Supporting information

Teaching and assessing systems thinking in first-year chemistry

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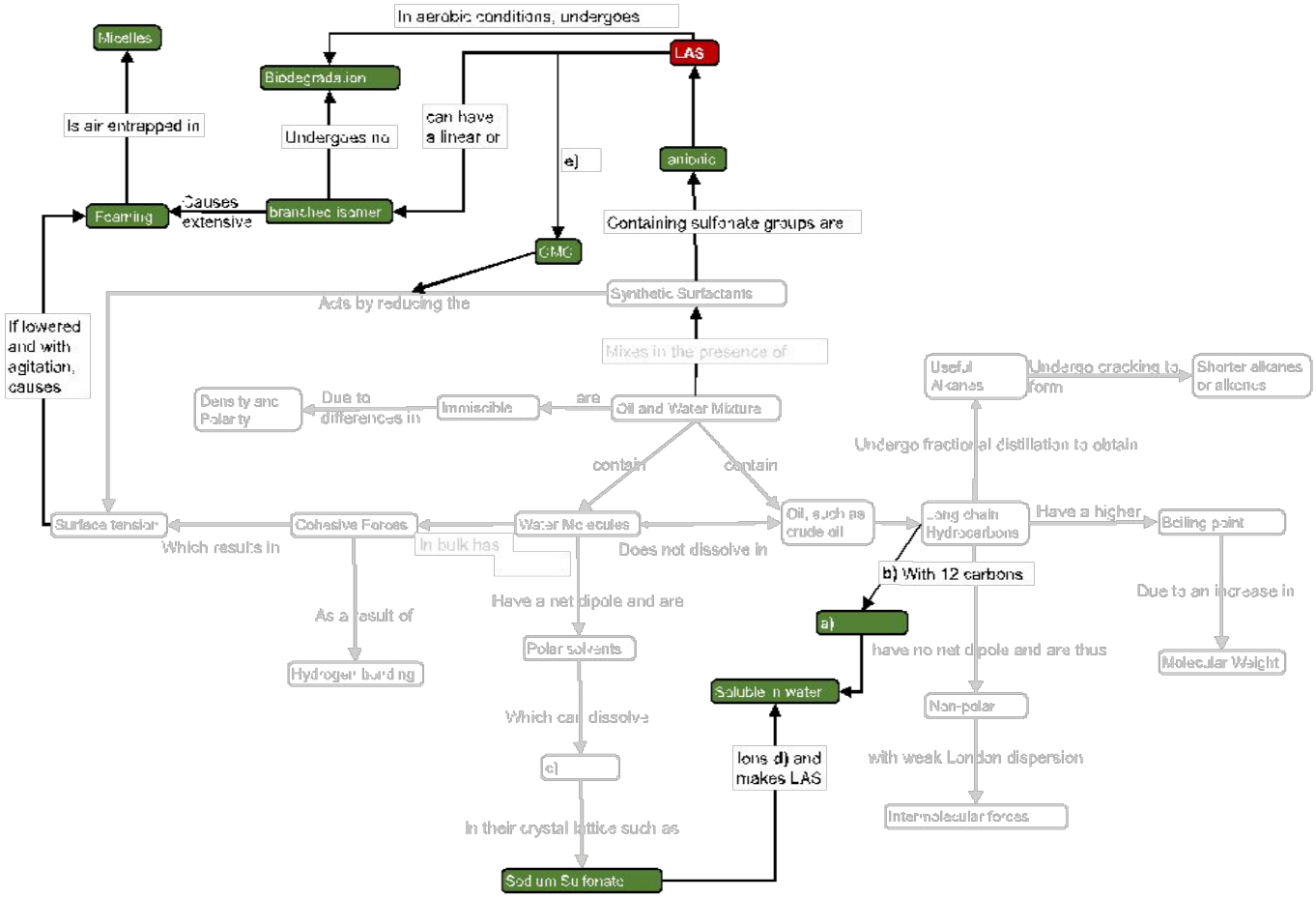
Practical Activity 1

Environmental Subsystem

Description

In this practical activity, you will collaborate with your group members to answer the questions about the environmental subsystem as in the expanded concept map.



Expanded Concept Map: Environmental subsystem

Instructions

Answer the following questions in your subsystem group. NB the expanded concept map is only given to show how concepts can be organized into the larger system.

