



# DO NOT OPEN

## UNTIL INSTRUCTED TO DO SO

*CHEM 111 – Dr. McCorkle – Exam #3A **KEY***

While you wait, please complete the following information:

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

**Student ID:** \_\_\_\_\_

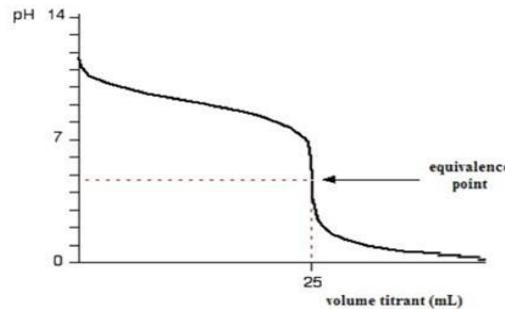
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# Periodic Table of the Elements

GROUP	PERIOD	VIIIA																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	2
IA	IIA	IIIA	IVIA	VIA	VIIA	VIIIA	III A	IV A	V A	VI A	VII A	VIIIA	He						
1	H 1.01																		4.00
2	Li 6.94	Be 9.01																	Ne
3	Na 22.99	Mg 24.31	Al 31.00	Si 28.09	Cl 35.45	P 30.97	S 32.07	Cl 35.45											20.18
4	K 39.10	Ca 40.08	Sc 44.96	Ti 47.88	V 50.94	Cr 52.00	Mn 54.94	Fe 55.85	Co 58.93	Ni 58.69	Cu 63.55	Zn 65.39	Ga 69.72	Ge 72.61	As 74.92	Se 78.97	Br 79.90	Kr 83.80	
5	Rb 85.47	Sr 87.62	Y 88.91	Zr 91.22	Nb 92.91	Mo 95.95	Tc (98)	Ru 101.07	Rh 102.91	Pd 106.42	Ag 107.87	Cd 112.41	In 114.82	Sn 118.71	Sb 121.75	Te 127.60		53	
6	Cs 132.91	Ba 137.33	La * 138.91	Hf 178.49	Ta 180.95	W 183.85	Re 186.21	Os 190.23	Ir 192.22	Pt 195.08	Au 196.97	Hg 200.59	Tl 204.38	Pb 207.2	Bi 208.98	Po (209)		54	
7	Fr (223)	Ra (226)	Ac ** (227)	Fr (267)	Db (268)	Sg (271)	Bh (270)	Hs (277)	Mt (276)	Ds (281)	Rg (280)	Cn (285)	Uut (284)	Fl (289)	Uup (288)	Ly (293)	Uus (294)	Uuo (294)	
<b>Lanthanide Series *</b>		58	59	60	61	62	63	64	65	66	67	68	69	70	71				
		Ce 140.12	Pr 140.91	Nd 144.24	Pm (145)	Sm 150.36	Eu 151.96	Gd 157.25	Tb 158.93	Dy 162.50	Ho 164.93	Er 167.26	Tm 168.93	Yb 173.05					
<b>Actinide Series **</b>		90	91	92	93	94	95	96	97	98	99	100	101	102	103				
		Th 232.04	Pa 231.04	U 238.03	Np (237)	Am (243)	Fm (247)	Cm (247)	Bk (247)	Cf (251)	Md (257)	No (258)							

**Multiple Choice – Choose the answer that best completes the question. Use an 815-E Scantron to record your response. [2 points each]**

