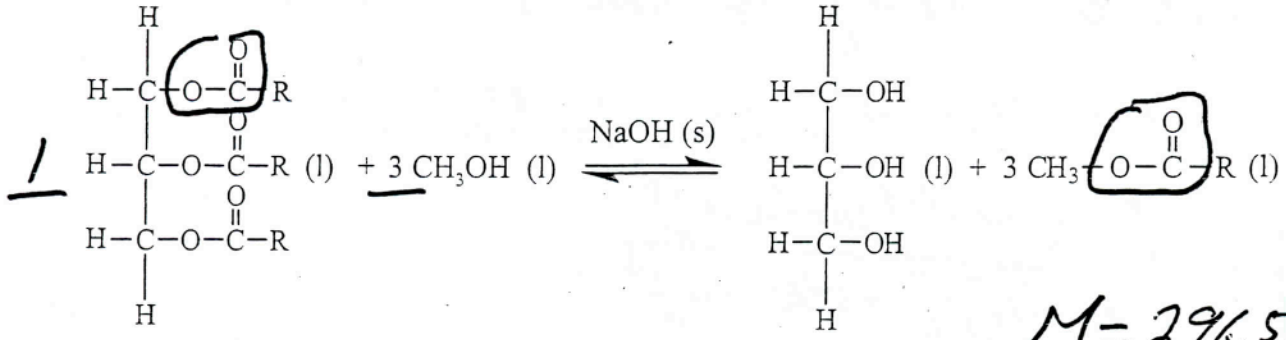
SECTION A

*Answer **all** the questions in the spaces provided.*

1. Biodiesel makes use of plants' ability to fix atmospheric carbon by photosynthesis. Many companies and individuals are now using biodiesel as a fuel in order to reduce their carbon footprint. Biodiesel can be synthesized from vegetable oil according to the following reaction.



vegetable oil methanol glycerol biodiesel

$M_r = 296.55$

(a) Identify the organic functional group present in both vegetable oil and biodiesel. [1]

An ester $R-O-\overset{O}{\overset{\|}{C}}-R'$

(b) For part of her extended essay investigation into the efficiency of the process, a student reacted a pure sample of a vegetable oil (where $R = C_{17}H_{33}$) with methanol. The raw data recorded for the reaction is below.

$mol = \frac{mass}{M_r}$

Mass of oil	= 1013.0 g
Mass of methanol	= 200.0 g
Mass of sodium hydroxide	= 3.5 g
Mass of biodiesel produced	= 811.0 g

The relative molecular mass of the oil used by the student is 885.6. Calculate the amount (in moles) of the oil and the methanol used, and hence the amount (in moles) of excess methanol used. [3]

$mol\ oil = \frac{1013.0\ g}{885.6} = 1.144\ mol\ oil$

$mol\ CH_3OH = \frac{200.0\ g}{32.014} = 6.247\ mol\ CH_3OH$

$1.144\ mol\ oil \times \frac{3\ mol\ CH_3OH}{1\ mol\ oil} = 3.432\ mol\ CH_3OH$ used

$6.247\ mol - 3.432\ mol = 2.815\ mol\ CH_3OH$ in excess

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(Question 1 continued)

(c) The reversible arrows in the equation indicate that the production of biodiesel is an equilibrium process.

(i) State what is meant by the term *dynamic equilibrium*. [1]

Both forward and reverse reactions are occuring at the same rate, and the concentrations of all reactants and products remain constant.

(ii) Using the abbreviations [vegetable oil], [methanol], [glycerol] and [biodiesel] deduce the equilibrium constant expression (K_c) for this reaction. [1]

$$K_c = \frac{[\text{glycerol}][\text{biodiesel}]^3}{[\text{veg. oil}][\text{methanol}]^3}$$

(iii) Suggest a reason why excess methanol is used in this process. [1]

To ensure that all the oil completely reacts.

(iv) State and explain the effect that the addition of the sodium hydroxide catalyst will have on the position of equilibrium. [2]

It will have no effect; only increases the rate at which equilibrium is reached.

(d) The reactants had to be stirred vigorously because they formed two distinct layers in the reaction vessel. Explain why they form two distinct layers and why stirring increases the rate of reaction. [2]

Oil is nonpolar, but methanol is polar, therefore they do not mix (are not miscible). Stirring increases the reaction rate by bringing the reactants into more contact with one another.

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(Question 1 continued)

(e) Calculate the percentage yield of biodiesel obtained in this process. *[2]*

$1.144\ \text{mol oil} \times \frac{3\ \text{mol biodiesel}}{1\ \text{mol oil}} \times \frac{296.55\ \text{g}}{1\ \text{mol}} = 1018\ \text{g}$

$\%\ \text{yield} = \frac{811.0\ \text{g}}{1018\ \text{g}} \times 100 = \boxed{79.67\%}$

(f) When biodiesel is combusted it produces carbon dioxide. Explain why the use of biodiesel as a fuel does not significantly contribute to global warming. *[1]*

Biofuel was derived from plants absorbing CO_2 that was already in the atmosphere, so there is no net increase when it is burned.