

**FORMULA SHEET (tear off)**

1A											8A						
1 H 1.01	2A										3A	4A	5A	6A	7A	2 He 4.00	
3 Li 6.94	4 Be 9.01										5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18	
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	
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	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 72.64	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
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
55 Cs 132.9	56 Ba 137.3	71 Lu 175.0	72 Hf 178.5	73 Ta 181.0	74 W 183.8	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]
87 Fr [223]	88 Ra [226]	103 Lr [262]	104 Rf [261]	105 Db [262]	106 Sg [266]												
		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 157.2	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0		
		89 Ac [227]	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np [237]	94 Pu [244]	95 Am [243]	96 Cm [247]	97 Bk [247]	98 Cf [251]	99 Es [252]	100 Fm [257]	101 Md [258]	102 No [259]		

$$N_A = 6.022 \times 10^{23}$$

$$1 \text{ amu} = 1.661 \times 10^{-27} \text{ kg}$$

$$1 \text{ atm} = 760 \text{ torr} = 760 \text{ mm Hg}$$

$$R = 0.08206 \text{ L}\cdot\text{atm}/\text{mol}\cdot\text{K}$$

$$R = 8.314 \text{ J}/\text{mol}\cdot\text{K}$$

$$F = 96485 \text{ C}/\text{mol}$$

$$^\circ\text{C} = (5/9)(^\circ\text{F} - 32)$$

$$^\circ\text{C} = \text{K} - 273.15$$

$$1 \text{ atm} = 1.013 \text{ bar}$$

$$1 \text{ L}\cdot\text{atm} = 101.3 \text{ J}$$

$$1 \text{ J} = 1 \text{ kg}\cdot\text{m}^2/\text{s}^2$$

$$^\circ\text{F} = (9/5)(^\circ\text{C}) + 32$$

$$\text{K} = ^\circ\text{C} + 273.15$$

$$pV = nRT$$

$$(1 \text{ volt})(1 \text{ Coulomb}) = 1 \text{ Joule}$$

$$p_A = X_A p_A^\circ$$

$$\Delta T_b = K_b m_B$$

$$[B] = k p_B$$

$$\Delta T_f = K_f m_B$$

$$\Delta p_A = X_B p_A^\circ$$

$$\Pi = [B]RT$$

$$H = U + pV$$

$$\Delta G_{\text{rxn}} = \Delta G^\circ_{\text{rxn}} + RT \ln Q$$

$$G = H - TS$$

$$\ln K = -\Delta G^\circ_{\text{rxn}}/RT$$

$$K_p = K_C (RT)^{\Delta n}$$

$$\text{If } ax^2 + bx + c = 0, \text{ then } x = \left( \frac{-b \pm [b^2 - 4ac]^{1/2}}{2a} \right)$$

$$K_a \cdot K_b = K_w = 1.0 \times 10^{-14} \text{ (at } T = 25^\circ\text{C)}$$

$$\text{pH} = \text{p}K_a + \log_{10}\{[\text{base}]/[\text{acid}]\}$$

$$\Delta G = -nFE_{\text{cell}}$$

$$E_{\text{cell}} = E^\circ_{\text{cell}} - (RT/nF) \ln Q$$

$$\ln K = nFE^\circ_{\text{cell}}/RT$$

$$[A]_t = [A]_0 e^{-kt}$$

$$[A]_t = [A]_0 / (1 + kt[A]_0)$$

$$k = A e^{-E_a/RT}$$

$$\ln[A]_t = \ln[A]_0 - kt$$

$$(1/[A]_t) = (1/[A]_0) + kt$$

$$\ln k = \ln A - (E_a/R)(1/T)$$

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

$$t_{1/2} = 1/(k[A]_0)$$

$$\ln(k_2/k_1) = - (E_a/R) [ (1/T_2) - (1/T_1) ]$$

**GENERAL CHEMISTRY 2  
FINAL EXAM  
June 14, 2019**

**Name** \_\_\_\_\_

**Panthersoft ID** \_\_\_\_\_

**Signature** \_\_\_\_\_

**Part 1** \_\_\_\_\_ (50 points)

**Part 2** \_\_\_\_\_ (59 points)

**Part 3** \_\_\_\_\_ (91 points)

**TOTAL** \_\_\_\_\_ (200 points)

**Do all of the following problems. Show your work.**

**Part 1. Multiple choice.** Circle the letter corresponding to the correct answer. There is one and only one correct answer per problem. [5 points each]

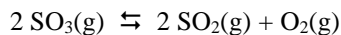
1) Which of the following mixtures of liquids is likely to form a solution?

