

Last Name: _____

First name: _____

Student Number: _____

CHM 1311 B Final Exam December 2013

Professor: Dr. Goto

There are 13 pages in this test. A periodic table, data tables, and a formula sheet are provided at the end. You may rip these pages off of the exam.

Please show all work to receive partial credit.

Marks may be deducted if an unreasonable number of sig figs are shown in your final answer.

You have 180 minutes to complete the exam.

Question	Points Possible	Points Earned
1	22	
2	10	
3	10	
4	10	
5	8	
6	10	
7	10	
8	10	
TOTAL	90	

Question 1. (22 marks)

- a) How many protons and electrons are in an ion of zinc having a 2+ charge?

Protons: 30

Electrons: 28

- b) Give the name for $K_2CO_3 \cdot 2H_2O$: potassium carbonate dihydrate

- c) The molecular formula for ferrous oxide is: FeO

- d) Will the addition of a strong acid lead to some precipitation of silver sulphate from a pure saturated solution of Ag_2SO_4 ?

YES

NO

- e) What volume of 1.00 mol/L $KMnO_4$ is required prepare a 50 mL solution of 0.100 mol/L $KMnO_4$?

Volume = 5 mL

- f) Write the full ground-state *spdf* electron configuration of the monoatomic ion most likely to be formed by Br.

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6$

- g) At the top of Mt. Everest atmospheric pressure is approximately 0.300 atm. The height of mercury in a barometer be at the top of this mountain is:

228 mm Hg

- h) Circle the term that is NOT a state function:

ENTHALPY

TEMPERATURE

INTERNAL ENERGY

HEAT

- i) The change in internal energy for an ideal gas that absorbs 560 J of heat and does 350 J of work

is: 210 J

- j) A frying pan is used to transfer energy from a stove-top heating element to food. Refer to the data sheet to identify the material that the pan should be constructed from to best perform this function. (Circle one.)

aluminum

gold

glass (SiO₂)

graphite

- k) Circle the quantum number designation that corresponds to an electron in a 3d orbital:

$$n = 2, l = 2, m_l = 1$$

$$n = 3, l = 2, m_l = 3$$

$$n = 3, l = 1, m_l = 0$$

$$n = 3, l = 2, m_l = -2$$

- l) When the volume of the reaction vessel is increased, the equilibrium reaction



shifts towards the:

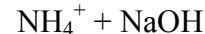
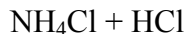
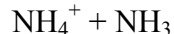
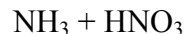
PRODUCTS

REACTANTS

- m) When a strong acid such as HCl is added to a solution of NH₃, the strong ammonia smell is eliminated. Write the equation of the equilibrium constant for this reaction in the box provided:

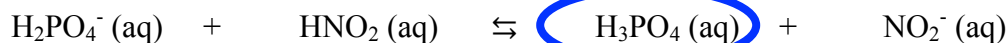
$$K = \frac{[\text{NH}_4^+]}{([\text{NH}_3][\text{H}_3\text{O}^+])}$$

- n) Circle one of the following combinations that will NOT produce a buffer.



- o) If a plot of $\frac{1}{[A]_t}$ versus time yields a straight line then the reaction is second order in A.

- p) Circle the species in the chemical reaction below that is the strongest acid, given that the equilibrium constant K for this reaction is <1.



- q) Increasing the temperature of an exothermic reaction will:

i) Increase the yield and rate

ii) Decrease the yield and increase the rate

iii) Increase the yield and decrease the rate

iv) Decrease the yield and rate

r) How many orbitals make up the 3d sublevel? 5

s) How many nodal planes are in the d orbital? 2

Question 2.