Total questions

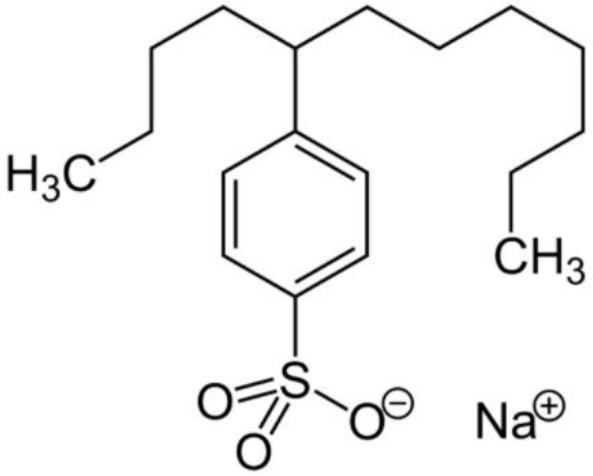
7

Total points

20

Question 1 (Jumbled sentence- 5 marks)

Alkanes aren't soluble in water, however, Linear Alkylbenzene Sulfonate (LAS) containing a long chain of 12 carbons, is soluble in water. The structure of a LAS molecule can be seen below.



<u>Choose the correct answers from the drop-down list that explain the solubility properties of LAS.</u> *(the options can be chosen more than once)*

An example of a long-chain hydrocarbon that contains 12 carbons is known as a **[a]** *(refer to a) on the concept map).* This alkane is **[b]** because of its symmetry and **[c]** spread electrons, making it **[d]** *(refer to b) on the concept map)* in water. Linear alkylbenzene sulfonate is soluble in water, even though it contains two alkyl substituents, a/an **[e]** group (8 carbons) and a/an **[f]** group (4 carbons). The benzene group has many carbon-hydrogen bonds that are equally spaced, and since benzene is a perfect hexagon with angles of 120°, it is also symmetrical and is, therefore **[g],** which makes it **[h]** soluble in water. To explain the high solubility of linear alkylbenzene sulfonate we can look *at **[i]** (refer to c) on the concept map),* such as sodium chloride, sodium sulfonate, and sodium linear alkylbenzene sulfonate, that can **[j]** *(refer to d) on the concept map)* into cations and anions. The ion-dipole attractive forces cause the water molecules to surround the sodium cations and the sulfonate anions in linear alkylbenzene sulfonate and make it soluble in water. It is the high solubility of linear alkylbenzene sulfonate that makes it an environmental concern as it can easily be transported in aquatic ecosystems and terrestrial ecosystems where it can be absorbed by aquatic life and food crops.

Drop-down list of answers
decane
dodecane
polar
non-polar
evenly
unevenly
soluble
insoluble
butyl
octyl
propyl
less
more
metallic compounds
ionic salts

ionise
dissociate

Question 2 (Multiple Choice- 1 mark)

Identify the correct linking phrase for the arrow e) on the expanded concept map.

At low concentrations, exceeds the Critical Micelle Concentration (CMC)
At high concentrations, exceeds the Critical Micelle Concentration (CMC)
At equal concentrations, exceeds the Critical Micelle Concentration (CMC)

Question 3 (Ordering- 5 points)

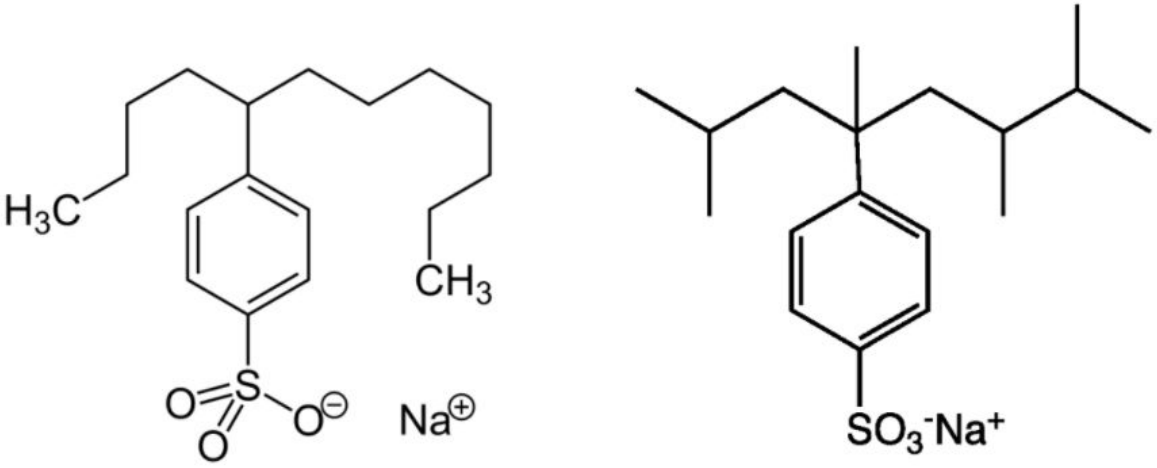
Surfactants are surface-active agents that can allow gas to mix with a liquid, a liquid to mix with a liquid, and a liquid to mix with a solid by lowering the surface tension of the liquid. To explain the mechanism behind the formation of foam.

