

Recitation Worksheet Five

Name:

key

MyID:

Textbook:

Chemistry & Chemical Reactivity

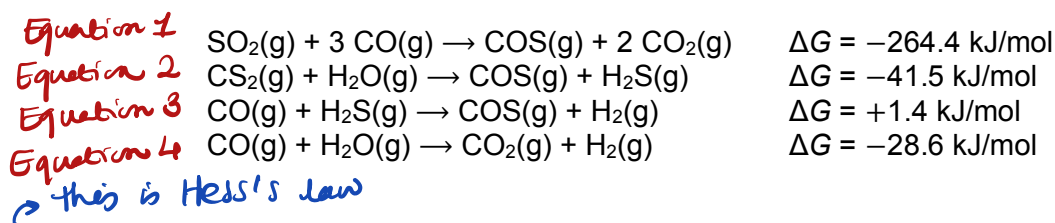
by John C. Kotz, Paul M. Treichel, John R. Townsend, David Treichel

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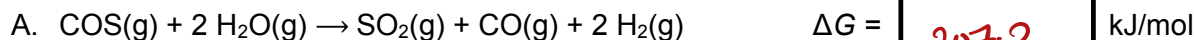
Instructions:

- 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 28th**.
- 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.

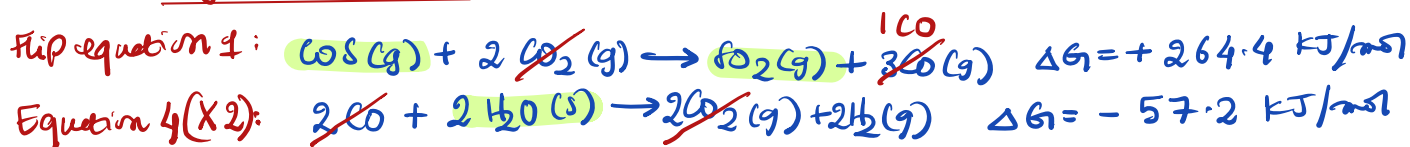
1. You are given a list of reactions below along with ΔG values.



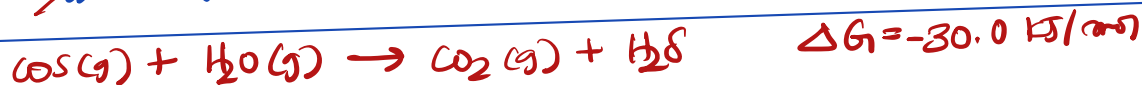
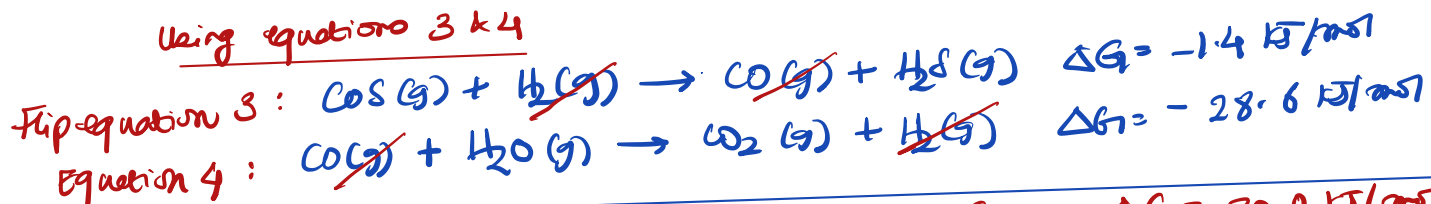
Combine the equations as necessary to obtain ΔG values for the following reactions:



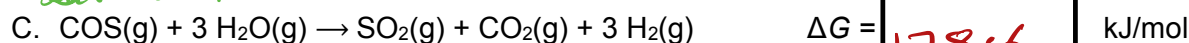
using equations 1 & 4



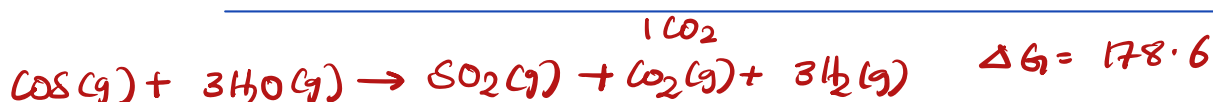
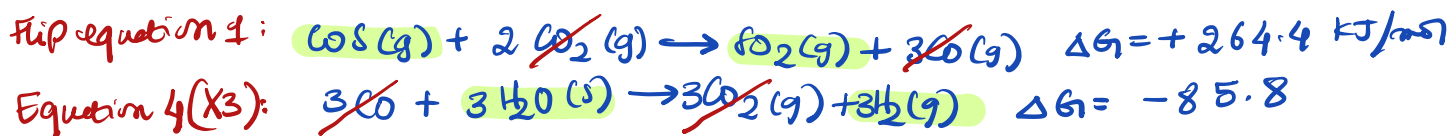
using equations 3 & 4



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 ΔH & ΔS 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 endothermic
 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 (C_3H_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) $\therefore \Delta S > 0$

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

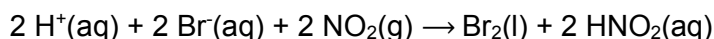
(-) (+)
 $\therefore \Delta G < 0$

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 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:

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

$$-221.47 \times 2 = [(2 \times x) + (1 \times 152.2)] - [(2 \times 0) + (2 \times 82.4) + (2 \times 240.1)]$$

$$-442.94 = 2x + 152.2 - 645.0$$

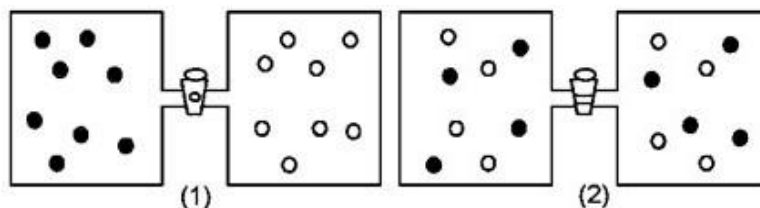
$$-442.94 = 2x - 492.8$$

$$492.8 - 442.94 = 2x$$

$$49.86 = 2x$$

$$x = 24.93 \frac{\text{J}}{\text{mol}\cdot\text{K}}$$

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 ΔH , ΔS , and ΔG 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. $\Delta H = -$, $\Delta S = +$, $\Delta G = -$

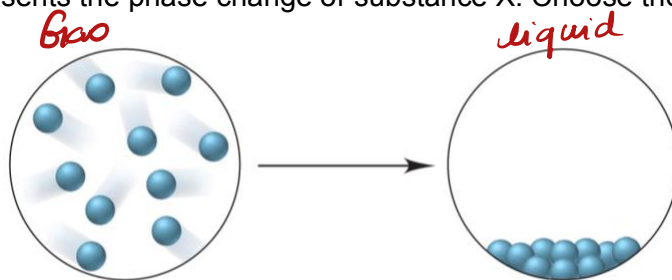
NO heat is produced or removed
 the two gases spontaneously mix $\therefore \Delta S > 0$

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

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

$$\therefore \Delta G < 0$$

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

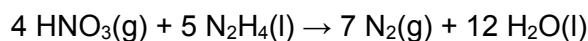


The sign for ΔH for this process is - (+ or -) and the sign for ΔS is - (+ or -).

This process is spontaneous (spontaneous or non-spontaneous) at low temperatures (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 ΔG_{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.**

-3.3 3 x10 kJ/mol



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

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

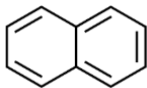
$$\begin{aligned} \Delta S_{\text{rxn}} &= (\sum n_p \times \Delta S^\circ_{\text{products}}) - (\sum n_r \times \Delta S^\circ_{\text{reactants}}) \\ &= [(7 \times 191.6) + (12 \times 70.0)] - [(4 \times 266.9) + (5 \times 121.2)] \\ &= 2181.2 - (1673.6) \\ &= 507.6 \text{ J/mol}\cdot\text{K} \end{aligned}$$

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

9. Substances that dissolve in water (H₂O) generally do not dissolve in benzene (C₆H₆). 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?