- a) A buffer that contains 0.150 mol/L NaF and 0.210 mol/L HF has a pH of 3.33. What is the pKa of HF? (2 marks)

$$\text{pH} = \text{pKa} + \log\left[\frac{[\text{F}^-]}{[\text{HF}]}\right]$$

$$\text{pKa} = \text{pH} - \log\left[\frac{[\text{F}^-]}{[\text{HF}]}\right] = 3.33 - \log(0.150)/(0.210) = 3.48$$

pKa = 3.48

- b) If 35.00 mL of a 0.150 mol/L solution of HF is titrated with 0.1000 mol/L NaOH, what volume of this NaOH solution will be required to reach the equivalence point? (3 marks)

$$n_{\text{HF}} = (0.150 \text{ M})(0.035 \text{ L}) = 0.0525 \text{ mol} = n_{\text{OH}^-}$$

$$V_{\text{OH}} = n_{\text{OH}^-}/c_{\text{OH}} = 0.0525 \text{ mol}/0.1000 \text{ M} = 0.525 \text{ L}$$

Answer: 52.5 mL

- c) What will be the pH of the solution at the equivalence point? (5 marks)

$$[\text{F}^-] = n_{\text{F}^-}/(V_{\text{HF}} + V_{\text{OH}}) = 0.0525 \text{ mol}/(0.035 + 0.0525) \text{ L} = 0.06 \text{ M}$$

$$K_{\text{b}} = K_{\text{w}}/K_{\text{a}} = 10^{-14}/10^{-3.48} = 3.02 \times 10^{-11}$$

	F ⁻	+	H ₂ O	⇌	HF	+	OH ⁻
Initial	0.06 M		----		0		0
Change	-x		----		x		x
Equilibrium	0.06 - x		----		x		x

Since $[\text{F}^-]_{\text{initial}}/K_{\text{b}} \gg 400$, therefore $[\text{F}^-]_{\text{equilibrium}} \sim 0.06 \text{ M}$.

$$K_{\text{b}} = [\text{HF}][\text{OH}^-]/[\text{F}^-] = x^2/0.06 \quad x = (K_{\text{b}} \cdot 0.06)^{0.5} = 1.35 \times 10^{-6}$$

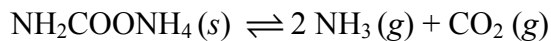
$$\text{pOH} = -\log(1.35 \times 10^{-6}) = 5.87$$

$$\text{pH} = \text{pK}_{\text{w}} - \text{pOH} = 14 - 5.87 = 8.13$$

Answer: 8.13

Question 3.

Ammonium carbamate ($\text{NH}_2\text{COONH}_4$) is a salt of carbamic acid that is found in the blood and urine of mammals. At 250°C $K_c = 1.58 \times 10^{-8}$ for the following equilibrium



- a) If 7.80 g of ammonium carbamate is put into a 0.500 L evacuated container, what is the total pressure at equilibrium? (6 marks)

	2 NH ₃	CO ₂
Initial	0	0
Change	2x	x
Equilibrium	2x	x

$$K_c = [\text{NH}_3]^2[\text{CO}_2] = (2x)^2(x) = 4x^3$$

$$x = (K_c/4)^{1/3} = 1.58 \times 10^{-3} \text{ M} = c_{\text{CO}_2}$$

$$p_{\text{CO}_2} = cRT = (1.58 \times 10^{-3} \text{ mol/L})(0.08206 \text{ atm L /K mol})(523 \text{ K}) = 0.0679 \text{ atm}$$

$$p_{\text{Total}} = p_{\text{CO}_2} + p_{\text{NH}_3} = 3p_{\text{CO}_2} = 3(0.0679 \text{ atm}) = 0.206 \text{ atm}$$

Answer: 0.206 atm

- b) What is the percent yield for this reaction? (3 marks)

$$c_{\text{carbamate}} = m/MV = 7.80 \text{ g}/(78.05 \text{ g/mol})(0.500 \text{ L}) = 0.200 \text{ mol/L} = \text{theoretical yield of CO}_2$$

$$\% \text{ yield} = \text{actual yield/theoretical yield} \times 100\% = 1.58 \times 10^{-3} \text{ M} / 0.200 \text{ M} \times 100\% = 0.79\%$$

Answer: 0.79%

- c) If this reaction had been done under constant pressure conditions, would the work be positive, negative or zero? (1 mark)

The gas that is produce must expand to fill the container therefore volume is increasing
 Since volume is increasing, ($\Delta V > 0$) and $w = -p\Delta V$, therefore work is negative.