- a) A mixture of two polar liquids
- b) A mixture of two nonpolar liquids
- D** c) A mixture of a polar liquid and a nonpolar liquid
- d) Both a and b
- e) Both a and c

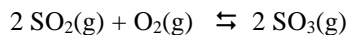
2) For a process to be spontaneous, which of the following must be true?

- a)  $\Delta S_{\text{univ}} > 0$
- b)  $\Delta S_{\text{syst}} > 0$
- A** c)  $\Delta S_{\text{surr}} > 0$
- d) Both b and c
- e) Both a and b and c

3) The numerical value for the equilibrium constant for the reaction



is  $K_C = 3.6 \times 10^{-7}$  at  $T = 350. \text{ }^\circ\text{C}$ . The numerical value for the equilibrium constant for the reaction



measured at the same temperature, is

- a)  $K_C = 3.6 \times 10^{-7}$
- b)  $K_C = 1.8 \times 10^{-5}$
- E** c)  $K_C = 6.0 \times 10^{-4}$
- d)  $K_C = 1.7 \times 10^3$
- e)  $K_C = 2.8 \times 10^6$

4) For an acidic aqueous solution at  $T = 25. \text{ }^\circ\text{C}$

- a)  $[\text{H}_3\text{O}^+] > 1.0 \times 10^{-7}$
- b)  $[\text{H}_3\text{O}^+] > [\text{OH}^-]$
- D** c)  $\text{pH} > 7.0$
- d) Both a and b
- e) Both a and b and c

5) Which of the following is a strong acid?

- a)  $\text{HClO}_4$
- b)  $\text{HI}$
- D** c)  $\text{HF}$
- d) Both a and b
- e) Both a and c

6) Consider the three substances  $\text{H}_2\text{SO}_4$ ,  $\text{H}_2\text{SeO}_4$ , and  $\text{H}_2\text{SeO}_3$ . Of these three substances

- a)  $\text{H}_2\text{SeO}_3$  is the strongest acid and  $\text{H}_2\text{SeO}_4$  is the weakest acid
- b)  $\text{H}_2\text{SeO}_4$  is the strongest acid and  $\text{H}_2\text{SeO}_3$  is the weakest acid
- D** c)  $\text{H}_2\text{SeO}_4$  is the strongest acid and  $\text{H}_2\text{SO}_4$  is the weakest acid
- d)  $\text{H}_2\text{SO}_4$  is the strongest acid and  $\text{H}_2\text{SeO}_3$  is the weakest acid
- e)  $\text{H}_2\text{SO}_4$  is the strongest acid and  $\text{H}_2\text{SeO}_4$  is the weakest acid

7) The indicator methyl red has  $pK_a = 5.1$ . Methyl red would be a good choice for an indicator for

- a) the titration of a strong acid with a strong base
- b) the titration of a strong base with a strong acid
- C** c) the titration of a weak base with a strong acid
- d) the titration of a weak acid with a strong base
- e) Methyl red would be a good choice of indicator for all of the above titrations

8) In which of the following substances does phosphorus have the largest value for oxidation number?

- a)  $PF_3(g)$
- b)  $P_4(s)$
- C** c)  $P_2O_5(s)$
- d)  $P_4O_6(s)$
- e)  $H_3PO_3(aq)$

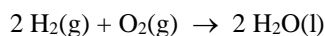
9) Consider the following two half cell reduction potentials



Based on this information, which reaction is most likely to occur for standard conditions

- a)  $Zn(s) \rightarrow Zn^{2+}(aq) + 2 e^-$
- b)  $Zn^{2+}(aq) + 2 e^- \rightarrow Zn(s)$
- A** c)  $Cu(s) \rightarrow Cu^{2+}(aq) + 2 e^-$
- d)  $Cu^{2+}(aq) + 2 e^- \rightarrow Cu(s)$
- e) All of these reactions are equally likely to occur for standard conditions

10) The stoichiometric equation for the reaction of hydrogen with oxygen to form water may be written as



