1. Using $\Delta_{\text{rxn}} H^0 = \sum m \Delta_f H^0 (\text{products}) - \sum n \Delta_f H^0 (\text{reactants})$, 

$$
\Delta_{\text{rxn}} H^0 = [\Delta_f H^0 (\text{C}_2\text{H}_2 (\text{g}) + \Delta_f H^0 (\text{Ca(OH)}_2 (\text{s})) - [\Delta_f H^0 (\text{CaC}_2 (\text{s})) + 2\Delta_f H^0 (\text{H}_2\text{O} (\text{l}))]
= [(+227) + (-986)] - [(-60) + (2 \times -285)]
= -129 \text{kJ mol}^{-1}
$$

The molar mass of CaC$_2$ is 40.08 (Ca) + 2 $\times$ 12.01 (C) = 64.1 g mol$^{-1}$

Hence, 10.0 g corresponds to

$$
\frac{\text{mass}}{\text{molar mass}} = \frac{10.0 \text{g}}{64.1 \text{g mol}^{-1}} = 0.156 \text{mol}
$$

As 1 mol releases 129 kJ mol$^{-1}$, this amount will give rise to an enthalpy change of:

$$
\Delta_{\text{rxn}} H^0 = (-129 \text{kJ mol}^{-1}) \times (0.156 \text{ mol}) = -20.1 \text{kJ}
$$

2. (a) \text{CH}_3(\text{CH}_2)_{14}\text{COOH} + 23\text{O}_2 \rightarrow 16\text{CO}_2 + 16\text{H}_2\text{O}

(b) Using $\Delta_{\text{rxn}} H^0 = \sum m \Delta_f H^0 (\text{products}) - \sum n \Delta_f H^0 (\text{reactants})$:

$$
\Delta_{\text{comb}} H^0 = [16 \times \Delta_f H^0 (\text{CO}_2) + 16 \times \Delta_f H^0 (\text{H}_2\text{O})] - [\Delta_f H^0 (\text{palmitic acid})]
$$

as $\Delta_f H^0 (\text{O}_2) = 0$ for the formation of an element in its standard state.

As the combustion is an exothermic process, $\Delta_{\text{comb}} H^0 = -9980 \text{kJ mol}^{-1}$.

Therefore:

$$
[16 \times -393.5 + 16 \times -285] - [\Delta_f H^0 (\text{palmitic acid})] = -9980 \text{kJ mol}^{-1}
$$

or

$$
\Delta_f H^0 (\text{palmitic acid}) = -889 \text{kJ mol}^{-1}
$$

(c) \text{CH}_3(\text{CH}_2)_{14}\text{COOH} \equiv \text{C}_{16}\text{H}_{32}\text{O}_2$. The molar mass of palmitic acid is:

$$
\text{molar mass} = 16 \times 12.01 \text{ (C)} + 32 \times 1.008 \text{ (H)} + 2 \times 16.00 \text{ (O)} = 256.416 \text{ g mol}^{-1}
$$

So,

$$
\Delta_{\text{comb}} H = -9980 \text{kJ mol}^{-1} \text{ or } \frac{-9980 \text{kJ mol}^{-1}}{256.416 \text{ g mol}^{-1}} = -38.9 \text{kJ g}^{-1}
$$
3. (a) The combustion of methyl stearate follows the equation:

\[
\text{CH}_3\text{(CH}_2\text{)}_{16}\text{COOCH}_3 + \frac{55}{2} \text{O}_2 \rightarrow 19\text{CO}_2(\text{g}) + 19\text{H}_2\text{O}(\text{l})
\]

As \( \Delta_{\text{rxn}} H^0 = \sum m\Delta_f H^0 (\text{products}) - \sum n\Delta_f H^0 (\text{reactants}) \) and \( \Delta_f H^0 (\text{O}_2(\text{g})) \) is zero, the heat of combustion is

\[
\Delta_{\text{rxn}} H^0 = [19\Delta_f H^0 (\text{CO}_2(\text{g})) + 19\Delta_f H^0 (\text{H}_2\text{O}(\text{l}))] - [\Delta_f H^0 (\text{CH}_3\text{(CH}_2\text{)}_{16}\text{COOCH}_3)]
\]

As \( \Delta_f H^0 (\text{CO}_2(\text{g})) = -393.5 \text{ kJ mol}^{-1} \), \( \Delta_f H^0 (\text{H}_2\text{O}(\text{l})) = -285 \text{ kJ mol}^{-1} \) and \( \Delta_f H^0 (\text{CH}_3\text{(CH}_2\text{)}_{16}\text{COOCH}_3) = -945.6 \text{ kJ mol}^{-1} \):

\[
\Delta_{\text{rxn}} H^0 = ([19 \times -393.5 + 19 \times -285] - [-945.6]) \text{ kJ mol}^{-1} = -11900 \text{ kJ mol}^{-1}
\]

(b) The molecular weight of \( \text{CH}_3\text{(CH}_2\text{)}_{16}\text{COOCH}_3 \) is:

\[
(19 \times 12.01 (\text{C}) + 38 \times 1.008 (\text{H}) + 2 \times 16.00 (\text{O})) \text{ g mol}^{-1} = 298.5 \text{ g mol}^{-1}
\]

Using \( \Delta_{\text{rxn}} H^0 = -11946 \text{ kJ mol}^{-1} \) from (a), the nett calorific value is:

\[
\text{nett calorific value} = \frac{11946 \text{ kJ mol}^{-1}}{298.5 \text{ g mol}^{-1}} = 40.0 \text{ kJ g}^{-1}
\]

This value is slightly less than for conventional diesel.

4. For a reaction to be spontaneous requires \( \Delta G^0 < 0 \), i.e. \( \Delta H^0 - T\Delta S^0 < 0 \).

For the reaction given, \( \Delta H^0 \) is positive, which would tend to make \( \Delta G^0 \) positive. To counteract this, entropy must increase, \( \Delta S^0 \) must be positive (which it is) and \( T\Delta S^0 \) must exceed \( \Delta H^0 \).

Thus, \( T\Delta S^0 > \Delta H^0 \) and \( T > \Delta H^0 / \Delta S^0 = 5.5 \times 10^3 \text{ J mol}^{-1} / 25 \text{ J K}^{-1} \text{ mol}^{-1} = 220\text{K} \).

An endothermic reaction is favoured by increasing the temperature (Le Chatelier’s principle).

5. Freezing water corresponds to the process:

\[\text{H}_2\text{O(}l\text{)} \rightarrow \text{H}_2\text{O(s)}\]

At -10 °C, water freezes spontaneously to give ice so \( \Delta G < 0 \).

The liquid \( \rightarrow \) solid process involves the molecules becoming more ordered so \( \Delta S < 0 \).

The liquid \( \rightarrow \) solid process involves the formation of intermolecular H-bonds between the water molecules so \( \Delta H < 0 \).
Water freezes when $\Delta G^0 < 0$, i.e. $\Delta H^0 - T\Delta S^0 < 0$.

$\Delta S^0$ is negative, which would tend to make $\Delta G^0$ positive.

To counteract this, the enthalpy change must be negative (which it is) and $\Delta H^0$ must be more negative than $T\Delta S^0$.

Thus, $|T\Delta S^0| < |\Delta H^0|$ and $T < |\Delta H^0| / |\Delta S^0|$