Question 4.

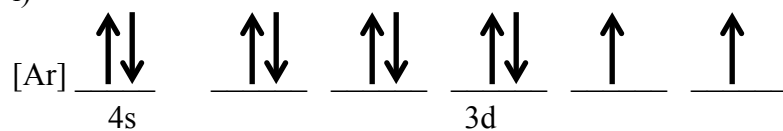
- a) An electron in the $n=5$ level of an H atom emits a photon wavelength 1281 nm. Calculate the energy level to which it moves. (5 marks)

$$\begin{aligned}\Delta E &= E_f - E_i = -R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right) = \frac{hc}{\lambda} \\ &= \frac{(6.62608 \times 10^{-34} \text{ J s})(2.9979 \times 10^8 \text{ m/s})}{(1281 \text{ nm})(10^{-9} \text{ m/nm})} \\ &= 1.55 \times 10^{-19} \text{ J} \\ \frac{1}{n_f^2} &= \frac{1}{n_i^2} - \frac{\Delta E}{R_H} = \frac{1}{5^2} - \frac{1.55 \times 10^{-19} \text{ J}}{-2.179 \times 10^{-18} \text{ J}} = 0.11113 \\ n_f &= 3\end{aligned}$$

Answer: 3

- b) i) Draw a partial (valence-shell) orbital diagram for $[\text{Ar}] 3d^8 4s^2$, and; ii) state the element that the neutral species corresponds to. (3 marks)

i)



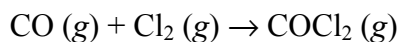
ii) Nickel

- c) Draw Lewis structures for two resonance forms of NO_2^- . (2 marks)



Question 5.

The toxic gas phosgene is prepared by the reaction:



A kinetics study of this reaction gave the following data:

Experiment	Initial rate (mol/L•s)	Initial [CO] (mol/L)	Initial [Cl ₂] (mol/L)
1	1.29 x 10 ⁻²⁹	1.00	0.100
2	1.33 x 10 ⁻³⁰	0.100	0.100
3	1.30 x 10 ⁻²⁹	0.100	1.00

a) Using the data provided, write the rate law for this reaction. (3 marks)

$$\frac{\text{Rate 1}}{\text{Rate 2}} = \frac{[\text{CO}]_1^m [\text{Cl}_2]_1^n}{[\text{CO}]_2^m [\text{Cl}_2]_2^n}$$

$$\frac{1.29 \times 10^{-29}}{1.33 \times 10^{-30}} = \left(\frac{1.00}{0.100} \right)^m$$

$$10 = 10^m \text{ Therefore } m = 1$$

$$\frac{\text{Rate 1}}{\text{Rate 2}} = \frac{[\text{CO}]_1^m [\text{Cl}_2]_1^n}{[\text{CO}]_2^m [\text{Cl}_2]_2^n}$$

$$\frac{1.29 \times 10^{-29}}{1.30 \times 10^{-29}} = \left(\frac{0.100}{1.00} \right)^n$$

$$10 = 10^n \text{ Therefore } n = 1$$

Answer: Rate = k[CO][Cl₂]

b) What is the rate constant (including units) for this reaction? (2 marks)

$$\text{Rate} = k[\text{CO}][\text{Cl}_2]$$

$$k = \text{rate}/[\text{CO}][\text{Cl}_2] = 1.29 \times 10^{-29} \text{ mol/L}\cdot\text{s}/(1.00 \text{ mol/L})(0.100 \text{ mol/L}) = 1.3 \times 10^{-28} \text{ L/mol}\cdot\text{s}$$