This reaction is

- a) 2<sup>nd</sup> order with respect to  $H_2(g)$
- b) 2<sup>nd</sup> order with respect to  $O_2(g)$
- E** c) 2<sup>nd</sup> order with respect to  $H_2O(l)$
- d) Both a and c
- e) Cannot tell from the information given

## Part 2. Short answer questions.

1) A 1.358 mol/L solution of glycerol ( $C_3H_8O_3$ , MW = 92.09 g/mol) in water ( $H_2O$ , MW = 18.02 g/mol) has a density  $D = 1.029$  g/mL. What is the percent by mass glycerol in the solution? [10 points]

Assume 1.000 L solution. Then

$$\text{grams glycerol} = 1.000 \text{ L soln} \times \frac{1.358 \text{ mol glycerol}}{\text{L soln}} \times \frac{92.09 \text{ g}}{1 \text{ mol}} = 125.1 \text{ g glycerol}$$

$$\text{grams solution} = 1.000 \text{ L soln} \times \frac{1000. \text{ mL}}{\text{L soln}} \times \frac{1.029 \text{ g}}{\text{mL soln}} = 1029. \text{ g solution}$$

$$\text{So percent by mass} = \frac{125.1 \text{ g}}{1029. \text{ g}} \times 100 \% = 12.2 \% \text{ by mass}$$

2) A solution is prepared by dissolving 0.0681 g of potassium bromide (KBr, MW = 119.0 g/mol), a soluble ionic compound, in water, at T = 30.0 °C. The final volume of the solution formed is V = 200.0 mL. What is the osmotic pressure of the solution (relative to pure water)? Give your final answer in units of torr. [12 points]

$$[\text{KBr}] = \frac{0.0681 \text{ g KBr}}{0.2000 \text{ L}} \cdot \frac{1 \text{ mol}}{119.0 \text{ g}} = 2.61 \times 10^{-3} \text{ mol/L KBr}$$

$$[\text{particle}] = \frac{2.61 \times 10^{-3} \text{ mol}}{\text{L}} \cdot \frac{2 \text{ mol particle}}{1 \text{ mol KBr}} = 5.22 \times 10^{-3} \text{ mol/L particles}$$

$$\Pi = [\text{B}] RT = (5.22 \times 10^{-3} \text{ mol/L}) (0.08206 \text{ L}\cdot\text{atm/mol}\cdot\text{K}) (303. \text{ K}) = 0.142 \text{ atm} \cdot \frac{760 \text{ torr}}{1 \text{ atm}} = 108. \text{ torr}$$

3) Define the following terms [5 points each]

a) amphoteric

A substance that can act as either a Bronsted acid or a Bronsted base (H<sub>2</sub>O, for example).

b) buffer

A solution that is resistant to changes in pH. Buffers usually contain weak acid/conjugate base or weak base/conjugate acid pairs.

c) electrode

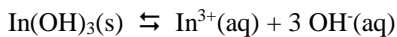
The site of an oxidation or reduction reaction in an electrochemical cell.



### Part 3. Problems

1) Thermochemistry is often useful in determining properties for substances that cannot be measured directly.

Consider the following reaction



Thermochemical data for the substances involved in the above reaction are given below.

Substance	$\Delta H^\circ_f$ (kJ/mol)	$\Delta G^\circ_f$ (kJ/mol)	$S^\circ$ (J/mol·K)
$\text{In}^{3+}(\text{aq})$	- 14.2	- 133.9	259.4
$\text{In(OH)}_3(\text{s})$	- 895.4	- 761.5	104.6
$\text{OH}^-(\text{aq})$	- 230.0	- 157.3	- 10.7

a) What are the values for  $\Delta S^\circ_{\text{rxn}}$  and  $\Delta G^\circ_{\text{rxn}}$  for the above reaction? [10 points]

$$\Delta S^\circ_{\text{rxn}} = [ S^\circ(\text{In}^{3+}(\text{aq})) + 3 S^\circ(\text{OH}^-(\text{aq})) ] - [ S^\circ(\text{In(OH)}_3(\text{s})) ]$$

$$= [ (259.4) + 3 ( - 10.7 ) ] - [ 104.6 ] = + 122.7 \text{ J/mol}\cdot\text{K}$$

