Name: ______________________________ Date: _______________

Soap Scum Transfer Task

Have you ever washed your hands and thought that they did not feel clean? It may be that something formed on your hands called soap scum! Soap scum forms when you wash your hands using some bar-shaped soaps with hard water. Hard water is water that contains high amounts of dissolved minerals, such as calcium bicarbonate, $Ca(HCO_3)_2$, common in rocks like limestone.

Calcium bicarbonate is an ionic compound that breaks apart into two ions when it dissolves in water: Ca^{2+} and HCO_3^-.

Having hard water not only can affect how clean your skin feels, it can also lead to serious issues with your home plumbing. Hard water can cause soap scum and other deposits to build up on the inside of pipes. This can lead to clogs in pipes and provide surfaces for bacterial growth.

Question 1. Develop an initial model to explain what you think might be happening between calcium bicarbonate and water before soap scum forms on the sink drain. Be sure to include the following components of the system and their interactions in your model:

- drain surface
- water molecules, including partial charges
- calcium and bicarbonate ions

Use *Periodic Table* from Lesson 7 and *Electronegativity Periodic Table* from Lesson 9 as you answer the items to figure out:

- How do the particle-level structures help further explain what causes soap scum?

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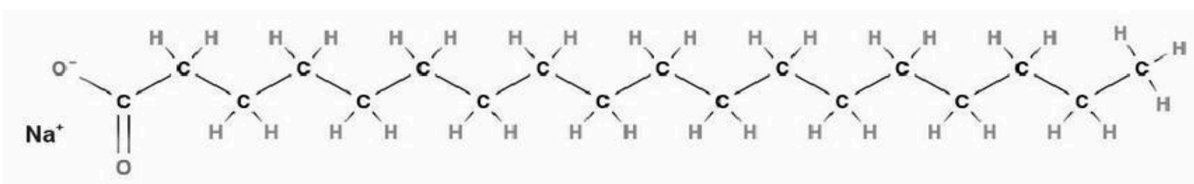
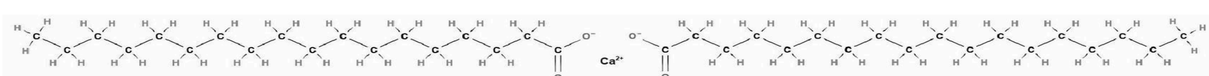
Bar soaps typically contain a compound called sodium stearate, $NaC_{18}H_{35}O_2$, which is soluble in water. When water has high quantities of dissolved calcium bicarbonate, $Ca(HCO_3)_2$, the calcium ions (Ca^{2+}) can replace the sodium ions (Na^+) to form calcium stearate or soap scum, $Ca(C_{18}H_{35}O_2)_2$. This substance is insoluble (cannot dissolve) in water and gets stuck on hands and in pipes.

Compound and name	Solubility in water
$NaC_{18}H_{35}O_2$, Sodium stearate (soap)	Soluble
Model	
	

Compound and name	Solubility in water
$Ca(C_{18}H_{35}O_2)_2$, Calcium stearate (soap scum)	Insoluble
Model	
	

Question 2. Balance the chemical equation for this reaction by adding coefficients on the provided lines. Use the table to help you keep track of atoms as you are balancing the chemical equation.

(Key: aq = aqueous (dissolved in water), l = liquid, s = solid)

_____$Ca(HCO_3)_2$ (aq) + ______ $NaC_{18}H_{35}O_2$ (aq) → ______ $NaHCO_3$ (aq) + _____$Ca(C_{18}H_{35}O_2)_2$ (s)

Elements	Reactants	Products
Ca, calcium		
HCO_3, bicarbonate		
Na, sodium		
$C_{18}H_{35}O_2$, stearate		

The chemical equation you balanced in **Question 2** summarized the overall process to form soap scum. It did not illustrate the process of sodium stearate, $NaC_{18}H_{35}O_2$, being dissolved in water. The sodium is attracted to the oxygen portion of the stearate ion. You know from prior lessons that the oxygen portion of a water molecule also has a negative charge.

