

## Recitation Worksheet Five

Name:

MyID:

### Textbook:

Chemistry & Chemical Reactivity

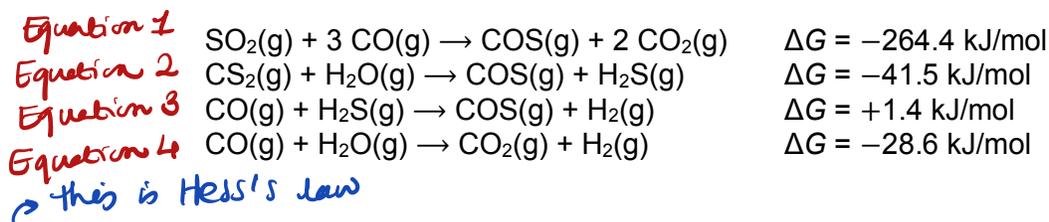
by John C. Kotz, Paul M. Treichel, John R. Townsend, David Treichel

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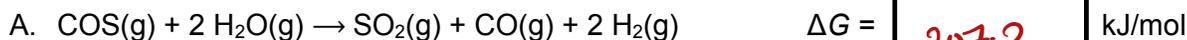
### Instructions:

- This recitation worksheet covers Ch. 18.3-18.6, 13.1-13.3
- Please enter your first and last name as it appears on the eLC roster (do not use a nickname that is not reflected in eLC).
- Your UGA myID is a combination of letters and numbers (example: Dr. Abdelrahman's MyID is ema88805@uga.edu). **Do not use your 81x number.**
- Your completed worksheet has to be submitted to **Gradescope**. You have multiple options for submission:
  - You may use an app to annotate the worksheet by placing your answers in the answer boxes and showing your work when appropriate. Afterward, submit the worksheet to Gradescope. You will not need to upload anything to eLC.
  - You may print out the worksheet, write your answers in the answer boxes, and show your work on it when appropriate. Afterward, convert the worksheet to a PDF and submit to Gradescope. You will not need to upload anything to eLC.
  - If you do not have access to a printer, you may type your answers directly into the worksheet PDF and then submit it to Gradescope. Write your work on separate sheets of paper, convert them to a PDF, and upload to the appropriate dropbox on eLC.
  - There is a Gradescope app available for both iOS and Android devices that allows you to scan and submit your printed work, or you can submit your fillable PDF directly.
- The following criteria **must** be met to be eligible for full credit:
  - You must make sure the pages are in the correct order and have the same layout as the original worksheet when submitting to Gradescope regardless of your submission type.
  - Answers must be written in the corresponding answer boxes.
  - You must show your work when appropriate.
- This worksheet is due no later than **12:00 PM (noon) on the Saturday, September 28<sup>th</sup>**.
- A periodic table and formula sheet are attached to the end of this worksheet. Please keep these attached to your worksheet in the correct order when submitting to Gradescope.

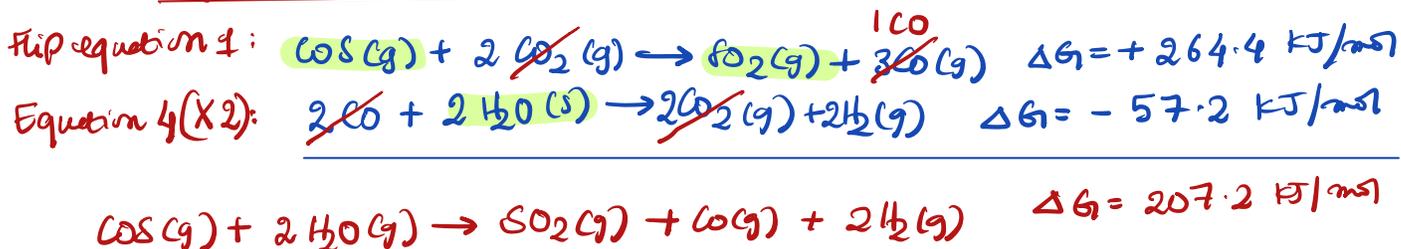
1. You are given a list of reactions below along with  $\Delta G$  values.



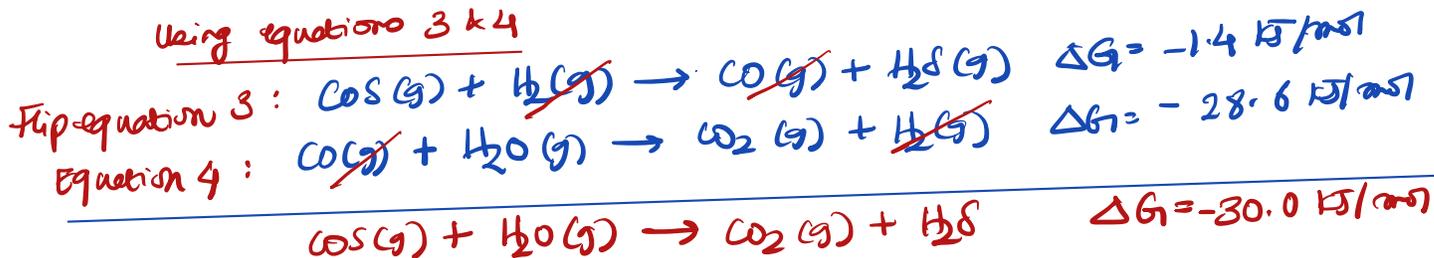
Combine the equations as necessary to obtain  $\Delta G$  values for the following reactions:



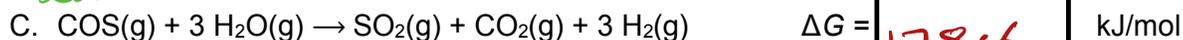
using equations 1 & 4



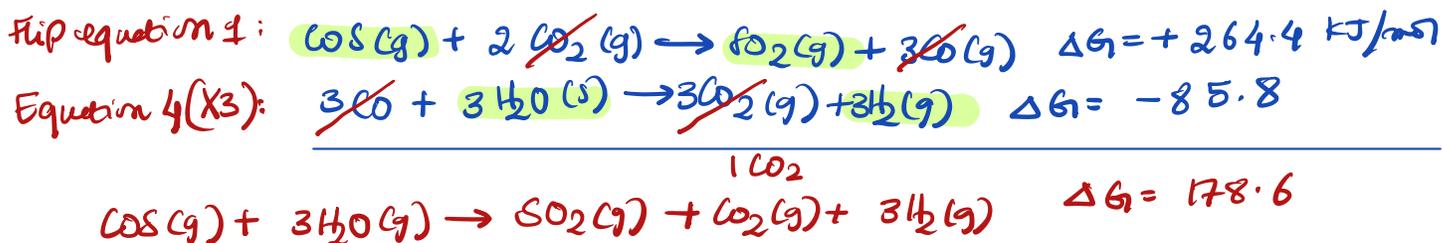
Using equations 3 & 4



Same as part A but instead multiply equation 4 times 3



using equations 1 & 4



2. Which of the reactions below will be spontaneous at **only at low temperatures**? Select all that apply. Insert letters without spaces in the answer box, example **ABCD**.