Use the expanded concept map to order the following statements in a logical order:

1. Foaming can block sunlight, prevent photosynthesis in river plants and decrease the available oxygen in the river
2. LAS has an amphiphilic structure, with a hydrophilic head that is attracted to water and a hydrophobic tail is attracted to air
3. As the concentration of LAS exceeds the critical micelle concentration, the surface tension of the water will reduce significantly
4. The surfactant micelles of LAS entrap air and results in more foaming as agitation increase
5. With a reduced surface tension, LAS causes air to mix with water upon agitation

Question 4.1 (Multiple Choice- 2 marks)

Branched alkyl benzene sulfonates (BAS) as indicated on the right of the diagram below, have a greater detergency power and produce more foaming, however in the 1960's BAS was phased out as excessive foaming and inability to biodegrade resulted in environmental concerns.

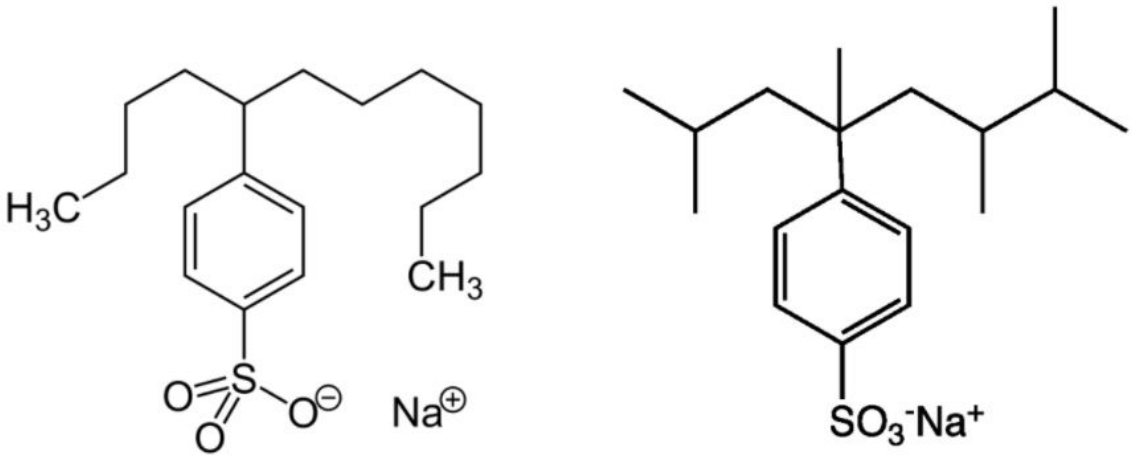


Select the correct answer that describes the definition of an isomer.

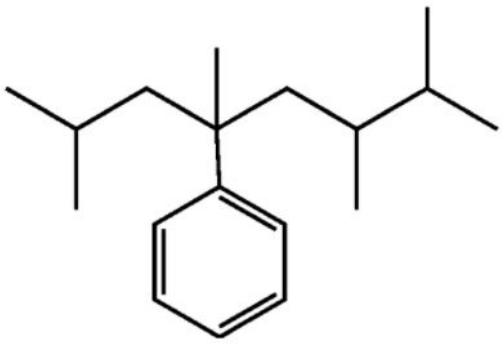
A. one of two or more atoms of a chemical element with the same atomic number and nearly identical chemical behaviour but with different atomic masses and physical properties
B. contain the same number of atoms for each element, but the atomic arrangement differs. Despite having the same molecular formula, the physical properties of each molecule may differ describes
C. a compound belonging to a series of compounds with similar chemical properties with the same general formula, differing from each other by a repeating unit.
D. contain the same number of atoms for each element, but the atomic arrangement differs. Despite having a different molecular formula, the physical properties of each molecule are the same

Question 4.2 (Multiple Choice- 2 marks)

Branched alkyl benzene sulfonates (BAS) as indicated on the right of the diagram below, have a greater detergency power and produce more foaming, however in the 1960's BAS was phased out as excessive foaming and inability to biodegrade resulted in environmental concerns.



