Name (Last, First): ___________________________________ ID Number: ___________________

WUCT: Chemistry of Cleaning Sample

1. Hard water is water that contains cations, especially Ca^{2+} and Mg^{2+}. When heated, these cations can form a solid precipitate, which can build up in household water pipes. An example of one of these precipitation reactions is that of Ca^{2+} with HCO_3^- to form solid calcium carbonate, $CaCO_3$.

$$\mathbf{Ca^{2+}\,(aq) + 2\,HCO_3^-\,(aq) \rightleftarrows CaCO_3\,(s) + CO_2\,(g) + H_2O\,(l)}$$

Selected Heats of Formation (kj/mol)	
$\Delta H^o_f\,(Ca^{2+}, aq)$	-542.8
$\Delta H^o_f\,(CO_3^{2-}, aq)$	-673.3
$\Delta H^o_f\,(CaCO_3, s)$	-1206.9
$\Delta H^o_f\,(CO_2, g)$	-393.5
$\Delta H^o_f\,(H_2O, g)$	-241.8
$\Delta H^o_{vap}\,(H_2O)$	44.0

a. Calculate ΔH^o_{rxn} for this reaction at 25℃.

$\Delta H^\circ_{rx} = \Delta H^\circ_f\,(CaCO_3, s) + \Delta H^\circ_f\,(CO_2, g) + \Delta H^\circ_f\,(H_2O, l) - \Delta H^\circ_f\,(Ca^{2+}, aq) - 2\,\Delta H^\circ_f\,(CO_3^{2-}, aq)$
$\Delta H^\circ_f\,(H_2O, l) = \Delta H^\circ_f\,(H_2O, g) - \Delta H^\circ_{vap}\,(H_2O) = -241.8\text{ kJ/mol} - 44.0\text{ kJ/mol} = -285.8\text{ kJ/mol}$
$\Delta H^\circ_{rx} = -1206.9\text{ kJ/mol} - 393.5\text{ kJ/mol} - 285.8\text{ kJ/mol} + 542.8\text{ kJ/mol} - 2(-673.3\text{ kJ/mol})$
$\Delta H^\circ_{rx} = 9.16\text{ kJ/mol}$

b. Using your answer form part a, explain why hard water causes more mineral deposits to build up when hot.

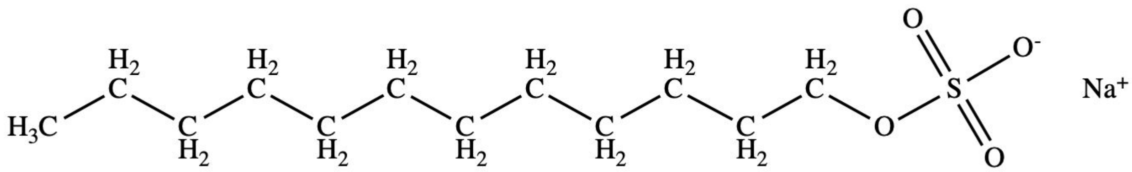
The reaction to form $CaCO_3$ (s) is endothermic. This means that as the temperature increases, the equilibrium constant K increases as well, pushing the reaction further to the right. This leads to more solid calcium carbonate formed, and thus more mineral deposits in hot water.

c. Calculate the equilibrium constant, K, for this reaction at 25℃ if $\Delta S^o = 0.15$ kj/mol*K

$$lnK = \frac{-\Delta H^\circ}{R}\cdot\frac{1}{T} + \frac{\Delta S^\circ}{R}$$
$$lnK = \frac{-9.16\,kJ/mol}{8.314*10^{-3}\,kJ/(mol{\cdot}K)}\cdot\frac{1}{298\,K} + \frac{0.15\text{ kJ/(mol·K)}}{8.314*10^{-3}\,kJ/(mol{\cdot}K)}$$
$$K = e^{14.34} = 1.70 * 10^6$$

Name (Last, First): ________________________________ ID Number: _________________

2. Shown below is the structure of Sodium Lauryl Sulfate (SLS), a common detergent found in many shampoos.



a. Circle and label any hydrophobic and hydrophilic regions on the structure above. Would you describe this molecule as hydrophilic, hydrophobic, or amphiphilic?