**ADE**

- A.  $2 \text{CO(g)} + \text{O}_2\text{(g)} \rightarrow 2 \text{CO}_2\text{(g)}$   $\Delta H_{\text{rxn}} = -566.0 \text{ kJ/mol}$   $\Delta S < 0$   
 B.  $2 \text{NO}_2\text{(g)} \rightarrow 2 \text{NO(g)} + \text{O}_2\text{(g)}$   $\Delta H_{\text{rxn}} = +1131.1 \text{ kJ/mol}$   $\Delta S > 0$  *Spontaneous only at high temperatures*  
 C.  $\text{NH}_4\text{CO}_2\text{NH}_2\text{(s)} \rightarrow 2 \text{NH}_3\text{(g)} + \text{CO}_2\text{(g)}$   $\Delta H_{\text{rxn}} = +159.2 \text{ kJ/mol}$   $\Delta S > 0$   
 D.  $\text{PCl}_3\text{(g)} + \text{Cl}_2\text{(g)} \rightarrow \text{PCl}_5\text{(g)}$   $\Delta H_{\text{rxn}} = -87.9 \text{ kJ/mol}$   
 E.  $\text{NO(g)} + \frac{1}{2} \text{Cl}_2\text{(g)} \rightarrow \text{NOCl(g)}$   $\Delta H_{\text{rxn}} = -38.54 \text{ kJ/mol}$   $\therefore \Delta S < 0$

For a reaction to be spontaneous only at low temperatures, the system will not be entropically favorable ( $\Delta S < 0$  &  $+\Delta S$ ) & negative value of the enthalpy will overcome the positive value of  $+\Delta S$

Tip: when spontaneity is temperature dependent, the signs for  $\Delta H$  &  $\Delta S$  are usually the same (either both + or both are negative)

3. Which of the following statements is true?

**C**

- A. A reaction in which the entropy of the system increases can be spontaneous only if it is exothermic  
 B. A reaction in which the entropy of the system increases can be spontaneous only if it is endothermic  
 C. A reaction in which the entropy of the system decreases can be spontaneous only if it is exothermic  
 D. A reaction in which the entropy of the system decreases can be spontaneous only if it is endothermic  
 E. None of the above statements are true

A: Entropy of the system can increase, if a reaction is endothermic as well but only at high temperatures  
 B: Entropy of the system can increase & the reaction is spontaneous if a reaction is exothermic  
 C: if  $\Delta S < 0$  (negative value)  $\therefore$  the term  $T\Delta S$  is positive & for a reaction to be spontaneous, it has to be exothermic & of a larger magnitude than  $T\Delta S$   
 D: A reaction in which entropy of the system decreases & is endothermic is non-spontaneous at all temperatures

4. Which of the following statement(s) is/are true regarding the combustion of propane ( $\text{C}_3\text{H}_8$ ) gas? Select all that apply. Insert letters without spaces in the answer box, example **ABCD**.

**AE**

- A.  $\Delta H < 0$  and  $\Delta S > 0$  for the combustion of propane  
 B.  $\Delta H > 0$  and  $\Delta S < 0$  for the combustion of propane  
 C. The combustion of propane is spontaneous only at low temperatures  
 D. The combustion of propane is spontaneous only at high temperatures  
 E. The combustion of propane is spontaneous at all temperatures  
 F. The combustion of propane is non-spontaneous at any temperatures



\* All combustion reactions are exothermic  $\therefore \Delta H < 0$   
 \* From the equation, entropy of the system increases (one additional mole of gas produced)  $\therefore \Delta S > 0$   
 \*  $\Delta G = \Delta H - T\Delta S$   
   (-)            (+)  
    $\therefore \Delta G < 0$

the combustion of propane is spontaneous at all temperatures

5. You are given the redox reaction below in acidic medium at 25 °C.  $\Delta H_{\text{rxn}} = -61.6 \text{ kJ/mol}$ ,  $\Delta G_{\text{rxn}} = 4.4 \text{ kJ/mol}$ , and the standard molar entropies for the reactants and products are also provided below. Calculate the standard molar entropy for  $\text{HNO}_2$  in  $\text{J/mol}\cdot\text{K}$ .

135.7

$\text{J/mol}\cdot\text{K}$



Substance	$\text{H}^+(\text{aq})$	$\text{Br}^-(\text{aq})$	$\text{NO}_2(\text{g})$	$\text{Br}_2(\text{l})$	$\text{HNO}_2(\text{aq})$
$S^\circ (\text{J/mol}\cdot\text{K})$	0	82.4	240.1	152.2	?

step 1:

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

$$4.4 \frac{\text{kJ}}{\text{mol}} = -61.6 \frac{\text{kJ}}{\text{mol}} - (25 + 273.15) \Delta S$$

$$66.0 \frac{\text{kJ}}{\text{mol}} = -298 \text{K} \times \Delta S$$

$$\therefore \Delta S = \frac{66.0 \frac{\text{kJ}}{\text{mol}} \times \frac{1000 \text{J}}{1 \text{kJ}}}{-298 \text{K}} = -221.47 \frac{\text{J}}{\text{mol}\cdot\text{K}}$$

step 2:

$$\Delta S_{\text{rxn}} = (\sum n_p \times \Delta S_{\text{products}}) - (\sum n_r \times \Delta S_{\text{reactants}})$$

$$-221.47 \text{ J/mol}\cdot\text{K} = [(2 \times x) + (1 \times 152.2)] - [(2 \times 0) + (2 \times 82.4) + (2 \times 240.1)]$$

$$-221.47 \text{ J/mol}\cdot\text{K} = [2x + 152.2] - [2 \times 404.6]$$

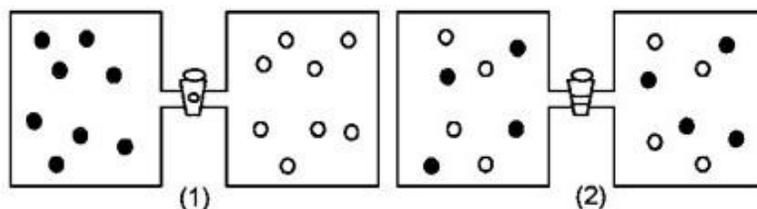
$$-221.47 \text{ J/mol}\cdot\text{K} = 2x + 152.2 - 809.2$$

$$-221.47 \text{ J/mol}\cdot\text{K} = 2x - 657.0$$

$$435.53 \text{ J/mol}\cdot\text{K} = 2x$$

$$x = 217.765 \text{ J/mol}\cdot\text{K}$$

6. In figure (1) below argon atoms, represented by unshaded spheres, and neon atoms, represented by shaded spheres, are in separate compartments in a closed system. Figure (2) shows the equilibrium state of the system after the stopcock separating the two compartments is opened. Assuming that argon and neon behave as ideal gases, what are the signs (+, -, or 0) of  $\Delta H$ ,  $\Delta S$ , and  $\Delta G$  for this process?