Answer: 1.3 x 10⁻²⁸ L/mol•s

c) Adsorption of Cl₂ gas to a platinum surface can reduce the activation energy of this reaction by 16.5 kJ/mol at 50°C. How much faster will the reaction go in the presence of this catalyst? (3 marks)

$$\frac{k_1}{k_2} = \frac{Ae^{\frac{-E_{a1}}{RT}}}{Ae^{\frac{-E_{a2}}{RT}}} = e^{-(E_{a1}-E_{a2})/RT} = e^{\frac{(-16500 \text{ J/mol})}{(8.314 \text{ J/K}\cdot\text{mol})(273+50)\text{K}}} = 466$$

Answer: 466 times faster

Question 6.

When 50.0 mL of 0.250 mol/L Ba(OH)₂ is mixed with 45 mL of 0.380 mol/L HCl in a coffee-cup calorimeter, the heat of the solution is 1.850 kJ.

a) Is this reaction exothermic or endothermic? (1 mark)

Exothermic

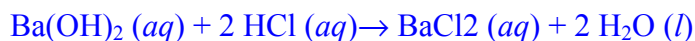
b) What is ΔT for the solution in reaction? (3 marks)

$$q_{\text{solution}} = m_{\text{H}_2\text{O}} c_{\text{H}_2\text{O}} \Delta T$$

$$\Delta T = \frac{q_{\text{solution}}}{m_{\text{H}_2\text{O}} c_{\text{H}_2\text{O}}} = \frac{1850 \text{ J}}{(95 \text{ g})(4.184 \text{ J/g}^\circ\text{C})} = 4.65^\circ\text{C}$$

Answer: 4.65°C

c) What is the ΔH of the reaction in kJ/mol of H₂O formed? (6 marks)



$$n_{\text{Ba(OH)}_2} = cV = (0.250 \text{ M})(0.050 \text{ L})$$

$$= 0.0125 \text{ mol} = 0.5n_{\text{H}_2\text{O}}$$

$$n_{\text{HCl}} = cV = (0.380 \text{ M})(0.045 \text{ L})$$

$$= 0.0171 \text{ mol} = n_{\text{H}_2\text{O}}$$

Therefore HCl is limiting reagent.

$$\Delta H_{\text{reaction}} = -\Delta H_{\text{solution}} = -1.850 \text{ kJ}$$

$$\Delta H_{\text{reaction}} / \text{mol H}_2\text{O} = -1.850 \text{ kJ} / 0.0171 \text{ mol H}_2\text{O formed} = -108 \text{ kJ/mol H}_2\text{O formed}$$

Answer: -108 kJ/mol H₂O formed

Question 7.

A steel tank at 21°C has a volume of 438 L and is filled with 1.257 kg of Ar. However, the valve was not completely closed, giving rise to a slow leak until it was discovered 6 hours later. According to the pressure gauge, the new pressure is 1.39 bar.

a) What mass of Ar was lost from the tank? (3 marks)

$$\begin{aligned} m_{\text{lost}} &= m_{\text{initial}} - m_{\text{final}} = m_{\text{initial}} - n_{\text{final}} M_{\text{Ar}} = m_{\text{initial}} - \frac{pV}{RT} M_{\text{Ar}} \\ &= 1.257 \text{ kg} (10^{-3} \text{ g/kg}) - \frac{(1.39 \text{ bar})(438 \text{ L})(39.95 \text{ g/mol})}{(0.08314 \text{ bar L/K/mol})(294 \text{ K})} \\ &= 1257 \text{ g} - 995 \text{ g} = 262 \text{ g} \end{aligned}$$