1. Which of the following combinations is the best choice for creating a buffer solution with a pH of 3.50?  
A) **HNO<sub>2</sub>/KNO<sub>2</sub>**      B) HCl/NaCl      C) NH<sub>3</sub>/NH<sub>4</sub>F  
D) HCHO<sub>2</sub>/NaC<sub>2</sub>H<sub>3</sub>O<sub>2</sub>      E) HClO<sub>2</sub>/NaClO<sub>2</sub>
2. If  $\Delta S$  is positive and  $\Delta H$  is positive, when is the reaction spontaneous?  
A) **high temperatures**      B) low temperatures      C) all temperatures  
D) never
3. Which of the following is more soluble in acidic solution than in pure water?  
A) AgCl      B) **MgCO<sub>3</sub>**      C) CaBr<sub>2</sub>      D) Ba(NO<sub>3</sub>)<sub>2</sub>      E) NaI
4. If the  $pK_a$  of HCHO<sub>2</sub> is 3.74 and the pH of an HCHO<sub>2</sub>/NaCHO<sub>2</sub> solution is 3.11, which of the following is true?  
A) [HCHO<sub>2</sub>] < [NaCHO<sub>2</sub>]  
B) [HCHO<sub>2</sub>] = [NaCHO<sub>2</sub>]  
C) [HCHO<sub>2</sub>] << [NaCHO<sub>2</sub>]  
**D) [HCHO<sub>2</sub>] > [NaCHO<sub>2</sub>]**  
E) It is not possible to make a buffer of this pH from HCHO<sub>2</sub> and NaCHO<sub>2</sub>.
5. The plot at right illustrates which type of titration?  
A) a weak acid titrated with a weak base  
B) a weak acid titrated with a strong base  
C) a strong base titrated with a weak acid  
**D) a weak base titrated with a strong acid**  
E) a weak base titrated with a weak acid
6. Without doing any calculations, which of the following processes would you expect to be spontaneous?  
A)  $2 \text{ KCl}(s) + 3 \text{ O}_2(g) \rightarrow 2 \text{ KClO}_3(s)$   
B)  $2 \text{ H}_2\text{S}(g) + 3 \text{ O}_2(g) \rightarrow 2 \text{ H}_2\text{O}(g) + 2 \text{ SO}_2(g)$   
C)  $\text{HCl}(g) + \text{NH}_3(g) \rightarrow \text{NH}_4\text{Cl}(g)$   
**D)  $\text{NaCl}(s) \rightarrow \text{Na}(s) + \frac{1}{2} \text{ Cl}_2(g)$**   
E)  $\text{N}_2(g) + 3 \text{ H}_2(g) \rightarrow 2 \text{ NH}_3(g)$



7. The \_\_\_\_\_ Law of Thermodynamics states that for any spontaneous process, the entropy of the universe increases.
- A) Zero      B) First      C) **Second**      D) Third      E) Fourth
8. A process is always spontaneous under which conditions?
- A) positive  $\Delta S$  and positive  $\Delta H$   
B) negative  $\Delta S$  and positive  $\Delta H$   
**C) positive  $\Delta S$  and negative  $\Delta H$**   
D) negative  $\Delta S$  and negative  $\Delta H$   
E) no process is always spontaneous
9. Place the following in increasing order of molar entropy at 298 K: NO, CO, SO
- A) NO < CO < SO  
B) SO < CO < NO  
C) SO < NO < CO  
D) CO < SO < NO  
**E) CO < NO < SO**
10. A reaction that is spontaneous as written \_\_\_\_\_.
- A) has an equilibrium position that lies far to the left  
B) is also spontaneous in the reverse direction  
**C) will proceed without outside intervention**  
D) is very rapid  
E) is very slow

**Calculations – Write your initials in the upper-right corner of every page that contains work. For full credit show all work and write neatly; give answers with correct significant figures and units. Place a box around your final answer.**

11. Use the Henderson–Hasselbalch equation to calculate the pH of a solution that is 10.0 g of  $\text{HC}_2\text{H}_3\text{O}_2$  and 12.0 g of  $\text{NaC}_2\text{H}_3\text{O}_2$  in 150.0 mL of solution. ( $K_a = 1.8 \times 10^{-5}$ ) [4 points]

$$[\text{HC}_2\text{H}_3\text{O}_2] = 10.0 \text{ g} \times \frac{1 \text{ mol HC}_2\text{H}_3\text{O}_2}{60.06 \text{ g}} = 0.1665 \div 0.1500 \text{ L} = 1.11 \text{ M}$$

$$[\text{NaC}_2\text{H}_3\text{O}_2] = 12.0 \text{ g} \times \frac{1 \text{ mol HC}_2\text{H}_3\text{O}_2}{82.04 \text{ g}} = 0.1462 \div 0.1500 \text{ L} = 0.975 \text{ M}$$