B

- A.  $\Delta H = +$ ,  $\Delta S = -$ ,  $\Delta G = +$   
 B.  $\Delta H = 0$ ,  $\Delta S = +$ ,  $\Delta G = -$   
 C.  $\Delta H = 0$ ,  $\Delta S = -$ ,  $\Delta G = +$   
 D.  $\Delta H = -$ ,  $\Delta S = +$ ,  $\Delta G = -$

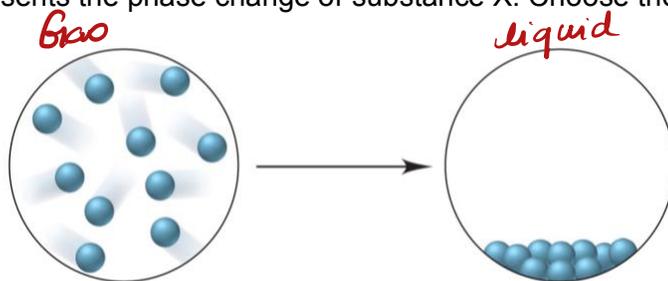
NO heat is produced or removed  
 the two gases spontaneously mix  $\therefore \Delta S > 0$

$$\text{if } \Delta G = \Delta H - T\Delta S$$

$$\Delta G = 0 - T\Delta S$$

$$\therefore \Delta G < 0$$

7. The illustration below represents the phase change of substance X. Choose the correct answer below.

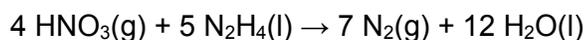


The sign for  $\Delta H$  for this process is  (+ or -) and the sign for  $\Delta S$  is  (+ or -).

This process is  (spontaneous or non-spontaneous) at  (at no temperatures, all temperatures, low temperatures, or high temperatures).

8. You get an internship at NASA, and you learn that the reaction of hydrazine ( $N_2H_4$ ) and nitric acid is used as rocket propellant. Calculate  $\Delta G_{rxn}$  in kJ/mol at 25 °C for the reaction of hydrazine and nitric acid using the information provided below. **Report your answer using scientific notation.**

kJ/mol  
x10



	$\text{HNO}_3(\text{g})$	$\text{N}_2\text{H}_4(\text{l})$	$\text{N}_2(\text{g})$	$\text{H}_2\text{O}(\text{l})$
$\Delta H^\circ$ (kJ/mol)	-133.9	50.6	0	-285.8
$\Delta S^\circ$ (J/mol·K)	266.9	121.2	191.6	70.0

$$\begin{aligned} \Delta H_{rxn} &= (\sum n_p \times \Delta H^\circ_{\text{products}}) - (\sum n_r \times \Delta H^\circ_{\text{reactants}}) \\ &= [(7 \times 0) + (12 \times -285.8)] - [(4 \times -133.9) + (5 \times 50.6)] \\ &= (-3429.6) - (-282.6) \\ &= -3147.0 \frac{\text{kJ}}{\text{mol}} \end{aligned}$$

$$\begin{aligned} \Delta S_{rxn} &= (\sum n_p \times \Delta S^\circ_{\text{products}}) - (\sum n_r \times \Delta S^\circ_{\text{reactants}}) \\ &= [(7 \times 191.6) + (12 \times 70.0)] - [(4 \times 266.9) + (5 \times 121.2)] \\ &= 2181.2 - (1673.6) \\ &= 507.6 \text{ J/mol}\cdot\text{K} \end{aligned}$$

$$\begin{aligned} \Delta G_{rxn} &= \Delta H_{rxn} - T \Delta S_{rxn} \\ &= (-3147.0 \frac{\text{kJ}}{\text{mol}} \times \frac{1000 \text{ J}}{1 \text{ kJ}}) - (25 + 273.15 \text{ K}) (507.6 \text{ J/mol}\cdot\text{K}) \\ &= -3.298 \times 10^6 \frac{\text{J}}{\text{mol}} = -3.30 \times 10^6 \frac{\text{J}}{\text{mol}} = -3.30 \times 10^3 \frac{\text{kJ}}{\text{mol}} \end{aligned}$$

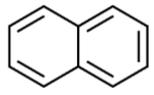
H-bonded to a highly electronegative atom  $\leftarrow \text{H}-\overset{\ominus}{\text{O}}-\text{H} \rightarrow$  water is capable of forming H-bonds (polar)

Benzene has C-H bonds which are non-polar  $\therefore$  is capable of forming LDFs

9. Substances that dissolve in water (H<sub>2</sub>O) generally do not dissolve in benzene (C<sub>6</sub>H<sub>6</sub>). However, some substances are moderately soluble in both. Which of the substances below do you think would be **moderately** soluble in **both** water and benzene?

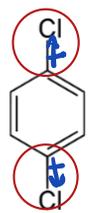
**D**

A. Naphthalene



Naphthalene has a similar structure to benzene (non-polar)  $\therefore$  capable of forming LDFs  
Naphthalene is soluble in benzene but not in H<sub>2</sub>O (polar)

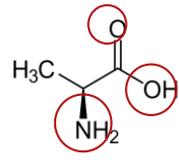
B. para-dichlorobenzene



Although C-Cl bonds are polar there are two Cl on the benzene ring with opposing dipoles

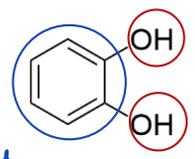
para-dichlorobenzene is a non-polar molecule  $\therefore$  capable of forming LDFs  
para-dichlorobenzene is soluble in benzene but not in water

C. Alanine (an amino acid)



C=O bond is polar can form DD forces while NH<sub>2</sub> & OH are capable of forming H-bond  $\therefore$  the alanine is an overall polar molecule (soluble in water but not in benzene)

**D**. ortho-hydroxyphenol



the cyclic ring consists of C-H bond  $\therefore$  non-polar (LDFs) similar to benzene

capable of forming H-bond  
ortho-hydroxyphenol is moderately soluble in both benzene & water

10. You want to prepare a perfectly roasted turkey for a family gathering and you must soak the turkey for at least 8 hours in a 3.87% by mass brine solution (a solution consisting of salt (NaCl) dissolved in water). How many liters of water are needed to dissolve 725 g of NaCl to prepare the 3.87% by mass brine solution?

