SI Chemistry - Full Discipline Demo

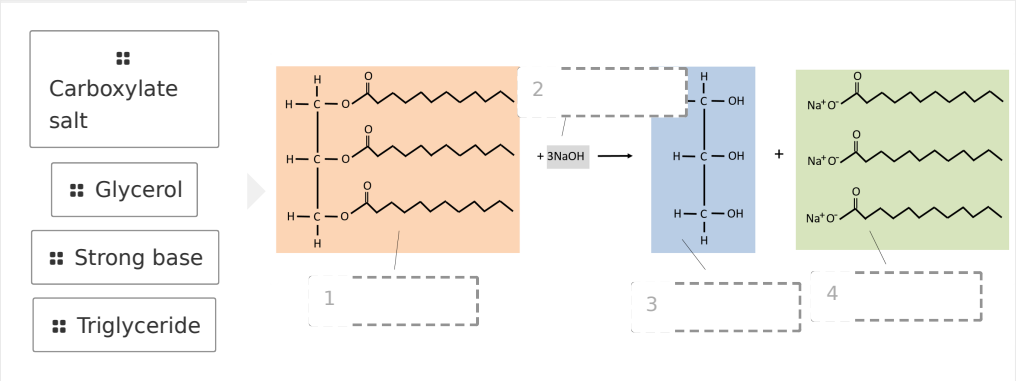
Synthesis and Analysis of Soap

Final Report - Answer Guide

Institution	Science Interactive University
Session	SI Chemistry - Full Discipline Demo
Course	SI Chemistry - Full Discipline Demo
Instructor	Sales SI Demo

Test Your Knowledge

Label the compounds of a saponification reaction.



Correct answers:

1 Triglyceride 2 Strong base 3 Glycerol 4 Carboxylate salt

Identify each statement as true or false.

- Glycerol is an insoluble fatty acid.
- Most triglyceride molecules contain only one type of fatty acid.
- The carbon-carbon bonds in saturated fatty acids are all single C-C bonds
- Triglycerides are derived from glycerol and fatty acids.

True	False
1	2

Correct answers:

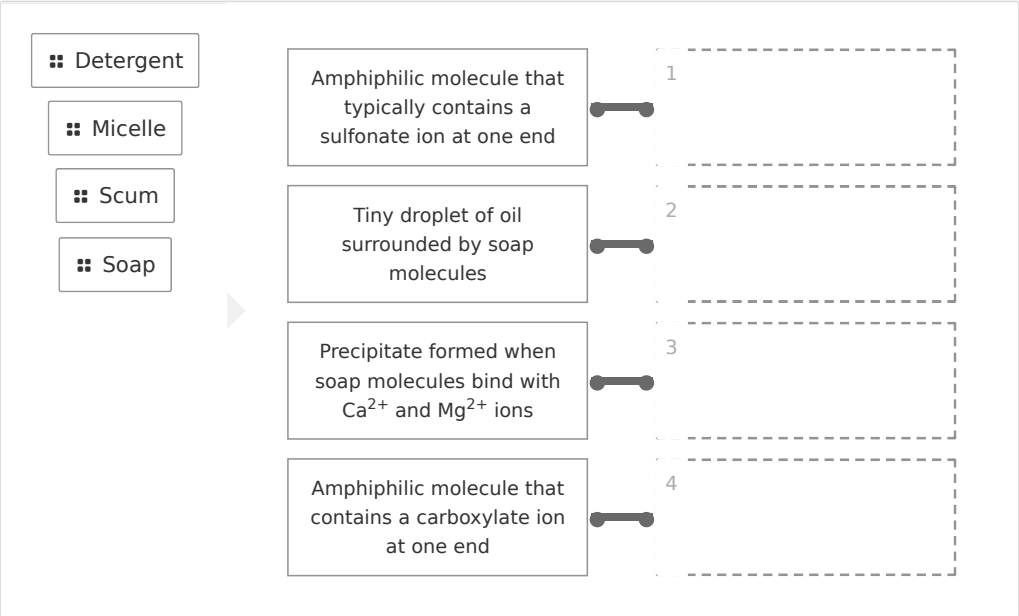
1 The carbon-carbon bonds in saturated fatty acids are all single C-C bonds

Triglycerides are derived from glycerol and fatty acids.

