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 cupric chloride is: _____________$CuCl_2$_____________

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 ($SiO_2$)    graphite

k) Circle the allowed combination from the options below:

$n = 1, l = 0\ m_l = -1$    $n = 2, l = 1, m_l = +1$    $n = 7, l = 1, m_l = +2$    $n = 3, l = 1, m_l = -2$

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

$$CaC_2O_4\ (s) \rightleftharpoons CaCO_3\ (s) + CO\ (g)$$

shifts towards the:    PRODUCTS    REACTANTS

m) When a strong acid such as HCl is added to a solution of $NH_3$, the strong ammonia smell is eliminated. Write the equation of the equilibrium constant for this reaction in the box provided:

$K = [NH_4^+]/([NH_3][H_3O^+])$

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

$NH_3 + HNO_3$    $NH_4^+ + NH_3$    $NH_4Cl + HCl$    $NH_4^+ + NaOH$

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.

$$H_2PO_4^-\ (aq) \quad + \quad HNO_2\ (aq) \quad \leftrightarrows \quad H_3PO_4\ (aq) \quad + \quad NO_2^-\ (aq)$$

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)

$$pH = pKa + \log[F-]/[HF]$$
$$pKa = pH - \log[F-]/[HF] = 3.33 - \log(0.150)/(.210) = 3.48$$

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)

$$n_{HF} = (0.150\ M)(0.035\ L) = 0.0525\ mol = n_{OH-}$$
$$V_{OH} = n_{OH}/c_{OH} = 0.0525\ mol/0.1000\ M = 0.525\ L$$

Answer: ___52.5 mL___

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

$[F-] = n_F/(V_{HF} + V_{OH}) = 0.00525\ mol/(0.0525 + 0.035)L = 0.06\ M$

$Kb = Kw/Ka = 10^{-14}/10^{-3.48} = 3.02 \times 10^{-11}$

| | $F-$ | + | $H_2O$ | ⇆ | HF | + | OH- |
|---|---|---|---|---|---|---|---|
| Initial | 0.06 M | | ---- | | 0 | | 0 |
| Change | -x | | ---- | | x | | x |
| Equilibrium | 0.06 – x | | ---- | | x | | x |

Since $[F]_{initial}/Kb >> 400$, therefore $[F-]_{equilibrium} \sim 0.06$ M.

$Kb = [HF][OH-]/[F-] = x^2/0.06$ $\qquad x = (Kb*0.06)^{0.5} = 1.35 \times 10^{-6}$

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

$pH = pKw - pOH = 14 - 5.87 = 8.13$

Answer: ___8.13___

**Question 3.**

Ammonium carbamate ($NH_2COONH_4$) is a salt of carbamic acid that is found in the blood and urine of mammals. At 250°C $Kc = 1.58 \times 10^{-8}$ for the following equilibrium

$$NH_2COONH_4\,(s) \rightleftharpoons 2\,NH_3\,(g) + CO_2\,(g)$$

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 | $2x$ | $x$ |

$Kc = [NH_3]^2[CO_2] = (2x)^2(x) = 4x^3$

$x = (Kc/4)^{1/3} = 1.58 \times 10^{-3}\ \text{M} = c_{CO2}$

$p_{CO2} = cRT = (1.58 \times 10^{-3}\ \text{mol/L})(0.08206\ \text{atm L /K mol})(523\ \text{K}) = 0.0679\ \text{atm}$

$p_{Total} = p_{CO2} + p_{NH3} = 3p_{CO2} = 3(0.0679\ \text{atm}) = 0.206\ \text{atm}$

Answer: ____________________0.206 atm_____________

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

$c_{carbamate} = m/MV = 7.80\ \text{g}/(78.05\ \text{g/mol})(0.500\ \text{L}) = 0.200\ \text{mol/L}$ = theoretical yield of $CO_2$