**18.0** L

3.87% by mass brine solution =

$$\frac{3.87 \text{ g NaCl}}{100 \text{ g solution}} \quad \begin{matrix} \text{solute} \\ \text{solvent} \end{matrix}$$

Mass of water in 3.87% by mass brine solution =  
 $100.00 \text{ g solution} - 3.87 \text{ g (NaCl)}$   
 $= 96.13 \text{ g H}_2\text{O}$

liters of water needed to dissolve 725g of NaCl

$$725 \text{ g NaCl} \times \frac{96.13 \text{ g H}_2\text{O}}{3.87 \text{ g NaCl}} \times \frac{1.00 \text{ mL}}{1 \text{ g H}_2\text{O}} \times \frac{1 \text{ L}}{1000 \text{ mL}}$$

$$= 18.00885 \sim 18.0 \text{ L}$$

or this question you are going use the idea "likeo dissolves likeo"

11. In CHEM 1212 lab, you are working on a freezing point depression experiment, and you decide to perform a rather dangerous trial. Instead of water as a solvent and  $\text{CaCl}_2$  as a solute, you decide to use carbon disulfide (neurotoxic agent) as a solvent and iodine as a solute. In the first step you want to prepare a 0.286 m solution of iodine in carbon disulfide. How many grams of iodine ( $\text{I}_2$ ) must be dissolved in 625 mL of carbon disulfide solution ( $\text{CS}_2$ , density = 1.261 g/mL) to produce the 0.286 m solution?

57.2

g 0.286 m solution of iodine in  $\text{CS}_2 =$

$$\frac{0.286 \text{ mol I}_2}{1 \text{ kg CS}_2}$$

$$1 \text{ kg CS}_2$$

Mass of  $\text{I}_2$  to be dissolved in 625 mL of  $\text{CS}_2 =$

$$625 \text{ mL CS}_2 \times \frac{1.261 \text{ g CS}_2}{\text{mL}} \times \frac{1 \text{ kg}}{1000 \text{ g}} \times \frac{0.286 \text{ mol I}_2}{1 \text{ kg CS}_2} \times \frac{253.809 \text{ g I}_2}{1 \text{ mol I}_2}$$

$$= 57.20747 \sim 57.2 \text{ g I}_2$$

12. Henry's law constant for gas X is  $3.30 \times 10^{-2} \text{ M/atm}$ . What total volume of solution is needed to completely dissolve 1.65 L of gas at a pressure of 725 torr and a temperature of 25 °C? (1 atm = 760 torr)

2.04

L Henry's law  $C_{\text{gas}} = K_H P_{\text{gas}}$

$$K_H = 3.30 \times 10^{-2} \frac{\text{mol}}{\text{L} \cdot \text{atm}}$$

$$P_{\text{gas}} = 725 \text{ torr} \times \frac{1 \text{ atm}}{760 \text{ torr}} = 0.95394737 \text{ atm}$$

$$C_{\text{gas}} = \frac{\text{mol of gas}}{\text{Liters of solution}} \rightarrow \text{can be determined using ideal gas law constant } PV = nRT$$

↳ to be determined

Using the ideal gas law to determine the mol of gas

$$0.95394737 \text{ atm} \times 1.65 \text{ L} = n \times 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times (25 + 273.15)$$

$$\therefore n = 0.064334219 \text{ mol}$$

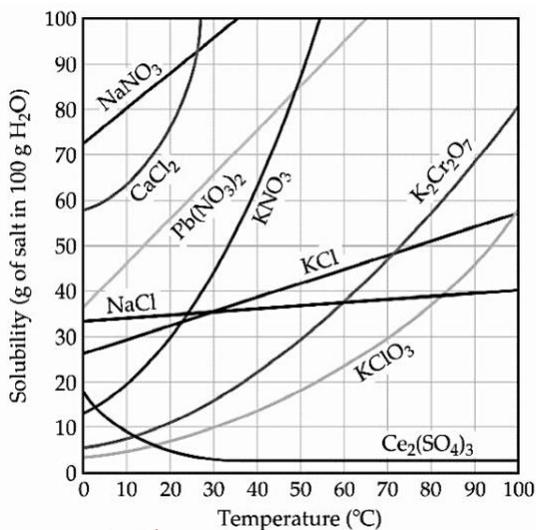
Using Henry's law constant  $C_{\text{gas}} = K_H P_{\text{gas}}$

$$C_{\text{gas}} = \frac{\text{mol of gas}}{\text{L of soln}} = K_H \times P_{\text{gas}} \Rightarrow \therefore \text{L of soln} = \frac{\text{mol of gas}}{K_H \times P_{\text{gas}}}$$

$$= \frac{0.064334219 \text{ mol}}{3.30 \times 10^{-2} \frac{\text{M}}{\text{atm}} \times 0.95394737 \text{ atm}}$$

$$= 2.04 \text{ L}$$

13. Refer to the plot below temperature versus solubility to answer the following question.



**KClO<sub>3</sub>**

A solution that is 2.75 m of potassium chlorate (molar mass = 122.55 g/mol) at 95 °C is considered

**B**

- A. Hydrated
- B. Unsaturated
- C. Saturated
- D. Supersaturated
- E. Dehydrated

2.75 m KClO<sub>3</sub>

$\frac{2.75 \text{ mol KClO}_3}{1 \text{ kg H}_2\text{O}}$   $\Rightarrow$  Convert to grams of salt in 100g of water

$$\frac{2.75 \text{ mol KClO}_3}{1 \text{ kg H}_2\text{O}} \times \frac{122.55 \text{ g KClO}_3}{1 \text{ mol KClO}_3} \times \frac{1 \text{ kg}}{1000 \text{ g}} \times 100 \text{ g H}_2\text{O} = 33.7 \text{ g KClO}_3 \text{ in } 100 \text{ g H}_2\text{O}$$

$$\text{Molar mass of } H_3PO_4 = 97.99 \text{ g/mol}$$

14. Phosphoric acid is commonly used as a cleaning detergent for removal of rust and stains. If a commercial detergent contains 26.0% by mass  $H_3PO_4$  and has a density of  $1.148 \text{ g/cm}^3$  at  $30^\circ\text{C}$ . What is the

A. Molality of  $H_3PO_4$  in the detergent solution?

$$1 \text{ g/cm}^3 = 1 \text{ g/mL}$$

$$\boxed{3.59} \text{ m}$$

$$\text{Molality} = \frac{\text{mol of } H_3PO_4}{1 \text{ kg of solvent}}$$

$$26.0\% \text{ by mass } H_3PO_4 = \frac{26.0 \text{ g } H_3PO_4}{100 \text{ g of solution}} \quad \therefore \text{mass of } H_2O = 100 \text{ g solution} - 26.0 \text{ g } H_3PO_4 = 74.0 \text{ g } H_2O$$

$$\frac{26.0 \text{ g } H_3PO_4}{74.0 \text{ g } H_2O} \times \frac{1 \text{ mol } H_3PO_4}{97.99 \text{ g } H_3PO_4} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 3.59 \text{ m}$$