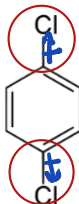
D

A. Naphthalene



Naphthalene has a similar structure to benzene (non-polar) \therefore capable of forming LDFs
Naphthalene is soluble in benzene but not in H₂O (polar)

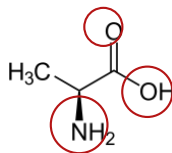
B. para-dichlorobenzene



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

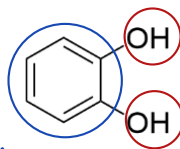
para-dichlorobenzene is a non-polar molecule \therefore capable of forming LDFs
para-dichlorobenzene is soluble in benzene but not in water

C. Alanine (an amino acid)



C=O bond is polar can form DD forces while NH₂ & 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 =

$$\frac{3.87 \text{ g NaCl}}{100 \text{ g solution}} \quad \text{— solvent}$$

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

Liters of water needed to dissolve 725g of NaCl

$$\begin{aligned} 725 \text{ g NaCl} \times \frac{96.13 \text{ g H}_2\text{O}}{3.87 \text{ g NaCl}} \times \frac{1.00 \text{ mL}}{1 \text{ g H}_2\text{O}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \\ = 18.00885 \sim 18.0 \text{ L} \end{aligned}$$

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 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 (I_2) must be dissolved in 625 mL of carbon disulfide solution (CS_2 , density = 1.261 g/mL) to produce the 0.286 m solution?

57.2

g

0.286 m solution of iodine in CS_2 =

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

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

Mass of I_2 to be dissolved in 625 mL of 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 $C_{\text{gas}} = K_H P_{\text{gas}}$

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

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

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

to be determined

Using the ideal gas law to determine the mol of gas

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

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

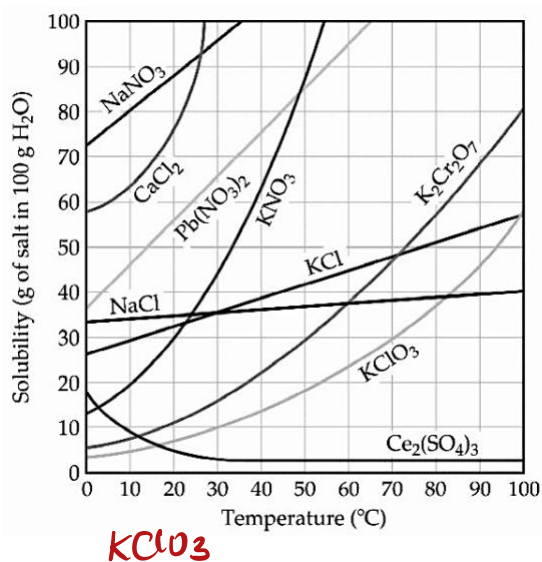
Using Henry's law constant $C_{\text{gas}} = K_H P_{\text{gas}}$

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

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

$$= 2.04 \text{ L}$$

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



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 KClO₃

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

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

$$\text{Molar mass of } \text{H}_3\text{PO}_4 = 97.99 \text{ g/mol}$$

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 g/cm^3 at 30°C . What is the

A. Molality of H_3PO_4 in the detergent solution?

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

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

$$\text{Molality} = \frac{\text{mol of } \text{H}_3\text{PO}_4}{1 \text{ kg of solvent}}$$

$$26.0\% \text{ by mass } \text{H}_3\text{PO}_4 = \frac{26.0 \text{ g } \text{H}_3\text{PO}_4}{100 \text{ g of solution}} \quad \therefore \text{mass of } \text{H}_2\text{O} = 100 \text{ g solution} - 26.0 \text{ g } \text{H}_3\text{PO}_4 = 74.0 \text{ g } \text{H}_2\text{O}$$

$$\frac{26.0 \text{ g } \text{H}_3\text{PO}_4}{74.0 \text{ g } \text{H}_2\text{O}} \times \frac{1 \text{ mol } \text{H}_3\text{PO}_4}{97.99 \text{ g } \text{H}_3\text{PO}_4} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 3.59 \text{ m}$$