$$\text{pH} = \text{p}K_a + \log \frac{[\text{base}]}{[\text{acid}]}$$

$$\text{pH} = 4.74 + \log \frac{0.975 \text{ M}}{1.11 \text{ M}}$$

$$\text{pH} = 4.68$$

12. What mass of sodium benzoate ( $\text{NaC}_7\text{H}_5\text{O}_2$ ) should be added to 180.0 mL of a 0.16 M benzoic acid ( $\text{HC}_7\text{H}_5\text{O}_2$ ) solution in order to obtain a buffer with a pH of 4.25? ( $K_a = 6.5 \times 10^{-5}$ ) [5]

$$\text{pH} = \text{p}K_a + \log \frac{[\text{base}]}{[\text{acid}]}$$

$$4.25 = 4.19 + \log \frac{[\text{base}]}{[\text{acid}]}$$

$$0.06 = \log \frac{[\text{base}]}{[\text{acid}]}$$

$$\frac{[\text{base}]}{[\text{acid}]} = 10^{0.06} = 1.15$$

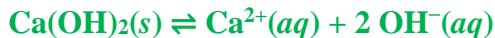
$$[\text{base}] = 1.15 [\text{acid}] = 1.15 (0.16) = 0.184 \text{ M}$$

$$[\text{base}] = 0.1800 \text{ L} \times \frac{0.184 \text{ mol}}{\text{L}} \times \frac{144.11 \text{ g}}{1 \text{ mol}} = 4.8 \text{ g}$$

13. Calculate the molar solubility of calcium hydroxide in a solution buffered at pH = 9.00.  
 $(K_{sp} = 4.68 \times 10^{-6})$  [5]

$$\text{pH} + \text{pOH} = 14 \quad \text{pOH} = 14 - 9.00 = 5.00$$

$$[\text{OH}^-] = 10^{-5.00} = 1.0 \times 10^{-5} M$$



I	--	0	$1.0 \times 10^{-5} M$
C		+S	$+2S$
E		S	$1.0 \times 10^{-5} + 2S$ $\approx 1.0 \times 10^{-5}$

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

$$4.68 \times 10^{-6} = (S)(1.0 \times 10^{-5})^2$$

$$S = 4.7 \times 10^4 M$$

14. Will a precipitate of MgF<sub>2</sub> form when 300. mL of  $1.1 \times 10^3 M$  MgCl<sub>2</sub> solution are added to 500. mL of  $1.2 \times 10^3 M$  NaF? ( $\text{MgF}_2, K_{sp} = 6.9 \times 10^9$ ) [5]



$$[\text{Mg}^{2+}]_{\text{initial}} = 1.1 \times 10^3 M$$

$$M_2 = \frac{M_1 V_1}{V_2} = \frac{(1.1 \times 10^3)(300. \text{ mL})}{(800. \text{ mL})} = 4.13 \times 10^2 M$$

$$[\text{F}^-]_{\text{initial}} = 1.2 \times 10^3 M$$

$$M_2 = \frac{M_1 V_1}{V_2} = \frac{(1.2 \times 10^3)(500. \text{ mL})}{(800. \text{ mL})} = 7.50 \times 10^2 M$$

$$Q = [\text{Mg}^{2+}][\text{F}^-]^2 = (4.13 \times 10^2)(7.50 \times 10^2)^2 = 2.3 \times 10^8$$

$Q < K_{sp}$  so a precipitate will NOT form

15. A 0.327 g sample of an unknown monoprotic acid was titrated with 0.127 M KOH. The equivalence point was determined to be 30.5 mL. What is the molar mass of the unknown acid? [3]

$$0.0305 \text{ L} \times \frac{0.127 \text{ mol KOH}}{\text{L}} = 3.87 \times 10^{-3} \text{ mol KOH}$$

**At equivalence point, moles acid = moles base**

$$\text{Molar mass} = \frac{0.327 \text{ g}}{3.87 \times 10^{-3} \text{ mol}} = 84.5 \text{ g/mol}$$

16. 250.0 mL of  $1.3 \times 10^{-4} \text{ M}$   $\text{Zn}(\text{NO}_3)_2$  is mixed with 175.0 mL of 0.150 M  $\text{NH}_3$ . After the solution reaches equilibrium, what concentration of  $\text{Zn}^{2+}(aq)$  remains? ( $[\text{Zn}(\text{NH}_3)_4]^{2+}$ ,  $K_f = 2.8 \times 10^9$ ) [7]



$$[\text{Zn}^{2+}] = \frac{(0.2500 \text{ L} \times 1.3 \times 10^{-4} \text{ M})}{(0.2500 \text{ L} + 0.1750 \text{ L})} = 7.65 \times 10^{-5} \text{ M}$$

$$[\text{NH}_3] = \frac{(0.1750 \text{ L} \times 0.150 \text{ M})}{(0.1750 \text{ L} + 0.2500 \text{ L})} = 6.18 \times 10^{-2} \text{ M}$$