$$\Delta G^\circ_{\text{rxn}} = [ \Delta G^\circ_f(\text{In}^{3+}(\text{aq})) + 3 \Delta G^\circ_f(\text{OH}^-(\text{aq})) ] - [ \Delta G^\circ_f(\text{In(OH)}_3(\text{s})) ]$$

$$= [ ( - 133.9 ) + 3 ( - 157.3 ) ] - [ - 761.5 ] = + 155.7 \text{ kJ/mol}$$

b) Give the expression for K (the equilibrium constant) for the above reaction, in terms of reactant and product concentrations. [5 points]

$$K = [\text{In}^{3+}] [\text{OH}^-]^3$$

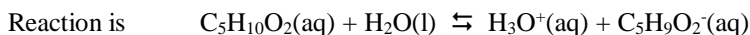
c) What is the numerical value for K, the equilibrium constant for the above reaction. [8 points]

$$\ln K = - \frac{\Delta G^\circ_{\text{rxn}}}{RT} = - \frac{(- 155700. \text{ J/mol})}{(8.314 \text{ J/mol}\cdot\text{K}) (298. \text{ K})} = - 62.84$$

$$K = e^{-62.84} = 5.1 \times 10^{-28}$$

2) Find the values for pH for the following two solutions.

a) A 0.0409 M solution of pivalic acid ( $C_5H_{10}O_2$ , MW = 102.1 g/mol), a weak monoprotic acid with  $K_a = 9.3 \times 10^{-6}$ . [10 points]



$K_a = \frac{[H_3O^+][C_5H_9O_2^-]}{[C_5H_{10}O_2]}$	$H_3O^+$	Initial	Change	Equilibrium
		0	x	x
	$C_5H_9O_2^-$	0	x	x
	$C_5H_{10}O_2$	0.0409	- x	0.0409 - x

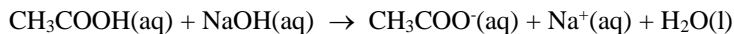
$\frac{(x)(x)}{(0.0409 - x)} = 9.3 \times 10^{-6}$  If we assume  $x \ll 0.0409$ , then

$\frac{x^2}{0.0409} = 9.3 \times 10^{-6}$        $x^2 = (9.3 \times 10^{-6})(0.0409) = 3.8 \times 10^{-7}$   
 $x = (3.8 \times 10^{-7})^{1/2} = 6.2 \times 10^{-4}$       So assumption was good.

$pH = -\log_{10}(6.2 \times 10^{-4}) = 3.21$

b) A solution that contains 0.0521 M of acetic acid ( $CH_3COOH$ , MW = 60.1 g/mol), a weak monoprotic acid with  $K_a = 1.8 \times 10^{-5}$ , and 0.0338 M sodium hydroxide ( $NaOH$ , MW = 40.0 g/mol), a strong soluble base. [15 points]

The neutralization reaction with  $NaOH$  is



Initial	0.0521	0.0338	
After neutralization	0.0183	0	0.0338

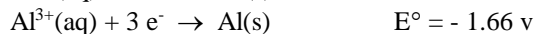
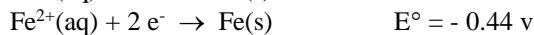
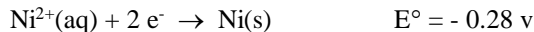
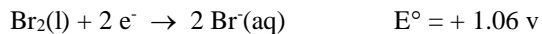
Since there are appreciable amounts of a weak acid and its conjugate base present, we can use the Henderson equation

$pH = pK_a + \log_{10}\left\{\frac{[base]}{[acid]}\right\} = -\log_{10}(1.8 \times 10^{-5}) + \log_{10}\left\{\frac{(0.0338)}{(0.0183)}\right\}$   
 $= 4.475 + 0.266 = 5.01$

Note: This problem can also be done by making an ICE table, using the concentrations present after the neutralization reaction is complete.