B. Molarity of H_3PO_4 in the solution?

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

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

$$\frac{26.0 \text{ g } \text{H}_3\text{PO}_4}{100 \text{ g solution}} \times \frac{1 \text{ mol } \text{H}_3\text{PO}_4}{97.99 \text{ g } \text{H}_3\text{PO}_4} \times \frac{1.148 \text{ g solution}}{1 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 3.05 \text{ M}$$

C. Mole fraction of H_3PO_4 in the detergent solution?

$$\boxed{0.0607}$$

$$\text{Mole fraction of } \text{H}_3\text{PO}_4 = \frac{\text{mol } \text{H}_3\text{PO}_4}{\text{mol } \text{H}_3\text{PO}_4 + \text{mol } \text{H}_2\text{O}}$$

$$\text{From part A you have the mass of } \text{H}_2\text{O} = 74.0 \text{ g}$$

$$\text{mol of } \text{H}_2\text{O} = 74.0 \text{ g } \text{H}_2\text{O} \times \frac{1 \text{ mol } \text{H}_2\text{O}}{18.01 \text{ g } \text{H}_2\text{O}} = 4.1083284 \text{ mol } \text{H}_2\text{O}$$

$$\text{mol of } \text{H}_3\text{PO}_4 = 26.0 \text{ g} \times \frac{1 \text{ mol } \text{H}_3\text{PO}_4}{97.99 \text{ g } \text{H}_3\text{PO}_4} = 0.2653332 \text{ mol } \text{H}_3\text{PO}_4$$

$$\text{mole fraction of } \text{H}_3\text{PO}_4 = \frac{0.2653332 \text{ mol } \text{H}_3\text{PO}_4}{0.2653332 \text{ mol } \text{H}_3\text{PO}_4 + 4.1083284 \text{ mol } \text{H}_2\text{O}} = 0.0607$$

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

- E**
- A. Li^+
 - B. Ca^{2+}
 - C. Ba^{2+}
 - D. Cs^+
 - E. 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, CHCl_3 . How many grams of CHCl_3 would be found in a glass of this water? (One glass of water = 250 mL).

2.4×10^{-6} g

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

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

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

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. ΔH_{soln} is negative and ΔS_{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? $1 \text{ M} = 10^{-6} \mu\text{M}$

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

B. Calculate the partial pressure of N_2 in the atmosphere.

$$\boxed{0.73} \text{ atm} \quad \text{Using Henry's law}$$

$$C_{\text{gas}} = K_H P_{\text{gas}}$$

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

$$\therefore P = 0.73$$

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? $1 \text{ L} = 10 \text{ dL}$

$$\boxed{780} \text{ ppm}$$

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

$$\frac{80. \text{ mg}}{\text{dL}} \times \frac{10 \text{ dL}}{1 \text{ L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{1 \text{ mL}}{1.025 \text{ g}} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 780 \text{ ppm}$$

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

$$\begin{aligned} & \frac{0.112 \text{ mol } C_6H_{12}O_6}{1 \text{ L solution}} \\ \text{Mass of solution} &= 1 \text{ L solution} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{1.006 \text{ g}}{\text{mL}} \\ &= 1006 \text{ g solution} \\ \text{Mass of } C_6H_{12}O_6 &= 0.112 \text{ mol } C_6H_{12}O_6 \times \frac{180.18 \text{ g } C_6H_{12}O_6}{1 \text{ mol } C_6H_{12}O_6} \\ &= 20.17 \text{ g} \\ \text{Mass of water} &= 1006 \text{ g} - 20.17 \text{ g} = 986 \text{ g} \\ 986 \text{ g H}_2\text{O} &\times \frac{1 \text{ mol H}_2\text{O}}{18.01 \text{ g H}_2\text{O}} = 54.7 \text{ mol} \\ \frac{0.112}{0.112 + 54.7} &= 0.00204 \end{aligned}$$

