected to the same conditions as part (a). Do you expect the mass of produced steam to be greater or smaller? Explain.

If s is higher, then the amount of heat released by the ball is larger. Thus the heat absorbed by the water is greater. Since the amount of heat needed to raise the temperature of the water is unchanged (q_1 is the same), that means more heat is leftover to boil the water (q_2 is larger). Therefore more steam will be produced.

#4. Dr. Fox's favourite single malt scotch whisky is *Lagavulin*, which is 43% ethanol (C_2H_5OH) by volume. While marking exams, Dr. Fox drinks 35 mL of the scotch, of which 22% of the ethanol by mass is absorbed into her blood.

- a) (5 pts) If Dr. Fox has 6.6 L of blood, what concentration (in g/mL) of ethanol is in her blood? (d of ethanol = 0.789 g/mL)

Let "EtOH" represent ethanol.

$$\begin{aligned} ? \text{ g EtOH absorbed} &= 35 \text{ mL scotch} \times \frac{43 \text{ mL EtOH}}{100 \text{ mL scotch}} \times \frac{0.789 \text{ g EtOH}}{\text{mL EtOH}} \times \frac{22 \text{ g EtOH absorbed}}{100 \text{ g EtOH consumed}} \\ &= 2.61 \text{ g} \\ \frac{? \text{ g EtOH absorbed}}{\text{mL blood}} &= \frac{2.61 \text{ g EtOH absorbed}}{6.6 \text{ L blood}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \\ &= 3.96 \times 10^{-4} \text{ g/mL} \end{aligned}$$

Answer: _____

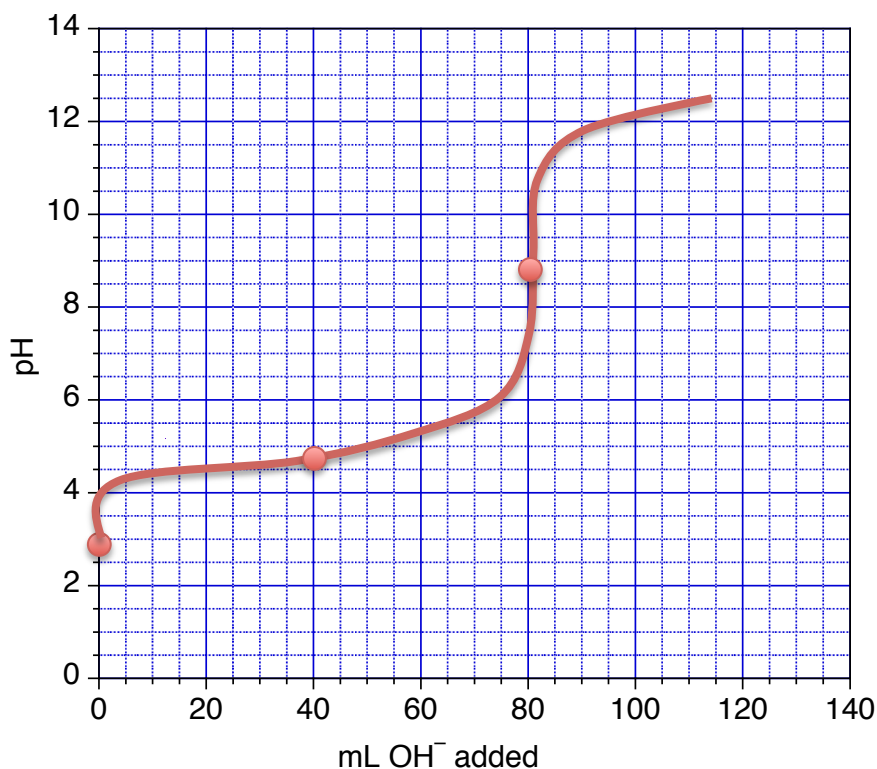
- b) (5 pts) How many mL of scotch (in total) will Dr. Fox need to drink to raise her blood alcohol level to 8.0×10^{-4} g/mL, the level at which she would be considered intoxicated and no longer able to mark exams?