I	$\text{Zn}^{2+}(aq)$	$+ 4 \text{ NH}_3(aq)$	$\rightleftharpoons [\text{Zn}(\text{NH}_3)_4]^{2+}(aq)$
	$7.65 \times 10^{-5}$	$6.18 \times 10^{-2}$	0

$K_f$  is large and  $[\text{NH}_3] \gg [\text{Zn}^{2+}]$  so assume most  $\text{Zn}^{2+}$  is consumed. Let  $x$  represent the amount of  $\text{Zn}^{2+}$  left.

C	$\approx (-7.65 \times 10^{-5})$	$\approx 4(-7.65 \times 10^{-5})$	$\approx (+7.65 \times 10^{-5})$
E	x	$6.18 \times 10^{-2}$	$7.65 \times 10^{-5}$

$$K_f = \frac{[\text{Zn}(\text{NH}_3)_4]^{2+}}{[\text{Zn}^{2+}][\text{NH}_3]^4} = \frac{7.65 \times 10^{-5}}{(x)(6.18 \times 10^{-2})^4}$$

$$x = \frac{7.65 \times 10^{-5}}{(K_f)(6.18 \times 10^{-2})^4} = \frac{7.65 \times 10^{-5}}{(2.8 \times 10^9)(6.18 \times 10^{-2})^4} = 1.9 \times 10^{-9} \text{ M}$$

17. Calculate the pH after 0.010 mol HCl is added to 225.0 mL of a buffer solution that is 0.10 M ethylamine and 0.15 M ethylammonium nitrate? (ethylamine,  $K_b = 6.4 \times 10^{-4}$ ) [7]



$$\text{CH}_3\text{CH}_2\text{NH}_2 = 0.2250 \text{ L} \times 0.10 \text{ M} = 0.0225 \text{ mol}$$

$$\text{CH}_3\text{CH}_2\text{NH}_3^+ = 0.2250 \text{ L} \times 0.15 \text{ M} = 0.0338 \text{ mol}$$

	$\text{CH}_3\text{CH}_2\text{NH}_2$	$\text{H}_3\text{O}^+$	$\text{CH}_3\text{CH}_2\text{NH}_3^+$
Before	0.0225 mol	0.010 mol	0.0338 mol
Change	- 0.010 mol	- 0.010 mol	+ 0.010 mol
After	0.0125 mol	0	0.0438 mol

$$K_a = K_w / K_b = 1 \times 10^{-14} / 6.4 \times 10^{-4} = 1.6 \times 10^{-11}$$

$$\text{p}K_a = 10.80$$

$$\text{pH} = \text{p}K_a + \log \frac{[\text{base}]}{[\text{acid}]}$$

$$\text{pH} = 10.80 + \log \frac{0.0125}{0.0438}$$

$$\text{pH} = 10.26$$

18. Consider the reaction:  $2 \text{ Hg}(g) + \text{O}_2(g) \rightarrow 2 \text{ HgO}(s)$        $\Delta G^\circ = -180.8 \text{ kJ}$

Calculate  $\Delta G_{\text{rxn}}$  at 25°C under these conditions:  $P_{\text{Hg}} = 0.025 \text{ atm}$ ,  $P_{\text{O}_2} = 0.037 \text{ atm}$  [5]

$$Q = \frac{1}{P_{\text{Hg}}^2 \cdot P_{\text{O}_2}} = \frac{1}{(0.025)^2 (0.037)} = 4.32 \times 10^4$$

$$\Delta G = \Delta G^\circ + RT \ln Q$$

$$\Delta G = \left( -180.8 \text{ kJ} \times \frac{10^3 \text{ J}}{1 \text{ kJ}} \right) + \left( 8.314 \frac{\text{J}}{\text{mol} \cdot \text{K}} \times 298 \text{ K} \right) \ln(4.32 \times 10^4)$$

$$\Delta G = -1.5 \times 10^5 \text{ J} = -1.5 \times 10^2 \text{ kJ}$$

19. Consider the titration of 30.00 mL of 0.0800 M acetic acid ( $\text{HC}_2\text{H}_3\text{O}_2$ ,  $K_a = 1.8 \times 10^{-5}$ ) with 0.1600 M NaOH. Calculate the pH of the resulting solution after the following volumes of NaOH have been added. [15]