B. Molarity of  $H_3PO_4$  in the solution?

$$\boxed{3.05} \text{ M}$$

$$\text{Molarity} = \frac{\text{mol of solute}}{\text{Liters of solution}}$$

$$\frac{26.0 \text{ g } H_3PO_4}{100 \text{ g solution}} \times \frac{1 \text{ mol } H_3PO_4}{97.99 \text{ g } H_3PO_4} \times \frac{1.148 \text{ g solution}}{\text{mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 3.05 \text{ M}$$

C. Mole fraction of  $H_3PO_4$  in the detergent solution?

$$\boxed{0.0607}$$

$$\text{Mole fraction of } H_3PO_4 = \frac{\text{mol } H_3PO_4}{\text{mol } H_3PO_4 + \text{mol } H_2O}$$

$$\text{From part A you have the mass of } H_2O = 74.0 \text{ g}$$

$$\text{mol of } H_2O = 74.0 \text{ g } H_2O \times \frac{1 \text{ mol } H_2O}{18.01 \text{ g } H_2O} = 4.1088284 \text{ mol } H_2O$$

$$\text{mol of } H_3PO_4 = 26.0 \text{ g} \times \frac{1 \text{ mol } H_3PO_4}{97.99 \text{ g } H_3PO_4} = 0.2653332 \text{ mol } H_3PO_4$$

$$\text{mole fraction of } H_3PO_4 = \frac{0.2653332 \text{ mol } H_3PO_4}{0.2653332 \text{ mol } H_3PO_4 + 4.1088284 \text{ mol } H_2O} = 0.0607$$

15. Which cation is expected to have the largest hydration energy?

- E**
- A.  $\text{Li}^+$
  - B.  $\text{Ca}^{2+}$
  - C.  $\text{Ba}^{2+}$
  - D.  $\text{Cs}^+$
  - E.  $\text{Al}^{3+}$**

*this is related to lattice energy. the higher the charge the larger the hydration energy*

16. A water sample is found to have 9.4 ppb of chloroform,  $\text{CHCl}_3$ . How many grams of  $\text{CHCl}_3$  would be found in a glass of this water? (One glass of water = 250 mL).

**$2.4 \times 10^{-6}$  g**

$\text{PPb} = \frac{\text{mg of solute}}{\text{kg of solution}}$

*For very dilute solutions the density  $\sim 1.0 \frac{\text{g}}{\text{mL}}$*

$$\frac{9.4 \text{ } \mu\text{g CHCl}_3}{1 \text{ kg of solution}} \times \frac{1 \text{ mg CHCl}_3}{1000 \text{ } \mu\text{g CHCl}_3} \times \frac{1 \text{ g CHCl}_3}{1000 \text{ mg CHCl}_3} \times \frac{1 \text{ kg soln}}{1000 \text{ g soln}} \times \frac{1.0 \text{ g}}{\text{mL}} \times 250 \text{ mL} = 2.4 \times 10^{-6} \text{ g}$$

**Ionic solid**

17. Lithium iodide (LiI) is used as a solid-state electrolyte for high temperature batteries. When LiI is dissolved in water, the solution becomes hotter. Which of the following statement(s) is true?

**E**

- A. The dissolution of LiI is exothermic ✓ *(solution is hot  $\therefore$  dissolution of LiI is exothermic)*
- B.  $|\Delta H_{\text{solute}}| < |\Delta H_{\text{hydration}}|$   $\Delta H_{\text{soln}} = \Delta H_{\text{solute}}^{(+)} - \Delta H_{\text{hydration}}^{(-)}$  ✓
- C.  $\Delta H_{\text{soln}}$  is negative and  $\Delta S_{\text{soln}}$  is positive ✓
- D. The solute-solvent interaction is greater than the solute-solute and the solvent-solvent interaction ✓
- E. All the above statements are true**

18. The concentration nitrogen gas in the ocean at 25 °C is 445 μM and Henry's law constant for nitrogen is  $0.61 \times 10^{-3} \text{ mol/L} \cdot \text{atm}$ .

A. What is the mass of nitrogen in a liter of ocean's water?  $1 \text{ M} = 10^{-6} \mu\text{M}$

**0.0125** g

$$\frac{445 \times 10^{-6} \text{ mol N}_2}{1 \text{ L of sea water}} \times \frac{28.0 \text{ g N}_2}{1 \text{ mol}} = 0.0125 \text{ g/L}$$

or 0.0125 g

B. Calculate the partial pressure of N<sub>2</sub> in the atmosphere.

**0.73** atm

Using Henry's law  
 $C_{\text{gas}} = K_H P_{\text{gas}}$

$$445 \times 10^{-6} \frac{\text{mol}}{\text{L}} = 0.61 \times 10^{-3} \text{ atm} \times P_{\text{atm}}$$

$$\therefore P = 0.73$$

19. A person is considered legally intoxicated with a blood alcohol level of 80. mg/dL. If blood plasma has a density of 1.025 g/mL, what is this concentration expressed in ppm?  $1 \text{ L} = 10 \text{ dL}$

**780** ppm

$$\text{ppm} = \frac{\text{mg of solute}}{\text{kg of solution}}$$

$$\frac{80. \text{ mg}}{\text{dL}} \times \frac{10 \text{ dL}}{1 \text{ L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{1 \text{ mL}}{1.025 \text{ g}} \times \frac{1000 \text{ g}}{1 \text{ kg}}$$

$$= 780 \text{ ppm}$$

20. Calculate the mole fraction of the solute in each of the following solutions:

A. 0.112 M  $C_6H_{12}O_6$  (density = 1.006 g/mL)

0.00204

$$\frac{0.112 \text{ mol } C_6H_{12}O_6}{1 \text{ L solution}}$$

$$\text{Mass of solution} = 1 \text{ L solution} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{1.006 \text{ g}}{\text{mL}} = 1006 \text{ g solution}$$

$$\text{Mass of } C_6H_{12}O_6 = 0.112 \text{ mol } C_6H_{12}O_6 \times \frac{180.18 \text{ g } C_6H_{12}O_6}{1 \text{ mol } C_6H_{12}O_6} = 20.17 \text{ g}$$

$$\text{Mass of water} = 1006 \text{ g} - 20.17 \text{ g} = 986 \text{ g}$$

$$986 \text{ g H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.01 \text{ g H}_2\text{O}} = 54.7 \text{ mol}$$

$$\frac{0.112}{0.112 + 54.7} = 0.00204$$

B. 3.20%  $C_2H_5OH$  by volume (density of pure  $C_2H_5OH$  = 0.789 g/mL)

0.0101

① 3.20% by volume  $C_2H_5OH$  to mole fraction of  $C_2H_5OH$  in solution

$$\frac{3.20 \text{ mL } C_2H_5OH}{100 \text{ mL solution}}$$

$$\text{Volume of H}_2\text{O} = 100 - 3.20 = 96.8 \text{ mL}$$

$$96.8 \text{ mL} \times \frac{1.00 \text{ g H}_2\text{O}}{\text{mL H}_2\text{O}} \times \frac{1 \text{ mol H}_2\text{O}}{18.01 \text{ g H}_2\text{O}} = 5.37 \text{ mol}$$