$$\begin{aligned} ? \text{ g EtOH absorbed} &= 6.6 \text{ L blood} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{8.0 \times 10^{-4} \text{ g EtOH absorbed}}{\text{mL blood}} \\ &= 5.28 \text{ g} \\ ? \text{ mL scotch} &= 5.28 \text{ g EtOH absorbed} \times \frac{100 \text{ g EtOH consumed}}{22 \text{ g EtOH absorbed}} \times \frac{\text{mL EtOH}}{0.789 \text{ g EtOH}} \times \frac{100 \text{ mL scotch}}{43 \text{ mL EtOH}} \\ &= 70.7 \text{ mL scotch} \end{aligned}$$

Answer: _____

#5. You are performing a titration of 80.0 mL of 0.120 M HN_3 with 0.120 M NaOH . Determine the pH of the solution:

- (3 pts) initially
- (2 pts) at the half-equivalence point
- (4 pts) at the equivalence point
- (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	0.120	-		0	0
C	-x	-		+x	+x
E	0.120 - x	-		x	x

$$\text{pH} = -\log(0.00151) = 2.82$$

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

$$1.9 \times 10^{-5} = \frac{x^2}{0.120 - x} \approx \frac{x^2}{0.120}$$

$$\therefore x \approx 0.00151 \text{ M} = [\text{H}_3\text{O}^+]$$

$$\text{Check: } \frac{0.00151}{0.120} \times 100\% = 0.04\% \longrightarrow \text{PASSES}$$

b) At the $\frac{1}{2}$ equivalence point: $\text{pH} = \text{p}K_a = -\log(1.9 \times 10^{-5}) = 4.72$ (after 40 mL added)

c) At the equivalence point:

mol HA = mol OH^- added = 0.0096 mol (this corresponds to adding 80.0 mL of base)
 new $[\text{A}^-] = 0.0096 \text{ mol} / (0.080 \text{ L} + 0.080 \text{ L}) = 0.060 \text{ M}$

Azide (N_3^-) is the conjugate base of a weak acid, so it hydrolyzes:

	A ⁻	+ H ₂ O	⇌	HA	+ OH ⁻
I	0.060	-		0	0
C	-x	-		+x	+x
E	0.060 - x	-		x	x

$$\text{pOH} = -\log(5.6 \times 10^{-6}) = 5.25$$

$$\text{pH} = 14 - 5.25 = 8.75$$

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

$$\frac{1.0 \times 10^{-14}}{1.9 \times 10^{-5}} = 5.2 \times 10^{-10} = \frac{x^2}{0.060 - x} \approx \frac{x^2}{0.060}$$

$$\therefore x \approx 5.6 \times 10^{-6} \text{ M} = [\text{OH}^-]$$

$$\text{Check: } \frac{5.6 \times 10^{-6}}{0.060} \times 100\% = 0.2\% \longrightarrow \text{PASSES}$$

#6. A hydrocarbon fuel containing only H and C is being considered as a possible energy source.

a) (4 pts) What is the molar mass of the gas if a 1.000 L flask containing 2.33 g of the gas at 25.0°C has a pressure of 600 mmHg?

Combining:

$$PV = nRT \quad \text{and} \quad n = m/MW$$

Gives:

$$MW = \frac{mRT}{PV} = \frac{2.33 \text{ g} \times 0.08206 \text{ L} \cdot \text{atm} / \text{mol} \cdot \text{K} \times 298 \text{ K}}{0.790 \text{ atm} \times 1.00 \text{ L}}$$

$$= 72.12 \text{ g/mol}$$

Answer: _____

b) (3 pts) Elemental analysis of the fuel indicates that each molecule contains exactly 5 carbon atoms. What is the molecular formula of the fuel?