The following table provides information about atomic radius and electronegativity of the atoms to help explain differences in polarity of the water molecules, H_2O, and stearate ions, $C_{18}H_{35}O_2^-$.

Atom	Radius (pm) 1 billion pm = 1 mm	Electronegativity of elements
Na, sodium	180	0.93
H, hydrogen	25	2.22
C, carbon	70	2.55
O, oxygen	60	3.44

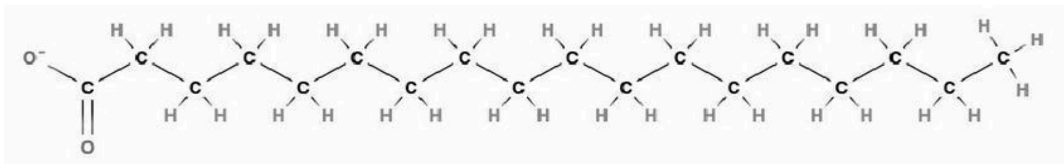
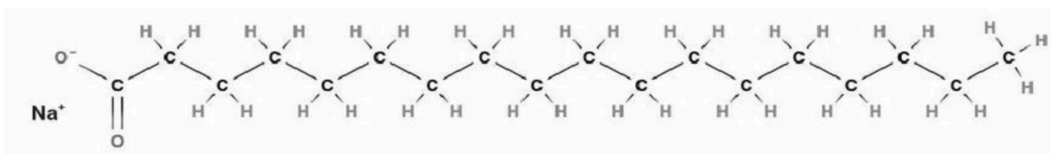
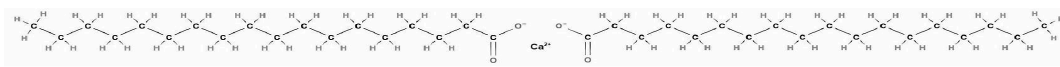
Question 3a. How is it possible that the oxygen atom in the water molecule is able to pull the sodium ion away from the oxygen molecule in the stearate ion? Construct an explanation of this phenomenon using differences in electronegativity between the atoms in water molecules and stearate ions. You may wish to use the following table to help you think through your evidence.

Bond	Difference in electronegativity
O - H (in water molecule)	
O - C (in stearate ion)	
O - Na (O in water, Na in sodium stearate)	

Another process in the chemical equation you balanced in **Question 2** was not shown. Just as sodium stearate, $NaC_{18}H_{35}O_2$, dissolves in water, so does calcium bicarbonate, $Ca(HCO_3)_2$. The free-floating stearate ions, $C_{18}H_{35}O_2^-$, and calcium ions, Ca^{2+}, are able to bond with each other to form calcium stearate, $Ca(C_{18}H_{35}O_2)_2$.

Question 3b. Why does the calcium ion attach to two stearate ions? Construct an explanation using evidence from patterns in the periodic table and information presented in this assessment as support.

Question 3c. The following table includes information about the stearate ion, electronegativities of its elements, and images of calcium stearate and sodium stearate. Use this information and patterns in the periodic table to explain why the sodium or calcium ion is likely to be closer to the oxygen atoms in the stearate ion rather than the portion containing carbon and hydrogen.

Ion/molecule and name	Radius (pm) 1 billion pm = 1 mm	Electronegativity of elements
$C_{18}H_{35}O_2^-$ Stearate ion	> 4000	C = 2.55 H = 2.22 O = 3.44
		
$NaC_{18}H_{35}O_2$ Sodium stearate		
$Ca(C_{18}H_{35}O_2)_2$ Calcium stearate		

Write your explanation in the space below.

Hard water can also contain other dissolved minerals which can lead to the formation of soap scum. Chemical engineers are studying two minerals and their likelihood to

cause damage to pipes: potassium carbonate, KCO_3, and magnesium bicarbonate, $Mg(HCO_3)_2$.

Question 4. Which mineral, potassium carbonate or magnesium bicarbonate, would most likely form soap scum by combining with stearate ion(s) to form an insoluble compound? Why?

- Use evidence from patterns in the periodic table and information presented in this assessment as support for your explanation.