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

$$\Delta E = E_f - E_i = -R_H\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = \frac{hc}{\lambda}$$

$$= \frac{\left(6.62608\times10^{-34}\ \text{J s}\right)\left(2.9979\times10^{8}\ \text{m/s}\right)}{\left(1281\ \text{nm}\right)\left(10^{-9}\ \text{m/nm}\right)}$$

$$= 1.55\times10^{-19}\ \text{J}$$

$$\frac{1}{n_f^2} = \frac{1}{n_i^2} - \frac{\Delta E}{R_H} = \frac{1}{5^2} - \frac{1.55\times10^{-19}\ \text{J}}{-2.179\times10^{-18}\ \text{J}} = 0.11113$$

$$n_f = 3$$

Answer: ________________3__________________

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

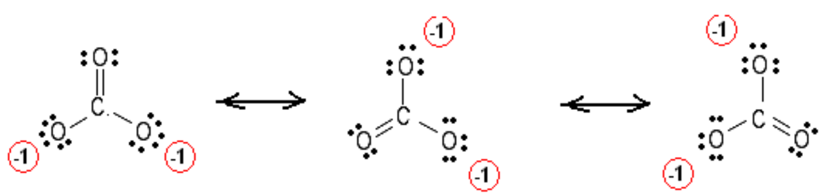
i)

[Ar] $\underline{\uparrow\downarrow}$ $\underline{\uparrow\downarrow}$ $\underline{\uparrow\downarrow}$ $\underline{\uparrow\downarrow}$ $\underline{\uparrow}$ $\underline{\uparrow}$

4s 3d

ii) Nickel

c) Draw Lewis structures for three resonance forms of $CO_3^{2-}$. (2 marks)



**Question 5.**

The toxic gas phosgene is prepared by the reaction:

$$CO\ (g) + Cl_2\ (g) \rightarrow COCl_2\ (g)$$

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 | $1.29 \times 10^{-29}$ | 1.00 | 0.100 |
| 2 | $1.33 \times 10^{-30}$ | 0.100 | 0.100 |
| 3 | $1.30 \times 10^{-29}$ | 0.100 | 1.00 |

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

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

$$\frac{1.29\times10^{-29}}{1.33\times10^{-30}} = \left(\frac{1.00}{0.100}\right)^m$$

$10 = 10^m$ Therefore m = 1

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

$$\frac{1.33\times10^{-30}}{1.30\times10^{-29}} = \left(\frac{0.100}{1.00}\right)^n$$

$10 = 10^n$ Therefore n = 1

Answer: ________Rate = k[CO][$Cl_2$]______________________

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

Rate = k[CO][$Cl_2$]

k = rate/[CO][$Cl_2$] = $1.29 \times 10^{-29}$ mol/L•s/(1.00 mol/L)(0.100 mol/L) = $1.3 \times 10^{-28}$ L/mol•s

Answer: _________$1.3 \times 10^{-28}$ L/mol•s_________________

c) Adsorption of $Cl_2$ 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)

$$\frac{k_1}{k_2} = \frac{Ae^{\frac{-E_{a_1}}{RT}}}{Ae^{\frac{-E_{a2}}{RT}}} = e^{-(Ea_1 - Ea_2)RT} = e^{-\frac{(-16500\ \text{J/mol})}{(8.314\ \text{J/K/mol})(273+50)\text{K}}} = 466$$

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)

$$q_{\text{solution}} = m_{H_2O} c_{H_2O} \Delta T$$

$$\Delta T = \frac{q_{\text{solution}}}{m_{H_2O} c_{H_2O}} = \frac{1850 \text{ J}}{(95 \text{ g})(4.184 \text{ J/g/}^{\circ}\text{C})} = 4.65^{\circ}\text{C}$$

Answer: __________4.65°C______________________________

c) What is the ΔH of the reaction in kJ/mol of $H_2O$ formed? (6 marks)

$$Ba(OH)_2\ (aq) + 2\ HCl\ (aq) \rightarrow BaCl2\ (aq) + 2\ H_2O\ (l)$$

$n_{Ba(OH)2} = cV = (0.250 \text{ M})(0.050 \text{ L})$
$= 0.0125 \text{ mol} = 0.5 n_{H2O}$

$n_{HCl} = cV = (0.380 \text{ M})(0.045 \text{ L})$
$= 0.0171 \text{ mol} = n_{H2O}$

Therefore HCl is limiting reagent.