$$5 \text{ carbons} = 5 \times 12.011 \text{ g/mol} = 60.055 \text{ g/mol}$$

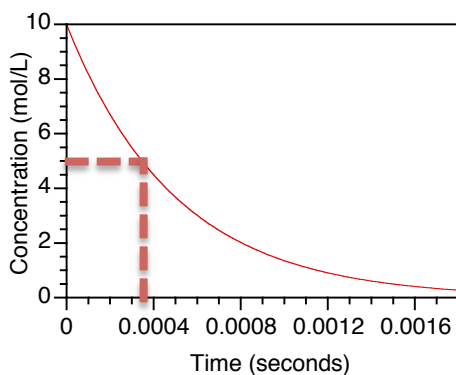
The rest is hydrogen:

$$m \text{ of H} = 72.12 \text{ g/mol} - 60.055 \text{ g/mol} = 12.068 \text{ g/mol}$$

$$\text{Therefore, the number of H's} = 12.068/1.0079 = 11.97 \sim 12$$

Answer: _____

c) (3 pts) The combustion of this hydrocarbon, in the presence of excess oxygen, follows *first order* kinetics, as shown in the graph below. What is the rate constant for the combustion?



Since it's first order:

$$t_{1/2} = \frac{\ln 2}{k}$$

$$k = \frac{\ln 2}{0.00035s} = 2.0 \times 10^3 \text{ s}^{-1}$$

Answer: _____

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

To a 2.50 L flask, A and B are added at initial pressures of 0.500 bar each. The mixture was allowed to equilibrate at 1000 K and the flask was found to contain 0.0147 mol of C.

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

$$P_C \text{ at EQM} = \frac{n_C RT}{V} = \frac{(0.0147 \text{ mol})(0.083145 \text{ L} \cdot \text{bar/mol} \cdot \text{K})(1000 \text{ K})}{2.50 \text{ L}}$$

$$= 0.489 \text{ bar}$$

	A(g) +	2 B(g)	\rightleftharpoons	2 C(g)
I	0.500	0.500		0
C	-0.245	-0.489		+0.489
E	0.255	0.011		0.489

$$K_P = \frac{(P_C)^2}{P_A \times (P_B)^2} = \frac{(0.489)^2}{(0.255)(0.011)^2} = 7.75 \times 10^3$$

b) (2 pts) What is the value of K_C for the reaction?

$$K_P = K_C (RT)^{\Delta n_{\text{gas}}}$$

$$K_C = \frac{K_P}{(RT)^{\Delta n_{\text{gas}}}} = \frac{7750}{(0.083145 \times 1000)^{2-3}} = 6.44 \times 10^5$$

c) (3 pts) What is the percent yield of C?

$$? \text{ theoretical } P_C \text{ from A} = 0.500 \text{ bar A} \times \frac{2 \text{ bar C}}{1 \text{ bar A}} = 1.00 \text{ bar}$$

$$? \text{ theoretical } P_C \text{ from B} = 0.500 \text{ bar B} \times \frac{2 \text{ bar C}}{2 \text{ bar B}} = 0.500 \text{ bar}$$

Therefore, B is the LIMITING REAGENT.

$$\% \text{ yield} = \frac{0.489 \text{ bar}}{0.500 \text{ bar}} \times 100\% = 97.8\%$$

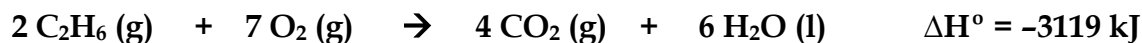
d) (1 pt) If the equilibrated gas mixture was then transferred to a container of larger volume, what would be the resulting effect on the equilibrium?

SHIFT TOWARDS REACTANTS

SHIFT TOWARDS PRODUCTS

NO EFFECT

#8. For the following reaction:



a) (3 pts) How much heat, in kJ, is associated with the combustion of 8.50 g of ethane?

$$? \text{ mol C}_2\text{H}_6 = 8.50 \text{ g} \times \frac{\text{mol}}{30.07 \text{ g}} = 0.2827 \text{ mol}$$

$$? \text{ mol kJ heat} = 0.2827 \text{ mol C}_2\text{H}_6 \times \frac{-3119 \text{ kJ}}{2 \text{ mol C}_2\text{H}_6} = -441 \text{ kJ}$$

Answer: _____

b) (3 pts) What is the quantity of work, in kJ, evolved in the combustion of 8.50 g of ethane at 25.00°C ? (Assume an exact stoichiometric quantity of oxygen is present).