②

$$\text{Moles of } C_2H_5OH = 3.20 \text{ mL} \times \frac{0.789 \text{ g}}{\text{mL}} \times \frac{1 \text{ mol } C_2H_5OH}{46.07 \text{ g } C_2H_5OH} = 0.0548$$

$$\chi_{C_2H_5OH} = \frac{0.0548}{5.37 + 0.0548} = \frac{0.0548}{5.42} = 0.0101$$

**Extra Practice Questions: these questions will not be graded**

1. What can be said about a chemical system that has reached a minimum in free energy (i.e., no change in free energy)?

C

- A. The reaction is complete.
- B. The system entropy is zero.
- C. The system has achieved equilibrium.
- D. The temperature is low.
- E. The reaction is very fast.

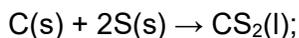
When  $\Delta G = 0$

this means that the system is at equilibrium

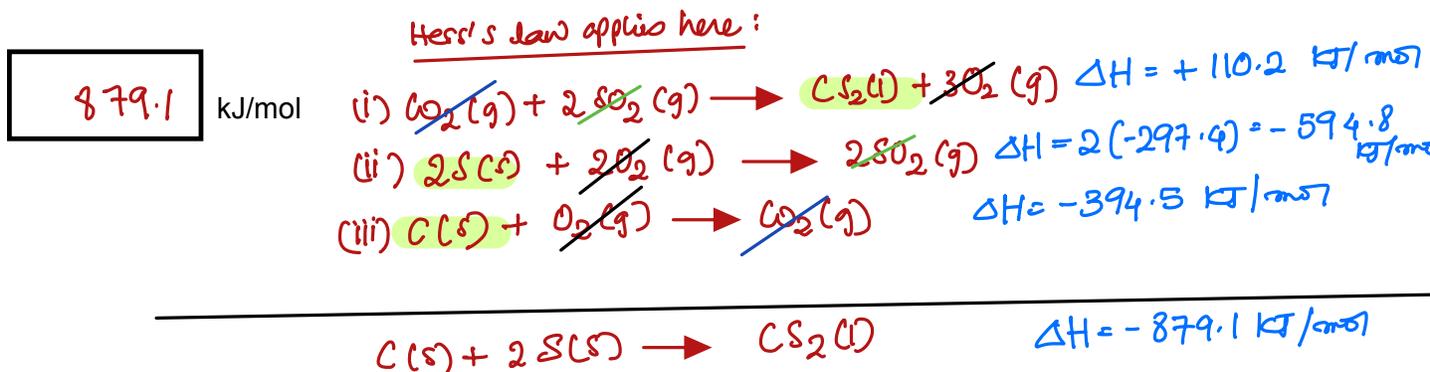
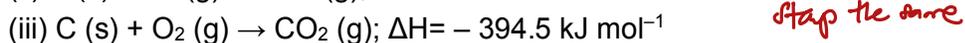
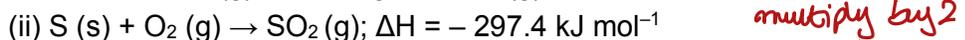
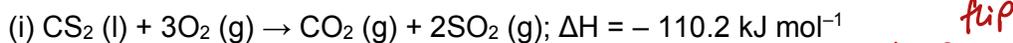
Remember:

- $\Delta G < 0$  spontaneous
- $\Delta G > 0$  non-spontaneous
- $\Delta G = 0$  equilibrium

2. Calculate the enthalpy of formation of carbon disulfide given the three reactions below.



Given



3. For the process



Assuming that the surroundings can be considered a large heat reservoir at 25 °C, calculate  $\Delta S_{\text{surr}}$  and  $\Delta S_{\text{total}}$  for the process at 25 °C and 1 atm pressure. Is the process spontaneous at 25 °C and 1 atm pressure?

- |          |  |
|----------|--|
| <b>B</b> | A. $\Delta S_{\text{surr}} = 4.2 \text{ J/K}, \Delta S_{\text{total}} = 0$ , not spontaneous                 |
|          | B. $\Delta S_{\text{surr}} = 0.7 \text{ J/K}, \Delta S_{\text{total}} = -3.5 \text{ J/K}$ , not spontaneous  |
|          | C. $\Delta S_{\text{surr}} = -0.7 \text{ J/K}, \Delta S_{\text{total}} = -4.9 \text{ J/K}$ , spontaneous     |
|          | D. $\Delta S_{\text{surr}} = -0.7 \text{ J/K}, \Delta S_{\text{total}} = -4.9 \text{ J/K}$ , not spontaneous |

$$\textcircled{1} \Delta S_{\text{surr}} = -\frac{\Delta H_{\text{sys}}}{T} = \frac{-(-0.21 \text{ kJ} \times 1000 \text{ J/kJ})}{25 + 273.15} = \frac{210 \text{ J}}{298.15 \text{ K}}$$

$$= 0.70434345 \text{ J/K} \approx 0.70 \text{ J/K}$$

$$\textcircled{2} \Delta S_{\text{total}} = \Delta S_{\text{sys}} + \Delta S_{\text{surr}}$$

$$= -4.2 \text{ J/K} + 0.70 \text{ J/K} = -3.5 \text{ J/K}$$

$\Delta S_{\text{total}} < 0$  non-spontaneous

$\Delta S_{\text{total}} > 0$  spontaneous

$\Delta S_{\text{total}} = 0$  equilibrium

4. Heptane and Hexane form an ideal solution. What are the signs of every term in the Gibbs free energy equation ( $\Delta G$ ,  $\Delta H$ ,  $T$ ,  $\Delta S$ )?

E

- A. +, -, +, -
- B. -, +, +, +
- C. -, +, +, -
- D. +, no sign, +, -
- E. -, no sign, +, +

Heptane =  $C_7H_{14}$   
 Hexane =  $C_6H_{12}$  } both are hydrocarbons & form LDFs only  $\therefore$  forms an ideal solution

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

$\Delta G$  (-) because a solution forms  $\therefore$  spontaneous due to some LDFs formed

$\Delta H$  0 no sign because no energy released due to some LDFs formed

$T$  + sign should have a positive sign for the term  $-T\Delta S$  be (-) for  $\Delta G < 0$

$\Delta S$  (+) entropy increases due to mixing

5. Fish are often tested for levels of the toxic compound methylmercury (MW: 215.63). If a particular swordfish was found to have 0.547 ppm of methylmercury, how many moles of methylmercury would be found if the fish weighed 71.8 kg?