3) Several reduction reactions and their half-cell potentials for standard conditions are given below



a) Which of the following metals is easiest to oxidize (circle the correct answer)? [5 points]

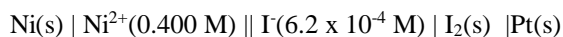
Ag(s)

Al(s)

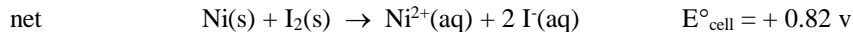
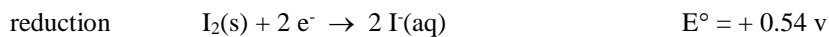
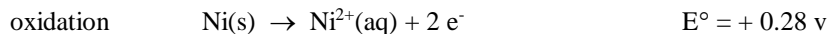
Fe(s)

Ni(s)

b) Consider the following galvanic cell



For the above galvanic cell, give the half-cell oxidation reaction, the half-cell reduction reaction, and the net cell reaction. Also find the values for  $E^\circ_{\text{cell}}$  and  $E_{\text{cell}}$  for the galvanic cell. [15 points]



From Nernst,  $E_{\text{cell}} = E^\circ_{\text{cell}} - (RT/nF) \ln Q$

$$Q = [\text{Ni}^{2+}] [\text{I}^-]^2 = (0.400) (6.2 \times 10^{-4})^2 = 1.5 \times 10^{-7}$$

$$E_{\text{cell}} = 0.82 \text{ v} - \frac{(8.314 \text{ J/mol}\cdot\text{K})(298. \text{ K}) \ln(1.5 \times 10^{-7})}{(2) (96485 \text{ Coulomb/mol})} = 0.82 \text{ v} + 0.20 \text{ v} = 1.02 \text{ v}$$

4) In the gas phase, dinitrogen pentoxide ( $\text{N}_2\text{O}_5$ , MW = 108.0 g/mol) decomposes to form nitrogen dioxide ( $\text{NO}_2$ , MW = 46.0 g/mol) and nitrogen trioxide ( $\text{NO}_3$ , MW = 62.0 g/mol). The balanced chemical equation for the reaction is



The reaction follows first order kinetics, with

$$\text{rate} = k [\text{N}_2\text{O}_5]$$

Experimentally, it is found that  $k = 3.4 \times 10^{-5} \text{ s}^{-1}$  at  $T = 30.0 \text{ }^\circ\text{C}$ , and  $k = 7.5 \times 10^{-4} \text{ s}^{-1}$  at  $T = 75.0 \text{ }^\circ\text{C}$ .

a) A system at  $T = 30.0 \text{ }^\circ\text{C}$  initially contains  $4.55 \times 10^{-2} \text{ mol/L}$  of  $\text{N}_2\text{O}_5$ . After 100.0 minutes, what will be the concentration of  $\text{N}_2\text{O}_5$  in the system? [8 points]

For first order kinetics,  $[\text{A}]_t = [\text{A}]_0 e^{-kt}$

$$T = 100.0 \text{ min (60 s/min)} = 6000. \text{ s}$$

$$\begin{aligned} \text{So } [\text{N}_2\text{O}_5]_t &= (4.55 \times 10^{-2} \text{ mol/L}) \exp(- (3.4 \times 10^{-5} \text{ s}^{-1}) (6000. \text{ s})) \\ &= (4.55 \times 10^{-2} \text{ mol/L}) (0.8155) = 3.71 \times 10^{-2} \text{ mol/L} \end{aligned}$$

b) Assuming the rate constant for this reaction obeys the Arrhenius equation, find the values for A and  $E_a$  (including correct units). [15 points]

$$\ln(k_2/k_1) = - (E_a/R) [ (1/T_2) - (1/T_1) ]$$

$$\begin{aligned} \text{So } E_a &= - \frac{R \ln(k_2/k_1)}{[ (1/T_2) - (1/T_1) ]} = - \frac{(8.314 \text{ J/mol}\cdot\text{K}) \ln(7.5 \times 10^{-4}/3.4 \times 10^{-5})}{[ (1/348.\text{K}) - (1/303. \text{K}) ]} \\ &= 60270. \text{ J/mol} = 60.27 \text{ kJ/mol} \end{aligned}$$

Since  $k = A e^{-E_a/RT}$ , then

$A = k e^{+E_a/RT}$ . We can use either value for k. If we use the value at  $T = 30. \text{ }^\circ\text{C}$ , then

$$\begin{aligned} A &= (3.4 \times 10^{-5} \text{ s}^{-1}) \exp[ (60270. \text{ J/mol})/(8.314 \text{ J/mol}\cdot\text{K})(303. \text{ K})] \\ &= (3.4 \times 10^{-5} \text{ s}^{-1}) \exp(23.92) = 8.4 \times 10^5 \text{ s}^{-1} \end{aligned}$$