$$? \text{ mol O}_2 = 0.2827 \text{ mol} \times \frac{7 \text{ mol O}_2}{2 \text{ mol C}_2\text{H}_6} = 0.9894 \text{ mol}$$

$$? \text{ mol CO}_2 = 0.2827 \text{ mol} \times \frac{4 \text{ mol CO}_2}{2 \text{ mol C}_2\text{H}_6} = 0.5654 \text{ mol}$$

$$T = 25.00 + 273.15 = 298.15 \text{ K}$$

$$W = -\Delta n_{\text{gas}} RT = -[0.5654 - (0.2827 + 0.9894) \text{ mol}] \times 8.3145 \text{ J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1} \times 298.15 \text{ K}$$

$$= +1750 \text{ J} \times \frac{1 \text{ kJ}}{1000 \text{ J}} = +1.75 \text{ kJ}$$

Answer: _____

c) (2 pts) Explain the significance of the *sign* of your answer in part (b) in one or two sentences.

POSITIVE work means the surroundings did work ON THE SYSTEM, which makes sense because this is a CONTRACTION.

d) (2 pts) Calculate the change in internal energy for the combustion of 8.50 g of ethane.

$$\Delta U = q + W = -441 \text{ kJ} + 1.75 \text{ kJ} = -439 \text{ kJ}$$

Answer: _____

#9. Wastewater resulting from metal processing is polluted with cadmium ions, Cd^{2+} , which must be removed before the water may be disposed. In one method, the water is treated with solutions of concentrated sodium hydroxide. Suppose 1.00×10^2 L of wastewater containing 1.2×10^{-5} M Cd^{2+} is treated with 1.0 L of 6.0 M NaOH solution.

a) (1 pt) What is the insoluble solid that precipitates out? $\text{Cd}(\text{OH})_2$

b) (6 pts) What is the residual concentration of aqueous cadmium ion after treatment?

$$? \text{ mol Cd}^{2+} = 100\text{L} \times \frac{1.2 \times 10^{-5} \text{ mol Cd}^{2+}}{\text{L}} = 0.0012 \text{ mol}$$

$$? \text{ mol OH}^- = 1.0\text{L} \times \frac{6.0 \text{ mol OH}^-}{\text{L}} = 6.0 \text{ mol}$$

First, let's assume ALL the cadmium ion is precipitated:

	Cd^{2+}	$+ 2 \text{OH}^-$	$\rightarrow \text{Cd}(\text{OH})_2(\text{s})$
B	0.0012	0	-
A		+6.0	-
M	-0.0012	-2(0.0012)	-
A	0	5.998	-

Now, how much will REDISSOLVE back into solution? Taking into account the new solution volume (100 L + 1 L = 101 L):

New $[\text{OH}^-] = 5.998 \text{ mol}/101 \text{ L} = 0.0599 \text{ M}$

	$\text{Cd}(\text{OH})_2(\text{s})$	$\rightleftharpoons \text{Cd}^{2+}$	$+ 2 \text{OH}^-$
I	-	0	0.0599
C	-	+s	+2s
E	-	s	0.0599 + 2s

$$K_{sp} = [\text{Cd}^{2+}][\text{OH}^-]^2$$

$$2.5 \times 10^{-14} = (s)(0.0599 + 2s)^2 \approx (s)(0.0599)^2$$

$$\therefore s \approx 7.0 \times 10^{-12} \text{ M} = [\text{Cd}^{2+}]$$

$$\text{Check: } \frac{7.0 \times 10^{-12}}{0.0599} \times 100\% < 5\% \longrightarrow \text{PASSES}$$

Answer: _____

c) (3 pts) What is the mass of the solid that precipitates out?

mol solid $\text{Cd}(\text{OH})_2 = 0.0012 \text{ mol} - 7.0 \times 10^{-10} \text{ mol} = 0.0012 \text{ mol}$

mass of solid $\text{Cd}(\text{OH})_2 = 0.0012 \text{ mol} \times 146 \text{ g/mol} = 0.18 \text{ g}$

Answer: _____