6. In an experiment to find the standard molar enthalpy of formation of butane (from its elements), the following values were determined experimentally from calorimetry:

(1) $C_4H_{10}(g) + \frac{13}{2} O_2(g) \rightarrow 4 CO_2(g) + 5 H_2O(g)$ $\Delta_r H° = -2657.4$ kJ

(2) $C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta_r H° = -393.5$ kJ

(3) $2 H_2(g) + O_2(g) \rightarrow 2 H_2O(g)$ $\Delta_r H° = -483.6$ kJ

Use Hess' law to determine the standard molar enthalpy of formation of butane. [3]

Net: $4C_{(s)} + 5H_{2(g)} \rightarrow C_4H_{10(g)}$ $\Delta_f H° = ?$

① $4CO_{2(g)} + 5H_2O_{(g)} \rightarrow C_4H_{10(g)} + \frac{13}{2}O_{2(g)}$ $\Delta_R H° = +2657.4$ KJ

② $4C_{(s)} + 4O_{2(g)} \rightarrow 4CO_{2(g)}$ $\Delta_R H° = -393.5$ KJ · 4 (-1574)

③ $5H_{2(g)} + \frac{5}{2}O_{2(g)} \rightarrow 5H_2O_{(g)}$ $\Delta_R H° = -483.6$ KJ · $\frac{5}{2}$ (-1209)

$\Delta_f H° = -125.6$ KJ/mol

7. One method of preparing methanol combines carbon monoxide and hydrogen at high temperature and pressure, in the presence of a catalyst.

$CO(g) + 2 H_2(g) \rightarrow CH_3OH(l)$ $\Delta_r H = ?$

a) Determine the enthalpy change for the reaction. [1]

$\Delta_R H = \Sigma n \cdot \Delta_f H_m - \Sigma n \cdot \Delta_{fr} H_m$

$\Delta_R H = 1\text{mol} \cdot -239.2 \frac{KJ}{mol} - (1\text{mol} \cdot -110.5 \frac{KJ}{mol} + 2\text{mol} \cdot 0 \frac{KJ}{mol}) = -128.7$ KJ

b) Determine the mass of liquid water that could be heated from 20.0 °C to 85.0 °C from the energy released by the formation of 1.00 kg of methanol. $CH_3OH_{(l)}$ [2]

$m = 1000$ g

$M = \frac{C: 1 \cdot 12.009 \text{ g/mol} + H: 4 \cdot 1.01 \text{ g/mol} + O: 1 \cdot 16.00 \text{ g/mol}}{32.04 \text{ g/mol}}$

$n = ?$

$n = \frac{m}{M} = \frac{1000 \text{ g}}{32.04 \text{ g/mol}}$

$n = 31.2$ mol

$\Delta_f H = n \cdot \Delta_f H_m$

$\Delta_f H = 31.2 \text{ mol} \cdot -128.7$ KJ

$\Delta_f H = 4,016.9$ KJ

$Q = mc\Delta t$

$m = \frac{Q}{c\Delta t}$

$m = \frac{4,016.9 \text{ KJ}}{(4.19 \frac{KJ}{kg°C} \cdot (85.0°C - 20.0°C))}$

$m = 14.7$ kg

6