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

$\Delta H_{reaction}$ / mol $H_2O$ = -1.850 kJ / 0.0171 mol $H_2O$ formed = -108 kJ/mol $H_2O$ formed

Answer: ___________-108 kJ/mol $H_2O$ 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)

$$m_{lost} = m_{initial} - m_{final} = m_{initial} - n_{final}M_{\text{Ar}} = m_{initial} - \frac{pV}{RT}M_{\text{Ar}}$$

$$= 1.257\text{ kg}\left(10^{-3}\text{ g/kg}\right) - \frac{(1.39\text{ bar})(438\text{ L})(39.95\text{ g/mol})}{(0.08314\text{ bar L/K/mol})(294\text{ K})}$$

$$= 1257\text{ g - }995\text{ g} = 262\text{ g}$$

Answer: 262 g

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

$$N_{\text{Ar}} = nN_A = \frac{m_{\text{Ar}}}{M_{\text{Ar}}}N_A = \frac{262\text{ g}}{39.95\text{ g/mol}} \times 6.023\times10^{23}\text{ molecules/mol} = 3.95\times10^{24}\text{ molecules}$$

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

$$rate = \frac{\text{Ar lost}}{\text{time}} = \frac{3.95\times10^{24}\text{ molecules}}{6\text{ hours}} = 6.58\times10^{23}\text{ molecules/hour}$$

d) If the tank had contained $N_2$ in place of Ar, how many grams of $N_2$ would have been lost from the tank in this 6 hour period? (5 marks)

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

$$\text{rate N}_2 = \text{rate Ar}\sqrt{\frac{M_{\text{Ar}}}{M_{\text{N}_2}}} = 6.58\times10^{23}\text{ molecules/hour} \times \sqrt{\frac{39.95}{28.00}} = 7.86\times10^{24}\text{ molecules/hour}$$

In 6 hours: $\text{N}_2\text{ lost} = \text{rate N}_2 \times \text{time} = 7.86\times10^{23}\text{ molecules/hour} \times 6\text{ hours} = 4.71\times10^{24}\text{ molecules}$

$$\text{mass N}_2\text{ lost} = nM = \frac{N_{\text{N}_2}M_{\text{N}_2}}{N_A} = \frac{(4.71\times10^{24}\text{ molecules})(28.00\text{ g/mol})}{6.022\times10^{23}\text{ molecules/mol}} = 219\text{ g}$$

Answer: 219 g

**Question 8.**

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

$$MnO_4^{-}\ (aq) + SO_3^{2-}\ (aq) \rightarrow MnO_2\ (s) + SO_4^{2-}\ (aq)$$

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

$SO_3^{2-}$

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

$$mass\% = \frac{M_{\mathrm{Mn}}}{M_{\mathrm{MnO_2}}} \times 100\% = \frac{54.94\ \text{g/mol}}{54.94\ \text{g/mol} + 2\left(16.00\ \text{g/mol}\right)} \times 100\% = 63.2\%$$

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

Oxidized: $SO_3^{2-}\ (aq) \rightarrow SO_4^{2-}\ (aq) + 2\ e\text{-}$

Reduced: $MnO_4^{-}\ (aq) + 3\ e\text{-} \rightarrow MnO_2\ (s)$

Balance oxygen, hydrogen: $H_2O + SO_3^{2-} \rightarrow SO_4^{2-} + 2\ e\text{-} + 2\ H^+$

$4\ H^+ + MnO_4^{-} + 3\ e\text{-} \rightarrow MnO_2 + 2\ H_2O$

Balance electrons: $[\ H_2O + SO_3^{2-} \rightarrow SO_4^{2-} + 2\ e\text{-} + 2\ H^+\ ] \times 3$

$[\ 4\ H^+ + MnO_4^{-} + 3\ e\text{-} \rightarrow MnO_2 + 2\ H_2O\ ] \times 2$

Add 2 half-equations: $3\ H_2O + 3\ SO_3^{2-} + 8\ H^+ + 2\ MnO_4^{-} \rightarrow 3\ SO_4^{2-} + 6\ H^+ + 2\ MnO_2 + 4\ H_2O$