2 Glycerol is an insoluble fatty acid.

Most triglyceride molecules contain only one type of fatty acid.

Match each term with the best definition.



Correct answers:

1 Detergent 2 Micelle 3 Scum 4 Soap

Exploration

Saponification produces soaps from the hydrolysis of _____.

- alcohols
- triglycerides ✔
- glycerol
- bases

Saturated fatty acids have at least one carbon-carbon double bond.

- True
- False ✔

Amphiphilic molecules have _____ regions.

- only polar
- only nonpolar
- both polar and nonpolar ✔

A soap molecule is composed of a nonpolar tail and a polar head.

- True ✔
- False

_____ is a precipitate formed when calcium ions bond with soap molecules.

- Soap scum ✔
- Micelle
- Surfactant
- All of the above

Detergent molecules contain _____ in their polar heads.

- $RCOO^-$
- Ca^{2+}
- Mg^{2+}
- $ROSO_3^-$ ✔

Exercise 1

Describe saponification. What are the starting reactants and final products? What bonds are broken during the chemical reaction?

Saponification is the base hydrolysis of a triglyceride with a strong base which yields carboxylate salts and glycerol. The starting reactants were 4 types of plant oils that contained triglycerides

and 6 M NaOH. The final products were soap (carboxylate salts) and glycerol. The ester bonds of the triglyceride were broken during the chemical reaction by OH- ions.

Based on your observations when you added the NaOH solution and before you heated and stirred the mixture, is the NaOH solution polar or nonpolar? Explain your answer.

The NaOH solution did not mix with the oils and the mixtures formed distinct layers. Oils are nonpolar, and nonpolar solutions do not mix with polar solutions. Therefore, the NaOH solution is polar.

Using the information in Table 1, describe the relationship between the consistency of each soap sample and its composition, paying particular attention to the unsaturated/saturated ratio of each starting oil. Note that substances that are brittle or easily broken when in thin layers equate to harder substances when in a larger mass (for example, when poured into a mold for making a bar of soap).

Table 1. Percent by weight of primary fatty acids, (S) saturated and (U) unsaturated.

Oil	U/S Ratio	Lauric Acid (S)	Myristic Acid (S)	Palmitic Acid (S)	Oleic Acid (U)	Linoleic Acid (U)	Alpha Linoleic Acid (U)
Canola	15.7	-	-	4	62	22	10
Coconut	0.1	47	18	9	6	2	-
Corn	6.7	-	-	11	28	58	1
Olive	4.6	-	-	13	71	10	1
Peanut	4.0	-	-	11	48	32	-
Sesame	6.6	-	-	9	41	45	-

Canola oil contains the highest percentage of unsaturated fatty acids, consisting primarily of oleic acid. The resultant dried soap had a bendy, soft consistency.

Coconut oil contains mostly saturated fatty acids, consisting primarily of lauric and myristic acids. The resultant dried soap was brittle, representing the hardest consistency soap.

Corn oil contains a mixture of saturated and unsaturated fatty acids, consisting primarily of palmitic, oleic, and linoleic acids. The consistency of the dried soap

layer was intermediate between the soaps formed from the coconut and canola oils.

Student results for olive, peanut, or sesame oils should also be intermediate to canola and coconut oils since these oils contain a similar proportion of saturated/unsaturated fatty acids.

Data Table 1: Saponification Observations
(SAMPLE ANSWER BELOW)

	Test Tube 1: Canola Oil	Test Tube 2: Corn Oil	Test Tube 3: Coconut Oil	Test Tub
Initial Color and Composition	Light yellow, viscous liquid	Yellow viscous liquid	Clear viscous liquid	
Observations after Adding NaOH	Forms two layers with oil on top	Forms two layers with oil on top	Forms two layers with oil on top	
Observations after Hot Water Bath	Thick, orange gel in upper ¾ of solution	Thick, yellow gel in upper ½ of solution	Thick white gel taking up most of upper solution	
Consistency Ranking In Test Tube after Cooling: 1 = Softest to 4 = Hardest	2	1	3	

Photo 1: Synthesized Soaps
(SAMPLE ANSWER BELOW)

Exercise 2

What is an amphiphilic molecule? How does this property influence the effectiveness of soaps?