Answer: 262 g

b) How many atoms of argon were lost in a)? (1 mark)

$$N_{\text{Ar}} = nN_A = \frac{m_{\text{Ar}}}{M_{\text{Ar}}} N_A = \frac{262 \text{ g}}{39.95 \text{ g/mol}} \times 6.023 \times 10^{23} \text{ molecules/mol} = 3.95 \times 10^{24} \text{ molecules}$$

c) Calculate the rate of effusion. (1 mark)

$$\text{rate} = \frac{\text{Ar lost}}{\text{time}} = \frac{3.95 \times 10^{24} \text{ molecules}}{6 \text{ hours}} = 6.58 \times 10^{23} \text{ molecules/hour}$$

d) If the tank had contained N₂ in place of Ar, how many grams of N₂ would have been lost from the tank in this 6 hour period? (5 marks)

$$\frac{\text{rate N}_2}{\text{rate Ar}} = \sqrt{\frac{M_{\text{Ar}}}{M_{\text{N}_2}}}$$

$$\text{rate N}_2 = \text{rate Ar} \sqrt{\frac{M_{\text{Ar}}}{M_{\text{N}_2}}} = 6.58 \times 10^{23} \text{ molecules/hour} \times \sqrt{\frac{39.95}{28.00}} = 7.86 \times 10^{24} \text{ molecules/hour}$$

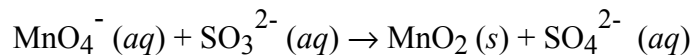
In 6 hours: N₂ lost = rate N₂ × time = 7.86 × 10²³ molecules/hour × 6 hours = 4.71 × 10²⁴ molecules

$$\text{mass N}_2 \text{ lost} = nM = \frac{N_{\text{N}_2} M_{\text{N}_2}}{N_A} = \frac{(4.71 \times 10^{24} \text{ molecules})(28.00 \text{ g/mol})}{6.022 \times 10^{23} \text{ molecules/mol}} = 219 \text{ g}$$

Answer: 219 g

Question 8.

The skeleton ionic equation for the reaction between KMnO_4 and K_2SO_3 is:



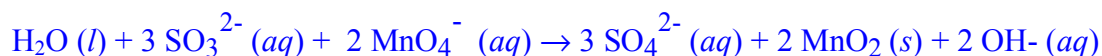
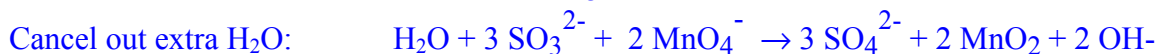
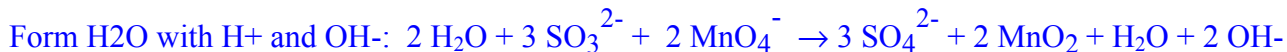
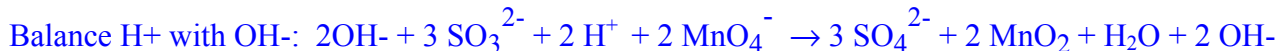
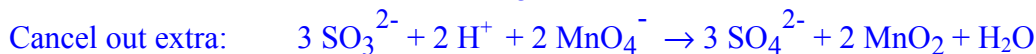
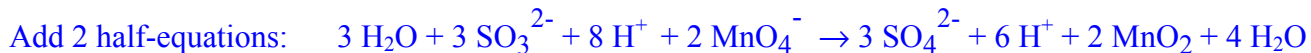
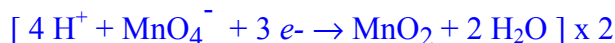
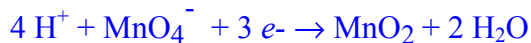
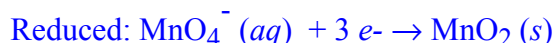
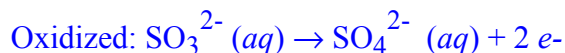
- a) Which compound is the reducing agent in the reaction? (Do not just give the element.) (1 mark)



- b) The solid product of this reaction is an oxide of manganese. What is the mass percent of manganese in this product? (1 mark)

$$\text{mass}\% = \frac{M_{\text{Mn}}}{M_{\text{MnO}_2}} \times 100\% = \frac{54.94 \text{ g/mol}}{54.94 \text{ g/mol} + 2(16.00 \text{ g/mol})} \times 100\% = 63.2\%$$

- c) Write the balanced molecular equation for this reaction in basic solution. (8 marks)