Cancel out extra: $3\ SO_3^{2-} + 2\ H^+ + 2\ MnO_4^{-} \rightarrow 3\ SO_4^{2-} + 2\ MnO_2 + H_2O$

Balance H+ with OH-: $2OH\text{-} + 3\ SO_3^{2-} + 2\ H^+ + 2\ MnO_4^{-} \rightarrow 3\ SO_4^{2-} + 2\ MnO_2 + H_2O + 2\ OH\text{-}$

Form H2O with H+ and OH-: $2\ H_2O + 3\ SO_3^{2-} + 2\ MnO_4^{-} \rightarrow 3\ SO_4^{2-} + 2\ MnO_2 + H_2O + 2\ OH\text{-}$

Cancel out extra $H_2O$: $H_2O + 3\ SO_3^{2-} + 2\ MnO_4^{-} \rightarrow 3\ SO_4^{2-} + 2\ MnO_2 + 2\ OH\text{-}$

$$H_2O\ (l) + 3\ SO_3^{2-}\ (aq) + 2\ MnO_4^{-}\ (aq) \rightarrow 3\ SO_4^{2-}\ (aq) + 2\ MnO_2\ (s) + 2\ OH\text{-}\ (aq)$$

## Constants and Conversion Factors

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

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

## Data For Water

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

MAIN-GROUP ELEMENTS — TRANSITION ELEMENTS — MAIN-GROUP ELEMENTS

Key: 4 — Atomic number; Be — Atomic symbol; 9.012 — Atomic mass (u)

- Metals (main-group)
- Metals (transition)
- Metals (inner transition)
- Metalloids
- Nonmetals

| Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 H 1.008 | | | | | | | | | | | | | | | | | 2 He 4.003 |
| 2 | 3 Li 6.941 | 4 Be 9.012 | | | | | | | | | | | 5 B 10.81 | 6 C 12.01 | 7 N 14.01 | 8 O 16.00 | 9 F 19.00 | 10 Ne 20.18 |
| 3 | 11 Na 22.99 | 12 Mg 24.31 | | | | | | | | | | | 13 Al 26.98 | 14 Si 28.09 | 15 P 30.97 | 16 S 32.07 | 17 Cl 35.45 | 18 Ar 39.95 |
| 4 | 19 K 39.10 | 20 Ca 40.08 | 21 Sc 44.96 | 22 Ti 47.88 | 23 V 50.94 | 24 Cr 52.00 | 25 Mn 54.94 | 26 Fe 55.85 | 27 Co 58.93 | 28 Ni 58.69 | 29 Cu 63.55 | 30 Zn 65.41 | 31 Ga 69.72 | 32 Ge 72.61 | 33 As 74.92 | 34 Se 78.96 | 35 Br 79.90 | 36 Kr 83.80 |
| 5 | 37 Rb 85.47 | 38 Sr 87.62 | 39 Y 88.91 | 40 Zr 91.22 | 41 Nb 92.91 | 42 Mo 95.94 | 43 Tc (98) | 44 Ru 101.1 | 45 Rh 102.9 | 46 Pd 106.4 | 47 Ag 107.9 | 48 Cd 112.4 | 49 In 114.8 | 50 Sn 118.7 | 51 Sb 121.8 | 52 Te 127.6 | 53 I 126.9 | 54 Xe 131.3 |
| 6 | 55 Cs 132.9 | 56 Ba 137.3 | | 72 Hf 178.5 | 73 Ta 180.9 | 74 W 183.9 | 75 Re 186.2 | 76 Os 190.2 | 77 Ir 192.2 | 78 Pt 195.1 | 79 Au 197.0 | 80 Hg 200.6 | 81 Tl 204.4 | 82 Pb 207.2 | 83 Bi 209.0 | 84 Po (209) | 85 At (210) | 86 Rn (222) |
| 7 | 87 Fr (223) | 88 Ra (226) | | 104 Rf (263) | 105 Db (262) | 106 Sg (266) | 107 Bh (267) | 108 Hs (277) | 109 Mt (268) | 110 Ds (281) | 111 Rg (272) | 112 Cn (285) | 113 Uut (284) | 114 Fl (289) | 115 Uup (288) | 116 Lv (292) | 117 Uus | 118 Uuo (294) |