$1.82 \times 10^{-4}$  mol

①  $ppm = \frac{mg \text{ of solute}}{kg \text{ of solvent}}$

$0.547 = \frac{mg \text{ of solute}}{71.8 \text{ kg}}$

$\therefore$  mass of solute = 39.2746 mg

②  $39.2746 \text{ mg} \times \frac{1 \text{ g}}{1000 \text{ mg}} = 3.92746 \times 10^{-2}$

③  $3.92746 \times 10^{-2} \text{ g} \times \frac{1 \text{ mol}}{215.63 \text{ g}} = 1.8214 \times 10^{-4} \text{ mol} \approx 1.82 \times 10^{-4} \text{ mol}$

6. A bottle containing 250 mL of water is pressurized with 4.23 atm of carbon dioxide gas. What is the percent by weight of  $CO_2$  in the solution? The Henry's Law constant for  $CO_2$  in water at 298 K is  $3.4 \times 10^{-2} \text{ mol/L} \cdot \text{atm}$ .

0.633 %

$C_{gas} = k_H \times P_{gas}$  partial pressure of  $CO_2$

$\downarrow$  Henry's law constant

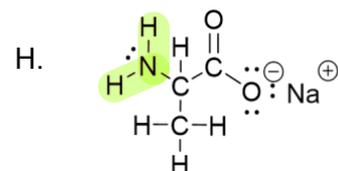
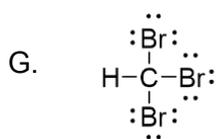
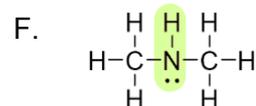
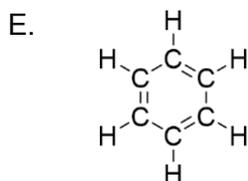
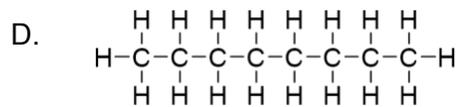
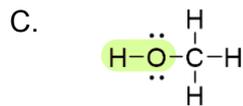
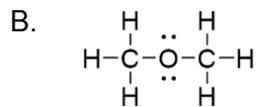
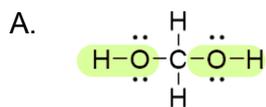
$C_{CO_2} = 3.4 \times 10^{-2} \frac{\text{mol}}{\text{L} \cdot \text{atm}} \times 4.23 \text{ atm}$

$= 0.14328 \frac{\text{mol}}{\text{L}} \times \frac{44.01 \text{ g } CO_2}{1 \text{ mol } CO_2}$

$= \frac{6.3295182 \text{ g}}{1000 \text{ mL}} \times \frac{1.0 \text{ mL}}{1 \text{ g}}$

$= \frac{6.3295182 \text{ g}}{1000 \text{ g solution}} \times 100 = 0.63295182\%$

7. Use the structures provided below to answer the following questions:



I. Which structures represent compounds that would most likely be soluble in ethylene glycol (HOCH<sub>2</sub>CH<sub>2</sub>OH)? Select all that apply.

**ACFH**

*Can form H-bonding*

II. Which 2 structures represent the compounds **most** likely to dissolve C<sub>6</sub>H<sub>14</sub>?

**DE**

## Formula Sheet

### Length

1 kilometer = 0.62137 mile  
1 inch = 2.54 centimeters (exactly)  
1 Ångstrom =  $1 \times 10^{-10}$  meter

### Energy

1 joule =  $1 \text{ kg}\cdot\text{m}^2/\text{s}^2$   
1 calorie = 4.184 joules  
1 Calorie = 1 kilocalorie = 1000 calories  
1 L·atm = 101.325 joules

### Pressure

1 pascal =  $1 \text{ N}/\text{m}^2 = 1 \text{ kg}/\text{m}\cdot\text{s}^2$   
1 atmosphere = 101.325 kilopascals = 760 mm Hg = 760 torr = 14.70 lb/in<sup>2</sup>  
1 bar =  $1 \times 10^5$  Pa (exactly)

### Temperature

0 K = -273.15°C  
K = °C + 273.15  
°C = (5/9)(°F - 32)

### Mass

1 kg = 2.205 lbs

### Volume

1 mL =  $1 \text{ cm}^3 = 1 \text{ cc}$

### Constants

$c = 2.998 \times 10^8 \text{ m}/\text{sec}$   
 $h = 6.626 \times 10^{-34} \text{ J}\cdot\text{sec}^{-1}$   
 $R = 0.08206 \text{ L}\cdot\text{atm}/\text{mol}\cdot\text{K} = 8.314 \text{ J}/\text{mol}\cdot\text{K}$   
Specific heat of water = 4.184 J/g·K  
Mass of an electron:  $9.109 \times 10^{-31} \text{ kg}$   
Mass of a proton:  $1.673 \times 10^{-27} \text{ kg}$   
 $RH = 2.18 \times 10^{-18} \text{ J}$   
Specific heat of water = 4.184 J/g·K  
STP = 273.15 K and 1 atm  
Avogadro's number:  $6.022 \times 10^{23}$

### Equations

d (density) =  $m/V$

$P_1V_1 = P_2V_2$

$V_1/T_1 = V_2/T_2$

$P_1V_1/n_1T_1 = P_2V_2/n_2T_2$

$PV = nRT$

$(P + a(n^2/V^2)) \cdot (V - nb) = nRT$

molar mass (M) =  $mRT/PV$

density (d) =  $MP/RT$

$x_A = n_A/n_{\text{tot}} = P_A/P_{\text{tot}} = V_A/V_{\text{tot}}$

$P_{\text{tot}} = P_A + P_B + \dots$

$n_{\text{tot}} = n_A + n_B + \dots$

$$\mu_{rms} = \sqrt{\frac{3RT}{M}}$$

$$\frac{\text{Rate of effusion A}}{\text{Rate of effusion B}} = \sqrt{\frac{MW_B}{MW_A}}$$

$$Q = C \times \Delta T = c_{\text{specific}} \times m \times \Delta T$$

$$Q = n \times \Delta H \text{ (kJ/mol)} = m \times \Delta H \text{ (kJ/g)}$$

$$w = -P\Delta V$$

$$\Delta E = q + w$$

$$\Delta H^\circ = \sum n\Delta H_f^\circ(\text{products}) - \sum n\Delta H_f^\circ(\text{reactants})$$

$$\Delta H^\circ = \sum n\Delta H^\circ(\text{bonds broken}) - \sum n\Delta H^\circ(\text{bonds formed})$$

$$E = hv$$

$$c = \lambda\nu$$

$$\lambda = h/mv$$

$$\Delta E = -2.18 \times 10^{-18} J \left( \frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta H_{vap}}{R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right)$$