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

$$\begin{aligned} & \frac{3.20 \text{ mL } C_2H_5OH}{100 \text{ mL solution}} \\ \text{Volume of H}_2\text{O} &= 100 - 3.20 = 96.8 \text{ mL} \\ 96.8 \text{ mL} &\times \frac{1.00 \text{ g H}_2\text{O}}{1 \text{ mL H}_2\text{O}} \times \frac{1 \text{ mol H}_2\text{O}}{18.01 \text{ g H}_2\text{O}} \\ &= 5.37 \text{ mol} \end{aligned}$$

②

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

$$\begin{aligned} \chi_{C_2H_5OH} &= \frac{0.0548}{5.37 + 0.0548} = \frac{0.0548}{5.42} \\ &= 0.0101 \end{aligned}$$

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.

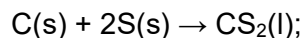
When $\Delta G = 0$

this means that the system is at equilibrium

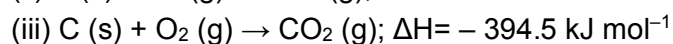
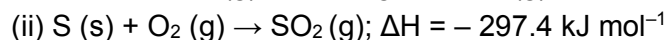
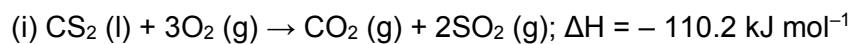
Remember:

$\Delta G < 0$ 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

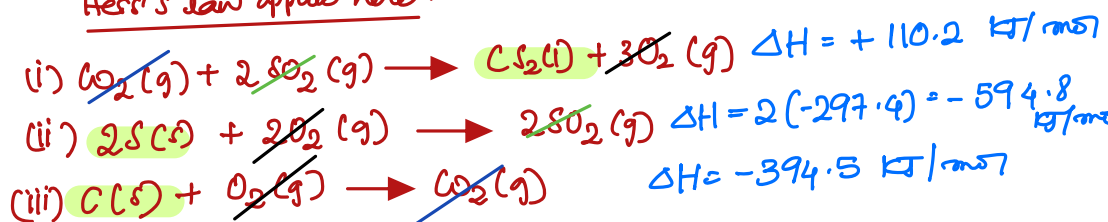


*flip
multiply by 2
flip the same*

Hess's law applies here:

879.1

kJ/mol



3. For the process



→ ΔS_{sys}

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

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

$$\begin{aligned} \textcircled{1} \Delta S_{\text{surr}} &= -\frac{\Delta H_{\text{sys}}}{T} = -\frac{(-0.21 \text{ kJ} \times 1000 \text{ J})}{25 + 273.15} = \frac{210 \text{ J}}{298.15 \text{ K}} \\ &= 0.70434345 \text{ J/K} \approx 0.70 \text{ J/K} \end{aligned}$$

$$\begin{aligned} \textcircled{2} \Delta S_{\text{total}} &= \Delta S_{\text{sys}} + \Delta S_{\text{surr}} \\ &= -4.2 \text{ J/K} + 0.70 \text{ J/K} = -3.5 \text{ J/K} \end{aligned}$$

$\Delta S_{\text{total}} < 0$ 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 (ΔG , ΔH , T , ΔS)?

E

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

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

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

ΔG (-) because a solution forms \therefore spontaneous
 ΔH 0 no sign because no energy released due to same LDFs formed
 T + sign should have a positive sign for the term $-T\Delta S$ be (-) for $\Delta G < 0$
 ΔS (+) 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?

