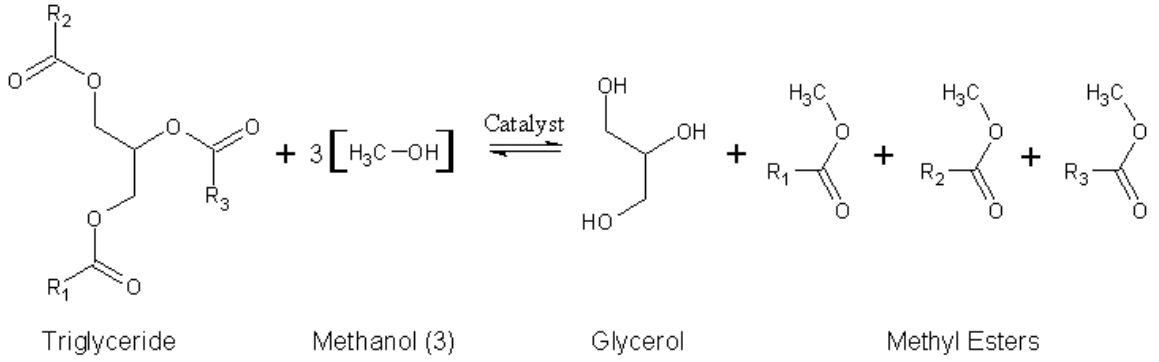
Design a flash separator for biodiesel separation

Biodiesel is a renewable transportation fuel consisting of fatty acid methyl esters (FAME), generally produced by transesterification of vegetable oils and animal fats.

Interest in biodiesel is continuing to increase in the U.S. and throughout the world. This is motivated primarily by: (1) concerns about greenhouse gas (GHG) emissions and global climate change, (2) a desire for renewable/sustainable energy sources, and (3) an interest in developing domestic and more secure fuel supplies [**1**].

Biodiesel is defined by ASTM as "a fuel comprised of mono-alkyl esters of long-chain fatty acids derived from vegetable oils or animal fats, designated B100" [**2**].

The vegetable- and animal-derived feedstocks used to produce biodiesel are known as triacylglycerides (TAGs), or more simply, triglycerides. Biodiesel is produced by a chemical process known as transesterification, by which the triglycerides are reacted with alcohols, in the presence of a catalyst, to produce fatty acid alkyl esters.



A byproduct of transesterification is glycerine, also known as glycerol. Since the most common alcohol used to produce biodiesel is methanol, another name for biodiesel is fatty acid methyl esters (FAME). Unless otherwise indicated, the term "biodiesel" refers to neat material – i.e. 100% FAME, often designated as B100. Lower concentrations, such as B20, are properly referred to as "biodiesel blends," not biodiesel itself.

Biodiesel fuel can be produced by transesterification of virtually any triglyceride feedstock. This includes oil-bearing crops, animal fats, and algal lipids. Although biodiesel fuel produced from transesterification of triglycerides contains numerous individual FAME species, a particular fuel is generally dominated by only a few species, including methyl palmitate ($C_{17}H_{34}O_2$), methyl stearate ($C_{19}H_{38}O_2$), methyl oleate ($C_{19}H_{36}O_2$), methyl linoleate ($C_{19}H_{34}O_2$), and methyl linolenate ($C_{19}H_{32}O_2$).

The glycerol is much denser than the biodiesel, and separates by gravity in a settler. The biodiesel is purified by separating it from methanol/water using simple flash distillation.

In one particular case study, after removing glycerol, the mixture contains 10 mol-% methanol, 50 mol-% water and 40 mol-% methyl esters. If we use the dominant composition, methyl linoleate, to represent the mixture of methyl esters, design a flash drum to separate methyl linoleate from methanol/water. The flash drum temperature needs to be maintained at 150°C and the mole fraction of methyl linoleate in the liquid phase needs to be greater than or equal to 0.98. At the same time, the mole fraction of the liquid phase cannot be lower than 35%. As an approximation, you can assume that Raoult's law applies to the system. The Antoine equation parameters for methanol and water can be found in the textbook [**3**]. The parameters for methyl linoleate are from a study on biodiesel [**4**] as shown below.

$\log_{10}(P) = A - (B / (T + C))$
P – vapor pressure (Pa)
T – temperature (K)

A	B	C
8.2175	1450.62	-188.03

Several references related to biodiesel production and flash separation have been enclosed.

1 Bibliography

[1] S K Hoekman, Amber Broch, Curtis Robbins, Eric Ceniceros, and Mani Natarajan, "Review of biodiesel composition, properties, and specifications," *Renewable and Sustainable Energy Reviews*, vol. 16, pp. 143 - 169, 2012.

[2] "ASTM D6751-09, Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels," , 2009.

[3] Joseph M Smith, Hendrick C Van Ness, and Michael M Abbott, *Introduction to chemical engineering thermodynamics*.: Boston: McGraw-Hill; 7th ed., 2005.

[4] W Yuan, AC Hansen, and Q Zhang, "Vapor pressure and normal boiling point predictions for pure methyl esters and biodiesel fuels," *Fuel*, vol. 84, pp. 943--950, 2005.