	$\text{HC}_2\text{H}_3\text{O}_2$	$\text{OH}^-$	$\text{C}_2\text{H}_3\text{O}_2^-$
Before	$2.40 \times 10^{-3}$ mol	$1.60 \times 10^{-3}$ mol	0 mol
Change	$-1.60 \times 10^{-3}$ mol	$-1.60 \times 10^{-3}$ mol	$+1.60 \times 10^{-3}$ mol
After	$0.80 \times 10^{-3}$ mol	0 mol	$1.60 \times 10^{-3}$ mol

$$\text{pH} = \text{p}K_a + \log \frac{[\text{base}]}{[\text{acid}]}$$

$$\text{pH} = 4.74 + \log \frac{(1.60 \times 10^{-3})}{(0.80 \times 10^{-3})}$$

$$\text{pH} = 5.04$$



	$\text{HC}_2\text{H}_3\text{O}_2$	$\text{OH}^-$	$\text{C}_2\text{H}_3\text{O}_2^-$
Before	$2.40 \times 10^{-3}$ mol	$2.40 \times 10^{-3}$ mol	0 mol
Change	$-2.40 \times 10^{-3}$ mol	$-2.40 \times 10^{-3}$ mol	$+2.40 \times 10^{-3}$ mol
After	0 mol	0 mol	$2.40 \times 10^{-3}$ mol

Only weak base left,  $K_b = 5.6 \times 10^{-10}$

$$[\text{C}_2\text{H}_3\text{O}_2^-] = \frac{2.40 \times 10^{-3} \text{ mol}}{(0.03000 \text{ L} + 0.01500 \text{ L})} = 0.0533 \text{ M}$$



$$5.6 \times 10^{-10} = \frac{[\text{HC}_2\text{H}_3\text{O}_2][\text{OH}^-]}{[\text{C}_2\text{H}_3\text{O}_2^-]} = \frac{x^2}{0.0533}$$

$$x = 5.5 \times 10^{-6} = [\text{OH}^-] \quad \text{pOH} = -\log(5.5 \times 10^{-6}) = 5.26 \quad \text{pH} = 8.74$$

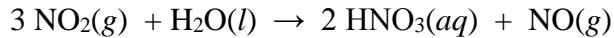


	$\text{HC}_2\text{H}_3\text{O}_2$	$\text{OH}^-$	$\text{C}_2\text{H}_3\text{O}_2^-$
Before	$2.4 \times 10^{-3}$ mol	$3.2 \times 10^{-3}$ mol	0 mol
Change	$-2.4 \times 10^{-3}$ mol	$-2.4 \times 10^{-3}$ mol	$+2.4 \times 10^{-3}$ mol
After	0 mol	$0.8 \times 10^{-3}$ mol	$2.4 \times 10^{-3}$ mol

$$[\text{OH}^-] = \frac{0.8 \times 10^{-3} \text{ mol}}{(0.03000 \text{ L} + 0.02000 \text{ L})} = \frac{0.8 \times 10^{-3} \text{ mol}}{0.05000 \text{ L}} = 0.016 \text{ M}$$

$$\text{pOH} = -\log[\text{OH}^-] = -\log(0.016) = 1.80 \quad \text{pH} = 14 - 1.80 = 12.20$$

20. Using the data provided, calculate  $\Delta H^\circ$ ,  $\Delta S^\circ$  and  $\Delta G^\circ$  at 298K for the following reaction.  
Also, show that  $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ . [8]