Constants and Conversion Factors

$1 \text{ mmHg} = 1 \text{ torr}$ $760 \text{ mmHg} = 1 \text{ atm}$ $1 \text{ atm} = 101.325 \text{ kPa}$ $1 \text{ atm} = 1.013125 \text{ bar}$
 $1 \text{ cm}^3 = 1 \text{ mL}$ $1 \text{ dm}^3 = 1 \text{ L} = 1000 \text{ mL}$ $1 \text{ m}^3 = 1000 \text{ L}$
 $1 \text{ cal} = 4.184 \text{ J}$

Avogadro's Number	N	$6.022 \times 10^{23} \text{ mol}^{-1}$
Atomic mass unit	u	$1.66054 \times 10^{-27} \text{ kg}$
Gas constant	R	$8.31451 \text{ J} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$
	R	$0.08206 \text{ atm} \cdot \text{L} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$
	R	$8.31451 \text{ m}^3 \text{ Pa} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$
	R	$0.0831451 \text{ bar L} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$
	R	
Planck's constant	h	$6.62608 \times 10^{-34} \text{ J} \cdot \text{s}$
Speed of Light	c	$2.99792458 \times 10^8 \text{ m} \cdot \text{s}^{-1}$
Rydberg constant	R_H	$2.18 \times 10^{-18} \text{ J}$

Data For Water

Density = 1.00 g/mL (at 25°C) $K_W = 1.0 \times 10^{-14}$
 $c = 4.184 \text{ J g}^{-1} \text{ K}^{-1}$ (liquid) $\Delta H^\circ_{\text{fus}} = 6.02 \text{ kJ mol}^{-1}$ $\Delta H^\circ_{\text{vap}} = 40.7 \text{ kJ mol}^{-1}$

Heat Capacity Data

graphite: 8.52 J/mol/K SiO_2 : 44.4 J/mol/K gold: 25.4 J/mol/K aluminum: 24.4 J/mol/K

The Modern Periodic Table

As of June 2012, elements 114 and 116 have been officially recognized. Elements 113, 115, 117, and 118 are pending verification by IUPAC.

MAIN-GROUP ELEMENTS																	
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17																	
18																	
19																	
20																	
21																	
22																	
23																	
24																	
25																	
26																	
27																	
28																	
29																	
30																	
31																	
32																	
33																	
34																	
35																	
36																	
37																	
38																	
39																	
40																	
41																	
42																	
43																	
44																	
45																	
46																	
47																	
48																	
49																	
50																	
51																	
52																	
53																	
54																	
55																	
56																	
57																	
58																	
59																	
60																	
61																	
62																	
63																	
64																	
65																	
66																	
67																	
68																	
69																	
70																	
71																	
72																	
73																	
74																	
75																	
76																	
77																	
78																	
79																	
80																	
81																	
82																	
83																	
84																	
85																	
86																	
87																	
88																	
89																	
90																	
91																	
92																	
93																	
94																	
95																	
96																	
97																	
98																	
99																	
100																	
101																	
102																	
103																	
104																	
105																	
106																	
107																	
108																	
109																	
110																	
111																	
112																	
113																	
114																	
115																	
116																	
117																	
118																	
119																	
120																	
121																	
122																	
123																	
124																	
125																	
126																	
127																	
128																	
129																	
130																	
131																	
132																	
133																	
134																	
135																	
136																	
137																	
138																	
139																	
140																	
141																	
142																	
143																	
144																	
145																	
146																	
147																	
148																	
149																	
150																	
151																	
152																	
153																	
154																	
155																	
156																	
157																	
158																	
159																	
160																	
161																	
162																	
163																	
164																	
165																	
166																	
167																	
168																	
169																	
170																	
171																	
172																	
173																	
174																	
175																	
176																	
177																	
178																	
179																	
180																	
181																	
182																	
183																	
184																	
185																	
186																	
187																	
188																	
189																	
190																	
191																	
192																	
193																	
194																	
195																	
196																	
197																	
198																	
199																	
200																	
201																	
202																	
203																	
204																	
205																	
206																	
207																	
208																	
209																	
210																	
211																	
212																	
213																	
214																	
215																	
216																	
217																	
218																	
219																	
220																	
221																	
222																	
223																	
224																	
225																	
226																	
227																	
228																	
229																	
230																	
231																	
232																	
233																	
234																	
235																	
236																	
237																	
238																	
239																	
240																	
241																	
242																	
243																	
244																	
245																	
246																	
247																	
248																	
249																	
250																	
251																	
252																	
253																	
254																	
255																	
256																	
257																	
258																	
259																	
260																	