1.82×10^{-4} mol

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

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

$\therefore \text{mass of solute} = 39.2746 \text{ mg}$

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 %

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

\downarrow Henry's law constant

\downarrow conc of gas

$C_{\text{CO}_2} = 3.4 \times 10^{-2} \frac{\text{mol}}{\text{L} \cdot \text{atm}} \times 4.23 \text{ atm}$

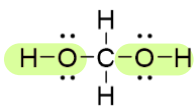
$= 0.14328 \frac{\text{mol CO}_2}{\text{L}} \times \frac{44.01 \text{ g CO}_2}{1 \text{ mol CO}_2}$

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

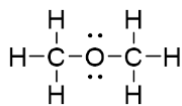
$= \frac{6.3295182 \text{ g}}{1000 \text{ g solution}} \times 100 = 0.63295182\%$

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

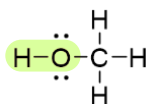
A.



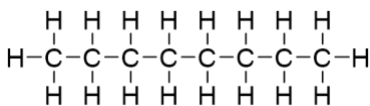
B.



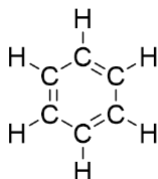
C.



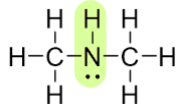
D.



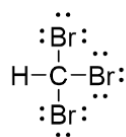
E.



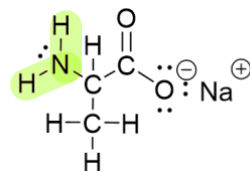
F.



G.



H.



Can form H-bonding

I. Which structures represent compounds that would most likely be soluble in ethylene glycol (HOCH₂CH₂OH)? Select all that apply.

ACFH

II. Which 2 structures represent the compounds **most** likely to dissolve C₆H₁₄?

DE

Formula Sheet

Length

1 kilometer = 0.62137 mile
1 inch = 2.54 centimeters (exactly)
1 Ångstrom = 1×10^{-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/in²
1 bar = 1×10^5 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

$c = 2.998 \times 10^8 \text{ m/sec}$
 $h = 6.626 \times 10^{-34} \text{ J} \cdot \text{sec}^{-1}$
 $R = 0.08206 \text{ L} \cdot \text{atm} / \text{mol} \cdot \text{K} = 8.314 \text{ J} / \text{mol} \cdot \text{K}$
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: 6.022×10^{23}

Equations

d (density) = m/V
 $P_1 V_1 = P_2 V_2$
 $V_1/T_1 = V_2/T_2$
 $P_1 V_1/n_1 T_1 = P_2 V_2/n_2 T_2$
 $PV = nRT$
 $(P + a(n^2/V^2)) \cdot (V - nb) = nRT$
molar mass (M) = mRT/PV
density (d) = MP/RT
 $x_A = n_A/n_{\text{tot}} = P_A/P_{\text{tot}} = V_A/V_{\text{tot}}$
 $P_{\text{tot}} = P_A + P_B + \dots$
 $n_{\text{tot}} = n_A + n_B + \dots$

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

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

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

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

$$w = -P\Delta V$$

$$\Delta E = q + w$$

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

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

$$E = h\nu$$

$$c = \lambda\nu$$

$$\lambda = h/mv$$

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

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

$$C_g = kP_g$$

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

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

$$\Delta T_b = K_b m_i$$

$$\Delta T_f = K_f m_i$$

$$\pi = MRTi$$

Thermodynamic and Electrochemistry

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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																		18	
1 H 1.01																2 He 4.00			
3 Li 6.94																10 Ne 20.18			
4 Be 9.01																9 F 19.00			
11 Na 22.99		12 Mg 24.31												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			
37 Rb 85.47		38 Sr 87.62		39 Y 88.91		40 Zr 91.22		41 Nb 92.91		42 Mo 95.95		43 Tc [97]		44 Ru 101.07		45 Rh 102.91			
56 Ba 132.91		57 La 138.91		58 Ce 140.12		59 Pr 140.91		60 Nd 144.24		61 Pm [145]		62 Sm 150.36		63 Eu 151.96		64 Gd 157.25			
87 Fr [223]		88 Ra [226]		104 Rf [267]		105 Db [268]		106 Sg [269]		107 Bh [270]		108 Hs [269]		109 Mt [277]		110 Ds [281]			
												</							