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

INNER TRANSITION ELEMENTS

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | Lanthanides | 57 La 138.9 | 58 Ce 140.1 | 59 Pr 140.9 | 60 Nd 144.2 | 61 Pm (145) | 62 Sm 150.4 | 63 Eu 152.0 | 64 Gd 157.3 | 65 Tb 158.9 | 66 Dy 162.5 | 67 Ho 164.9 | 68 Er 167.3 | 69 Tm 168.9 | 70 Yb 173.0 | 71 Lu 175.0 |
| 7 | Actinides | 89 Ac (227) | 90 Th 232.0 | 91 Pa (231) | 92 U 238.0 | 93 Np (237) | 94 Pu (242) | 95 Am (243) | 96 Cm (247) | 97 Bk (247) | 98 Cf (251) | 99 Es (252) | 100 Fm (257) | 101 Md (258) | 102 No (259) | 103 Lr (260) |

## Post-Midterm 2 Equations

$$\text{pH} = \text{p}K_a + \log\frac{[\text{A-}]}{[\text{HA}]} \qquad c = \lambda \times v \qquad \Delta E = nhv \qquad \lambda = \frac{h}{mv} \qquad E_n = -\frac{R_H}{n^2}$$

## Midterm 2 Equations

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

$$q = c \times m \times \Delta T \qquad \text{Rate} = \frac{1}{v_\text{X}}\frac{\Delta[\text{X}]}{\Delta t} \qquad \text{Rate} = k[\text{A}]^m[\text{B}]^n \ldots$$

$$k = Ae^{-\frac{E_a}{RT}} \qquad [\text{A}]_t - [\text{A}]_o = -kt \qquad \ln\frac{[\text{A}]_o}{[\text{A}]_t} = kt$$

$$\frac{1}{[\text{A}]_t} - \frac{1}{[\text{A}]_o} = kt \qquad \ln\left(\frac{k_2}{k_1}\right) = -\frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right) \qquad K = K_c(RT)^{\Delta n(\text{gas})}$$

$$\ln\left(\frac{K_2}{K_1}\right) = -\frac{\Delta_r H^o}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right) \qquad ax^2 + bx + c = 0 \qquad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\text{pH} = -\log[\text{H}_3\text{O}^+] \qquad \text{pOH} = -\log[\text{OH}^-] \qquad \text{pH} + \text{pOH} = 14$$

$$K_a \times K_b = K_w \qquad pK_a = -\log K_a \qquad pK_b = -\log K_b$$

## Midterm 1 Equations

$$T(\text{in K}) = T(\text{in }^\circ\text{C}) + 273.15\text{ K} \qquad n = \frac{m}{M} \qquad \%\text{ Yield} = \frac{\text{actual yield}}{\text{theoretical yield}}$$

$$c(\text{mol / L}) = \frac{n}{V} \qquad m(\text{mol}/kg) = \frac{n_{solute}}{m_{solvent}} \qquad c_1V_1 = c_2V_2 = n$$

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2} \qquad pV = nRT \qquad p_T = p_1 + p_2 + p_3 + \ldots$$

$$p_A = X_A \times p_T \qquad X_A = \frac{n_A}{n_T} \qquad d = \frac{m}{V} = \frac{p \cdot MM}{RT}$$

$$E_K = \frac{1}{2}m\text{v}^2 \qquad u_{rms} = \sqrt{\frac{3RT}{M}} \qquad \frac{Rate\ A}{Rate\ B} = \sqrt{\frac{M_B}{M_A}}$$

$$\left(p + \frac{n^2a}{V^2}\right)(V - nb) = nRT \qquad w = -p\Delta V \qquad \Delta U = U_{final} - U_{initial} = q + w$$

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