Post-Midterm 2 Equations

$$\text{pH} = \text{p}K_a + \log \frac{[\text{A}^-]}{[\text{HA}]}$$

$$c = \lambda \times \nu$$

$$\Delta E = nh\nu$$

$$\lambda = \frac{h}{m\nu}$$

$$E_n = -\frac{R_H}{n^2}$$

Midterm 2 Equations

$$\Delta_r H^\circ = \sum m \Delta_f H^\circ (\text{products}) - \sum n \Delta_f H^\circ (\text{reactants})$$

$$\Delta_r H^\circ = \sum m \text{BE} (\text{reactants}) - \sum n \text{BE} (\text{products})$$

$$q = c \times m \times \Delta T$$

$$\text{Rate} = \frac{1}{\nu_x} \frac{\Delta[\text{X}]}{\Delta t}$$

$$\text{Rate} = k[\text{A}]^m [\text{B}]^n \dots$$

$$k = A e^{-\frac{E_a}{RT}}$$

$$[\text{A}]_t - [\text{A}]_o = -kt$$

$$\ln \frac{[\text{A}]_o}{[\text{A}]_t} = kt$$

$$\frac{1}{[\text{A}]_t} - \frac{1}{[\text{A}]_o} = kt$$

$$\ln \left(\frac{k_2}{k_1} \right) = -\frac{E_a}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$$

$$K = K_c (RT)^{\Delta n(\text{gas})}$$

$$\ln \left(\frac{K_2}{K_1} \right) = -\frac{\Delta_r H^\circ}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$$

$$ax^2 + bx + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\text{pH} = -\log [\text{H}_3\text{O}^+]$$

$$\text{pOH} = -\log [\text{OH}^-]$$

$$\text{pH} + \text{pOH} = 14$$

$$K_a \times K_b = K_w$$

$$\text{p}K_a = -\log K_a$$

$$\text{p}K_b = -\log K_b$$

Midterm 1 Equations

$$T(\text{in K}) = T(\text{in } ^\circ\text{C}) + 273.15 \text{ K}$$

$$n = \frac{m}{M}$$

$$\% \text{ Yield} = \frac{\text{actual yield}}{\text{theoretical yield}}$$

$$c(\text{mol/L}) = \frac{n}{V}$$

$$m(\text{mol/kg}) = \frac{n_{\text{solute}}}{m_{\text{solvent}}}$$

$$c_1 V_1 = c_2 V_2 = n$$

$$\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$$

$$pV = nRT$$

$$p_T = p_1 + p_2 + p_3 + \dots$$

$$p_A = X_A \times p_T$$

$$X_A = \frac{n_A}{n_T}$$

$$d = \frac{m}{V} = \frac{p \cdot MM}{RT}$$

$$E_K = \frac{1}{2} m v^2$$

$$u_{\text{rms}} = \sqrt{\frac{3RT}{M}}$$

$$\frac{\text{Rate A}}{\text{Rate B}} = \sqrt{\frac{M_B}{M_A}}$$

$$\left(p + \frac{n^2 a}{V^2} \right) (V - nb) = nRT$$

$$w = -p\Delta V$$

$$\Delta U = U_{\text{final}} - U_{\text{initial}} = q + w$$

$$\Delta H = \Delta U + p\Delta V$$