Amphiphilic molecules contain both polar and nonpolar regions. In soap, the polar head of the molecule is attracted to water, and the nonpolar tail to oils. By acting as a bridge between oil and water, soap molecules form micelles containing oils that emulsify in wash water.

Why was sud production used to assess the effectiveness of the synthesized soaps?

Soap molecules function as surfactants by decreasing the surface tension of water leading to the formation of suds when the water surface is agitated. Suds production can be used to indicate the effectiveness of soaps since both properties are reliant on the amphiphilic structure of soap molecules.

Explain the chemical reaction that occurs between soap molecules and the ions in hard water? How were the synthesized soaps affected by hard water?

Hard water contains calcium or magnesium ions that bond to carboxylate ions in the polar heads of soap molecules. These calcium compounds are not water soluble and are precipitated as soap scum. All soaps produced soap scum in hard water.

What is the difference between soaps and detergents? How did the detergent tested in this laboratory compare to the soaps in both distilled water and hard water?

Soaps are carboxylate salts produced from the base hydrolysis of triglycerides. Detergents are amphiphilic molecules containing SO_3^- instead of COO^-. The detergent in this experiment produced more suds than the soaps in distilled water and was the only compound that produced abundant suds in hard water. Similarly, no scum formed in the detergent in hard water in contrast to each of the soaps which formed scum.

Of the synthesized soaps produced from canola oil, corn oil, and coconut oil (samples 1 – 3), which soap had the best cleaning ability? Support your answer with the results recorded in Data Table 2.

The canola oil soap appeared to have the best cleaning abilities because it produced more suds than both the corn and canola oil soaps.

Data Table 2: Soap Cleaning Efficiency Tests
(SAMPLE ANSWER BELOW)

	Test Tube 1: Canola Oil	Test Tube 2: Corn Oil	Test Tube 3: Cocor
Precipitation in Distilled Water (Yes/No)	No	No	No
Distilled Water Sud Production Ranking (1 = Most to 5 = Least)	2	3	4
Sud Production in Hard Water Compared to Distilled Water	Less	Less	Less

(More/Less/Equal			
Precipitation in Hard Water (Yes/No)	Yes	Yes	Yes

Competency Review

The products of a saponification reaction are _____.

- a triglyceride and glycerol
- a strong base and carboxylate salts
- glycerol and carboxylate salts ✔

Triglycerides are esters derived from _____ glycerol molecule(s) and _____ fatty acids.

- one; two
- two; four
- one; three ✔
- two; three

Triglycerides are generally composed of identical fatty acids.

- True
- False ✔

The nonpolar tail of a soap molecule is _____.

- hydrophilic
- hydrophobic ✔
- hygroscopic

_____ are tiny droplets of oil surrounded by soap molecules.

- [x] Micelles
- [ ] Surfactants
- [ ] Suds
- [ ] Scum

_____ lower the surface tension of water.

- [ ] Micelles
- [x] Surfactants
- [ ] Scums

Soap molecules react with _____ ions to produce soap scum.

- [ ] COO^-
- [ ] SO_3^-
- [ ] Na^+
- [x] Ca^{2+} and Mg^{2+}

Detergents are produced by saponification.

- [ ] True
- [x] False

Triglyceride composition of the oil used determines the consistency of the resulting soap.

- [x] True
- [ ] False

Reactants in a saponification are stirred because they differ in _____.

- molecular size
- polarity ✔
- volume

Hard water _____ the amount of suds produced by soaps.

- decreases ✔
- increases
- does not affect

Soaps and detergents both produce precipitates in hard water.

- True
- False ✔

Extension Questions

Canola oil is a source of biodiesel fuel. Research how the triglycerides in canola oil are converted to diesel fuel and compare this chemical reaction to the saponification reaction used with canola oil in this experiment. (SAMPLE ANSWER BELOW)

Canola oil is converted to biodiesel fuel by the transesterification of triglycerides. In a transesterification reaction the existing carboxylic acid ester is converted into a different carboxylic acid ester. Canola oil is reacted with methanol and a strong base to form methyl esters used as fuel. Canola oil was converted to soap in the experiment by the base hydrolysis of triglycerides using a strong base to break up the triglyceride molecules into glycerol and carboxylate salts (soap).