Hydrocarbon should be circled and labeled as hydrophobic, sulfate should be circled and labeled as hydrophilic. Overall, this molecule is amphiphilic.

b. Explain why detergents are used to clean hair. In other words, how to detergents interact with the water from a shower and the oil present on hair?

Detergents like the one above are amphiphilic, so the hydrophobic region will interact with the hydrophobic oils on the hair and the hydrophilic region will interact with the water from the shower. As a result, when you wash off the shampoo, the detergent acts as a tether between the water and the oil and pulls the oil off the hair as the water flows through the hair. Without the detergent, the water would just run off and the oil would remain because they are immiscible.

c. A key step in the preparation of SLS is the sulfonation of lauryl alcohol with sulfuric acid.

i. Write the balanced net ionic equation for the reaction of Lauryl Alcohol with Sulfuric Acid.

$C_{12}H_{26}O + H_2SO_4 \rightarrow CH_3(CH_2)_{10}CH_2OSO_3H + H_2O$

ii. If excess pure sulfuric is added to 500 ml pure lauryl alcohol (density: 0.83 g/ml), how much SLS will be produced assuming the reaction continues to completion?

(500 ml)(0.83 g/ml)(1 mol / 186.34 g) = 2.23 mol lauryl alcohol
With excess acid, 2.23 mol SLS will be formed.

3. The main reactive ingredient of bleach, a common household cleaning agent, is sodium hypochlorite (NaOCl). Bleach is also used to clean swimming pools, and if you have ever been in a swimming pool, you have probably felt its effects on your eyes. Bleach was originally produced industrially using the reaction below:

$$\mathbf{Cl_2\,(g) + H_2O \rightleftarrows HOCl + HCl\,(aq)}$$

a. Which way would the equilibrium shift if any acid was added to the reaction?

The addition of more acid effectively increases the concentration of HCl, pushing the reaction by le chatlier's principle to the left.

b. Is the backward reaction a redox reaction, ion exchange, or some other type?

The backwards reaction is a redox reaction with the HOCl oxidizing the HCl to produce the chlorine gas.

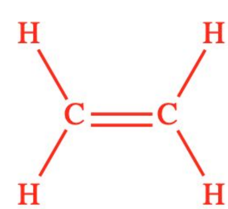
c. The active ingredient in household bleach is NaOCl, as mentioned above. Why would adding something acidic, like vinegar (acetic acid) be a bad idea? Use the following reaction to explain your answer qualitatively:

$$\mathbf{NaOCl + H_2O \rightleftharpoons HOCl + OH^-}$$

In every bleach solution, some of the active agent exists as HOCl as seen in the above equilibrium. However, HOCl can oxidize HCl to produce poisonous chlorine gas. With the addition of something like acetic acid, though it won't increase the amount of HCl, it will siphon out hydroxide ions from the above equilibrium, pushing it to the right and leaving more HOCl in solution. This opens up the chance for chlorine gas production.

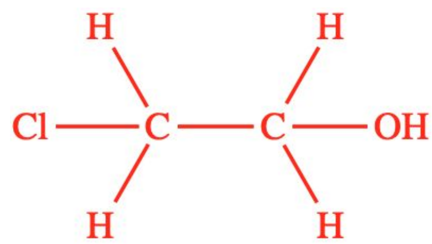
d. Organic compounds that produce unwanted colors can be found on many surfaces in our homes. The color of these compounds is correlated to the number of double bonds in the compound. A class of bleaches, known as reducing bleaches, is most often used to whiten these surfaces.

   i. To better understand how reducing bleaches work, draw the Lewis structure for ethene (C_2H_4) and assign oxidation numbers to each carbon.



-2 on each carbon

   ii. When reacted with bleach, the product is C_2H_5OCl. Draw the Lewis structure for this molecule and assign oxidation numbers to each carbon. Is the change in oxidation numbers expected?



-1 on each carbon

Yes, the change is expected. NaOCl is an oxidizing agent and the carbons have been oxidized.

iii. Using your answers to parts i, ii, and the information presented in part d, explain how reducing bleaches serve as whitening agents.

In going from double to single bonds bonded to more electronegative atoms, the carbons have been oxidized. This can be carried out by bleaches. They break double bonds to produce single bonds. This takes away color because color is correlated to the number of double bonds, effectively whitening the surfaces.