Substance	$\Delta H_f^\circ$ (kJ/mol)	$\Delta G_f^\circ$ (kJ/mol)	$S^\circ$ (J/mol·K)
$\text{H}_2\text{O}(l)$	-285.8	-237.1	70.0
$\text{HNO}_3(aq)$	-207	-110.9	146
$\text{NO}(g)$	91.3	87.6	210.8
$\text{NO}_2(g)$	33.2	51.3	240.1

$$\Delta H^\circ_{\text{rxn}} = \sum n(\Delta H^\circ_{\text{prod}}) - \sum n(\Delta H^\circ_{\text{reac}})$$

$$\Delta H^\circ_{\text{rxn}} = (2 \times -207 + 91.3) - (3 \times 33.2 + -285.8) = -136.5 \text{ kJ}$$

$$\Delta S^\circ_{\text{rxn}} = \sum n(S^\circ_{\text{prod}}) - \sum n(S^\circ_{\text{reac}})$$

$$\Delta S^\circ_{\text{rxn}} = (2 \times 146 + 210.8) - (3 \times 240.1 + 70.0) = -287.5 \text{ J/K}$$

$$\Delta G^\circ_{\text{rxn}} = \sum n(\Delta G^\circ_{\text{prod}}) - \sum n(\Delta G^\circ_{\text{reac}})$$

$$\Delta G^\circ_{\text{rxn}} = (2 \times -110.9 + 87.6) - (3 \times 51.3 + -237.1) = -51.0 \text{ kJ}$$

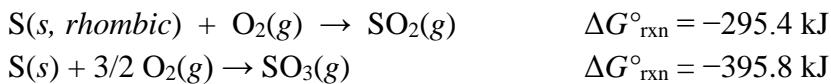
$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

$$\Delta G^\circ = -136.5 \text{ kJ} - (298 \text{ K} \times -287.5 \frac{\text{J}}{\text{K}} \times \frac{1 \text{ kJ}}{10^3 \text{ J}}) = 50.8 \text{ kJ}$$

Same via both methods  
 (when considering significant digits)

21. **Challenge Question:** Consider the following reaction:  $2 \text{SO}_2(g) + \text{O}_2(g) \rightarrow 2 \text{SO}_3(g)$

Using the information below, solve for the  $\Delta H^\circ_f$  of  $\text{SO}_3$ . [10 points]



Substance	$\Delta H^\circ_f$ (kJ/mol)	$S^\circ$ (J/mol·K)
$\text{O}_2(g)$	0	205.2
$\text{S(s, rhombic)}$	0	32.1
$\text{SO}_2(g)$	-296.8	248.2
$\text{SO}_3(g)$	???	256.8



$$\Delta S^\circ_{\text{rxn}} = \sum n(S^\circ_{\text{prod}}) - \sum n(S^\circ_{\text{reac}})$$

$$\Delta S^\circ_{\text{rxn}} = (2 \times 256.8) - (2 \times 248.2 + 205.2) = 188.0 \text{ J/K}$$

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

$$\Delta H^\circ = \Delta G^\circ + T\Delta S^\circ$$

$$\Delta H^\circ = -200.8 \text{ kJ} + (298 \text{ K} \times -188.0 \frac{\text{J}}{\text{K}} \times \frac{1 \text{ kJ}}{10^3 \text{ J}}) = -256.8 \text{ kJ}$$

$$\Delta H^\circ_{\text{rxn}} = \sum n(\Delta H^\circ_{\text{prod}}) - \sum n(\Delta H^\circ_{\text{reac}})$$

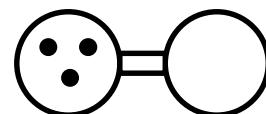
$$\Delta H^\circ_{\text{rxn}} = [2 \times \Delta H^\circ(\text{SO}_3)] - [2 \times \Delta H^\circ(\text{SO}_2) + \Delta H^\circ(\text{O}_2)]$$

$$-256.8 \text{ kJ} = [2 \times \Delta H^\circ(\text{SO}_3)] - [2 \times -296.8 + 0]$$

$$2 \times \Delta H^\circ(\text{SO}_3) = -850.4 \text{ kJ}$$

$$\Delta H^\circ(\text{SO}_3) = -425.2 \text{ kJ}$$

**Extra Credit:** Consider two flasks that are joined together, one evacuated and one containing 3 molecules of a gas. When the flasks are allowed to mix, how many microstates are possible? [2 points]