$$C_g = kP_g$$

$$P_{\text{solution}} = P_{\text{solvent}} X_{\text{solvent}}$$

$$P_{\text{solution}} = \sum P_j = \sum P_j X_j$$

$$\Delta T_b = K_b m_i$$

$$\Delta T_f = K_f m_i$$

$$\pi = MRT_i$$

### Thermodynamic and Electrochemistry

$$S = k_b \times \ln(W)$$

$$k_b = 1.381 \times 10^{-23} \text{ J/K}$$

$$\Delta S = q_{\text{rev}}/T$$

$$\Delta S_{\text{surr}} = q_{\text{surr}}/T = -q_{\text{rev}}/T$$

$$\Delta S_{\text{univ}} = \Delta S_{\text{sys}} + \Delta S_{\text{surr}}$$

$$\Delta S^\circ_{\text{rxn}} = \sum \nu S^\circ_{\text{products}} - \sum \nu S^\circ_{\text{reactants}}$$

$$\Delta H^\circ_{\text{rxn}} = \sum \nu H^\circ_{\text{products}} - \sum \nu H^\circ_{\text{reactants}}$$

$$\Delta G^\circ_{\text{rxn}} = \sum \nu G^\circ_{\text{products}} - \sum \nu G^\circ_{\text{reactants}}$$

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

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

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

$$\Delta G^\circ = -RT \cdot \ln K$$

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

$$F = 96485 \text{ J/(V}\cdot\text{mol e}^-)$$

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

$$E^\circ_{\text{cell}} = (0.0257/n) \ln K = (0.0592/n) \log K$$

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

$$E_{\text{cell}} = E^\circ_{\text{cell}} - (0.0257/n) \ln Q$$

$$\text{Electrolysis: } Q \text{ (total charge)} = I \times t = n \times F$$

### Integrated Rate Laws & half-life

$$\ln \frac{[A]}{[A]_0} = -kt$$

$$\frac{1}{[A]} = kt + \frac{1}{[A]_0}$$

$$[A] = -kt + [A]_0$$

$$t_{1/2} = \frac{[A]_0}{2k}$$

$$t_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{k}$$

$$t_{1/2} = \frac{1}{k[A]_0}$$

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

### Equilibrium and Acid / Base

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

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

$$K_w = 1.0 \times 10^{-14} \text{ at } 25^\circ\text{C}$$

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

$$K_w = K_a \times K_b$$

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

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

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

# Periodic Table of the Elements

1 <b>H</b> 1.01																	2 <b>He</b> 4.00									
3 <b>Li</b> 6.94	4 <b>Be</b> 9.01											5 <b>B</b> 10.81	6 <b>C</b> 12.01	7 <b>N</b> 14.01	8 <b>O</b> 16.00	9 <b>F</b> 19.00	10 <b>Ne</b> 20.18									
11 <b>Na</b> 22.99	12 <b>Mg</b> 24.31	3 <b>Al</b> 26.98	13 <b>Si</b> 28.09	14 <b>P</b> 30.97	15 <b>S</b> 32.06	16 <b>Cl</b> 35.45	17 <b>Ar</b> 39.95											18 <b>Kr</b> 83.80								
19 <b>K</b> 39.10	20 <b>Ca</b> 40.08	21 <b>Sc</b> 44.96	22 <b>Ti</b> 47.87	23 <b>V</b> 50.94	24 <b>Cr</b> 52.00	25 <b>Mn</b> 54.94	26 <b>Fe</b> 55.85	27 <b>Co</b> 58.93	28 <b>Ni</b> 58.69	29 <b>Cu</b> 63.55	30 <b>Zn</b> 65.38	31 <b>Ga</b> 69.72	32 <b>Ge</b> 72.63	33 <b>As</b> 74.92	34 <b>Se</b> 78.97	35 <b>Br</b> 79.90	36 <b>Kr</b> 83.80									
37 <b>Rb</b> 85.47	38 <b>Sr</b> 87.62	39 <b>Y</b> 88.91	40 <b>Zr</b> 91.22	41 <b>Nb</b> 92.91	42 <b>Mo</b> 95.95	43 <b>Tc</b> [97]	44 <b>Ru</b> 101.07	45 <b>Rh</b> 102.91	46 <b>Pd</b> 106.42	47 <b>Ag</b> 107.87	48 <b>Cd</b> 112.41	49 <b>In</b> 114.82	50 <b>Sn</b> 118.71	51 <b>Sb</b> 121.76	52 <b>Te</b> 127.60	53 <b>I</b> 126.90	54 <b>Xe</b> 131.29									
55 <b>Cs</b> 132.91	56 <b>Ba</b> 137.33											71 <b>Hf</b> 178.49	72 <b>Ta</b> 180.95	73 <b>W</b> 183.84	74 <b>Re</b> 186.21	75 <b>Os</b> 190.23	76 <b>Ir</b> 192.22	77 <b>Pt</b> 195.08	78 <b>Au</b> 196.97	79 <b>Hg</b> 200.59	80 <b>Tl</b> 204.38	81 <b>Pb</b> 207.2	82 <b>Bi</b> 208.98	83 <b>Po</b> [209]	84 <b>At</b> [210]	85 <b>Rn</b> [222]
87 <b>Fr</b> [223]	88 <b>Ra</b> [226]											104 <b>Rf</b> [267]	105 <b>Db</b> [268]	106 <b>Sg</b> [269]	107 <b>Bh</b> [270]	108 <b>Hs</b> [269]	109 <b>Mt</b> [277]	110 <b>Ds</b> [281]	111 <b>Rg</b> [282]	112 <b>Cn</b> [285]	113 <b>Nh</b> [286]	114 <b>Fl</b> [290]	115 <b>Mc</b> [290]	116 <b>Lv</b> [293]	117 <b>Ts</b> [294]	118 <b>Og</b> [294]
57 <b>La</b> 138.91	58 <b>Ce</b> 140.12	59 <b>Pr</b> 140.91	60 <b>Nd</b> 144.24	61 <b>Pm</b> [145]	62 <b>Sm</b> 150.36	63 <b>Eu</b> 151.96	64 <b>Gd</b> 157.25	65 <b>Tb</b> 158.93	66 <b>Dy</b> 162.50	67 <b>Ho</b> 164.93	68 <b>Er</b> 167.26	69 <b>Tm</b> 168.93	70 <b>Yb</b> 173.05	71 <b>Lu</b> 174.97												
89 <b>Ac</b> [227]	90 <b>Th</b> 232.04	91 <b>Pa</b> 231.04	92 <b>U</b> 238.03	93 <b>Np</b> [237]	94 <b>Pu</b> [244]	95 <b>Am</b> [243]	96 <b>Cm</b> [247]	97 <b>Bk</b> [247]	98 <b>Cf</b> [251]	99 <b>Es</b> [252]	100 <b>Fm</b> [257]	101 <b>Md</b> [258]	102 <b>No</b> [259]	103 <b>Lr</b> [262]												