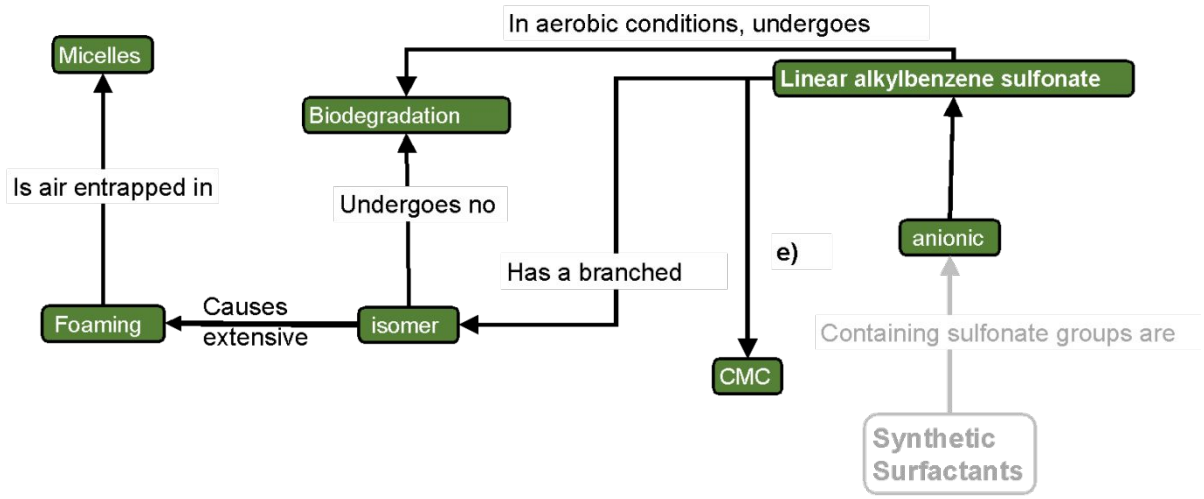
<u>Identify the IUPAC name of the benzene pre-cursor of BAS as shown below. (Hint: the benzene substituent is known as a phenyl group.)</u>



A. 2, 3, 5, 7-tetramethyl- 5-phenyloctane
B. 4-phenyl-2, 4, 6, 7-tetramethyloctane
C. 2, 4, 6, 7-tetramethyl-4-phenyloctane

Question 5 (Hotspot- 1 mark)

Linear alkylbenzene sulfonate becomes ecotoxic to aquatic life at high concentrations. **Click on the concept (block)** responsible for changing the concentration of linear alkylbenzene sulfonate over time.



Question 6 (Matching- 4 marks)

Anionic surfactants with longer chain lengths have a higher detergency power, however longer chain lengths increase the ecotoxicity of surfactants. Only 3.2 mg/l of the 12-carbon linear alkyl benzene is required to cause the death of 50% of aquatic life, such as the fish *Pimephales promelas.*
Which concept is described in each case (choose between lethal concentration, volatility, surface tension and solubility)

Question	Answer
A. Longer carbon chains on ionic salts, such as surfactants, require more energy to weaken the intermolecular forces, therefore decreasing the …….of surfactants, allowing accumulation in aquatic and terrestrial ecosystems.	
B. Longer chains, together with branched chains, decrease the ……. which allows it to settle into soils, sorbs to organic matter, and can be absorbed by aquatic life. Therefore increasing the bioavailability of LAS.	
C. Longer carbon chains exhibit lower critical micelle concentrations, therefore it can reduce the …….at lower concentrations and allow the surfactant to cause extensive foaming.	
D. The concentration of LAS required to kill 50% of the Pimephales promelas fish species, is 3.2 mg/l.	

Discuss in your group whether these concepts belong to the social, economic, or environmental subsystem and fill in the blank.

- Drinking water can potentially fit within the **[a]** subsystem
- Wastewater Treatment Plants can potentially fit within the **[b]** subsystem
- Sewage can potentially fit within the **[c]** subsystem
- Rural villages can potentially fit within the **[d]** subsystem
- Food can potentially fit within the **[e]** subsystem
- Cytotoxic can potentially fit within the **[f]** subsystem
- Household can potentially fit within the **[g]** subsystem
- Chemical waste can potentially fit within the **[h]** subsystem
- Health risks can potentially fit within the **[i]** subsystem
- Population can potentially fit within the **[j]** subsystem

For further enrichment discuss the following in your subsystem group:

1. How you would link these concepts to other concepts in the societal subsystem?
2. What would your linking words be on the arrows when you connect two or three concepts in the societal subsystem?