**8 possible microstates**

**Scratch Page**  
**(to be handed in)**

## Formulas & Constants

$$M = \frac{\text{mol solute}}{\text{liters solution}}$$

$$m = \frac{\text{mol solute}}{\text{kg solvent}}$$

$$\chi_A = \frac{\text{mol A}}{\text{total moles}}$$

$$P_A = \chi_A \cdot P_A^0$$

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

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

$$\Delta T_f = \underline{m} \cdot K_f$$

$$\Delta T_b = \underline{m} \cdot K_b$$

$$\Pi = \underline{M}RT$$

$$\Delta T_f = i \cdot \underline{m} \cdot K_f$$

$$\Delta T_b = i \cdot \underline{m} \cdot K_b$$

$$\Pi = i \cdot \underline{M}RT$$

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

$$1 \text{ atm} = 760 \text{ torr} = 760 \text{ mmHg}$$

$$S_{\text{gas}} = k_H \cdot P_{\text{gas}}$$

$$\Delta H_{\text{sol'n}} = \Delta H_{\text{hydration}} - \Delta H_{\text{lattice}}$$

$$f = e^{-E_a/RT}$$

$$k = Ae^{-E_a/RT}$$

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

$$\ln k = -\frac{E_a}{R} \left( \frac{1}{T} \right) + \ln A$$

$$1 \text{ V} = 1 \text{ J/C}$$

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

$$K_w = 1.0 \times 10^{-14}$$

$$K_a \times K_b = K_w$$

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

$$\text{pH} = \text{p}K_a + \log \frac{[\text{base}]}{[\text{acid}]}$$

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

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

$$\Delta G = \Delta G^\circ + RT \ln Q$$

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

$$\Delta S^\circ_{\text{rxn}} = \sum n(S^\circ_{\text{prod}}) - \sum n(S^\circ_{\text{reac}})$$

$$\Delta H^\circ_{\text{rxn}} = \sum n(\Delta H^\circ_{\text{prod}}) - \sum n(\Delta H^\circ_{\text{reac}}) \quad K = e^{-\Delta G^\circ/RT}$$

$$\Delta G^\circ = -nFE^\circ$$

$$\Delta G^\circ_{\text{rxn}} = \sum n(\Delta G^\circ_{\text{prod}}) - \sum n(\Delta G^\circ_{\text{reac}}) \quad F = 96,485 \text{ J/V} \cdot \text{mol}$$

$$S = k \ln W$$

$$k = 1.38 \times 10^{-38} \text{ J/K}$$

$$1 \text{ A} = 1 \text{ C/s}$$

$$E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$$

$$E = E^\circ - (0.0592/n) \log Q$$

$$E = E^\circ - (RT/nF) \ln Q$$

Order in [A]	Rate Law	Integrated Form, $y = mx + b$	Straight Line Plot	Half-Life $t_{1/2}$
zero-order (n = 0)	$\text{rate} = k [A]^0 = k$	$[A]_t = -kt + [A]_0$	$[A]_t$ vs. $t$	$t_{1/2} = \frac{[A]_0}{2k}$
first-order (n = 1)	$\text{rate} = k [A]^1$	$\ln[A]_t = -kt + \ln[A]_0$	$\ln[A]_t$ vs. $t$	$t_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{k}$
second-order (n = 2)	$\text{rate} = k [A]^2$	$\frac{1}{[A]_t} = kt + \frac{1}{[A]_0}$	$\frac{1}{[A]_t}$ vs. $t$	$t_{1/2} = \frac{1}{k[A]_0}$

**Various Constants at 25°C**

Substance	Formula	
Formic acid	HCHO <sub>2</sub>	$K_a = 1.8 \times 10^{-4}$
Chlorous acid	HClO <sub>2</sub>	$K_a = 1.1 \times 10^{-2}$
Nitrous acid	HNO <sub>2</sub>	$K_a = 4.6 \times 10^{-4}$
Ammonia	NH <sub>3</sub>	$K_b = 1.76 \times 10^{-5}$
Ethylamine	CH <sub>3</sub> CH <sub>2</sub> NH <sub>2</sub>	$K_b = 6.4 \times 10^{-4}$
Magnesium fluoride	MgF <sub>2</sub>	$K_{sp} = 6.9 \times 10^9$
Tetraamminezinc(II) ion	[Zn(NH <sub>3</sub> ) <sub>4</sub> ] <sup>2+</sup>	$K_f = 2.8 \times 10^9$