

Introduction to thermodynamics Part 2: Answers.

1) ΔH when 1 mol vapourises = +43.5 kJ

So need to calculate the amount of moles in 0.5g and then ΔH .

$$M_r(\text{C}_2\text{H}_5\text{OH}) = 46.07$$

$$\text{Moles} = \text{Mass} / M_r$$

$$= 0.5 / 46.07 = 0.011 \text{ mol}$$

$$\Delta H = 0.011 \text{ mol} \times +43.5 \text{ kJ mol}^{-1} = +0.5 \text{ kJ}$$

2) To turn ice $\rightarrow$ steam requires 3 stages:

i) melting ii) heat water ($0 \rightarrow 100^\circ\text{C}$) iii) boil the water

$$\Delta H_{\text{total}} = \Delta H_{(i)} + \Delta H_{(ii)} + \Delta H_{(iii)}$$

So need to find ΔH for:

i) 1 mol ice at $0^\circ\text{C} \rightarrow$ 1 mol water at 0°C . This is the enthalpy change of Fusion: $\Delta H_{\text{fus}} = \Delta H_{(i)}$

ii) 1 mol water at $0^\circ\text{C} \rightarrow$ 1 mol water at 100°C .

iii) 1 mol water at $100^\circ\text{C} \rightarrow$ 1 mol steam at 100°C . This is the enthalpy change of Vapourisation: $\Delta H_{\text{vap}} = \Delta H_{(iii)}$

$$\Delta H_{\text{fus}} = +6.01 \text{ kJ mol}^{-1}$$

To calculate ΔH for 1 mol H₂O $0^\circ\text{C} \rightarrow 100^\circ\text{C}$, we need to find its molar specific heat capacity:

$$C_m = \frac{q}{n \Delta T} \quad \text{so} \quad q = C_m n \Delta T$$

$$n = 1 \text{ mol}$$

$$q = -75.1 \times 1 \times (373 - 273)$$

$$= -7510 \text{ J} = -7.51 \text{ kJ}$$

$$\Delta H = +7.51 \text{ kJ mol}^{-1}$$

Now calculate ΔH_{vap} :

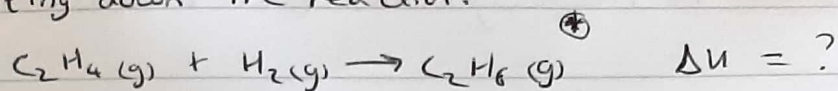
$$\Delta H_{\text{vap}} = +40.7 \text{ kJ mol}^{-1}$$

Now add all three contributions together.

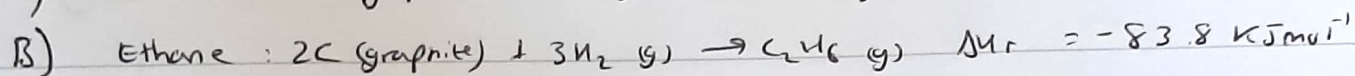
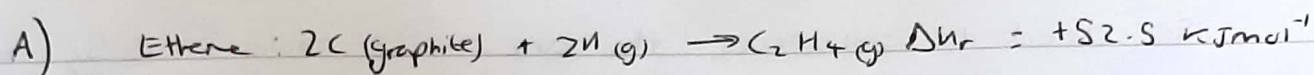
$$\Delta H = +6.01 + 7.51 + 40.7$$

$$= +54.2 \text{ kJ mol}^{-1}$$

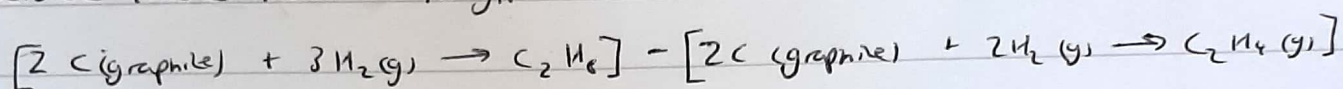
3) Start by writing down the reaction:



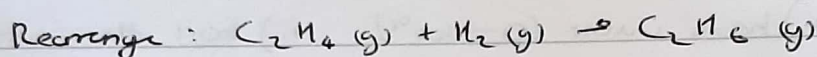
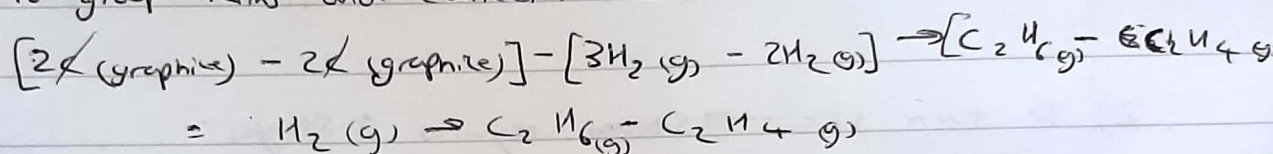
Then write the thermochemical reactions:



Manipulate these reactions to give the reaction of interest.



Rearrange to group terms and cancel:



using the ΔH_r provided, calculate the required ΔH_r .

$$\Delta H_r = \Delta H_r(\text{B}) - \Delta H_r(\text{A})$$

$$= -83.8 - (+52.5)$$

$$= -136.3 \text{ kJ mol}^{-1}$$

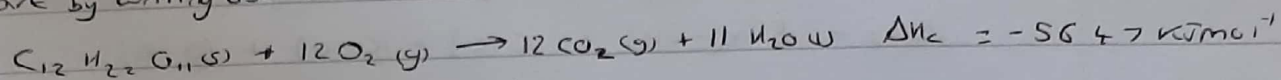
4) so, we need to use $\Delta H_r = \Delta H(\text{products}) - \Delta H(\text{reactants})$.

$$= [6 \times \Delta H_f(\text{FeO}) + 3 \times \Delta H_f(\text{H}_2\text{O}) + \Delta H_f(\text{N}_2)]$$

$$- [3 \times \Delta H_f(\text{Fe}_2\text{O}_3) + 2 \times \Delta H_f(\text{NH}_3)]$$

$$= (-2455.2) - (-2564.8) = 110 \text{ kJ mol}^{-1}$$

5) Start by writing out the reaction of interest



Then use $\Delta H_r = \Delta H_f(\text{products}) - \Delta H_f(\text{reactants})$

$$-5647 = [12 \times \Delta H_f(\text{CO}_2(\text{g})) + 11 \times \Delta H_f(\text{H}_2\text{O}(\text{l}))]$$

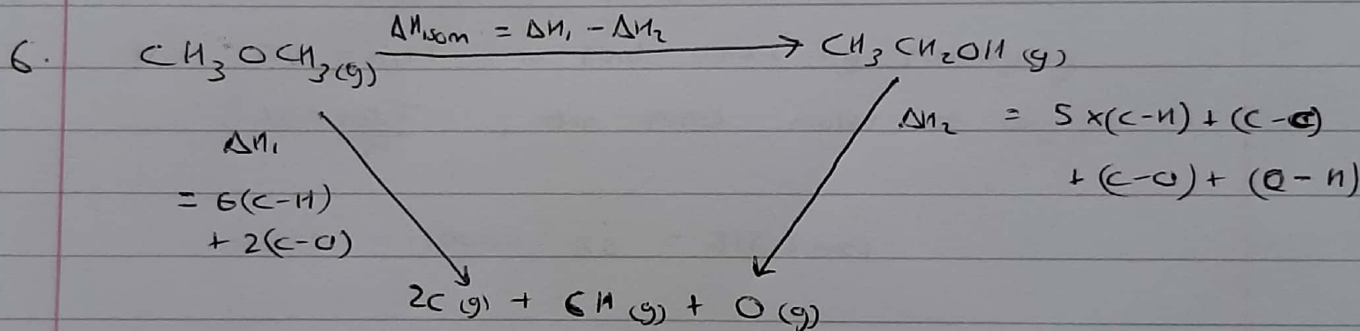
$$- [\Delta H_f(\text{C}_{12}\text{H}_{22}\text{O}_{11}(\text{s})) + 12 \times \Delta H_f(\text{O}_2(\text{g}))]$$

$$= [12 \times (-393.5) + 11 \times (-285.8)] - [\Delta H_f(\text{C}_{12}\text{H}_{22}\text{O}_{11}(\text{s})) + (12 \times 0)]$$

$$= (-4722) + (-3144) - \Delta H_f(\text{C}_{12}\text{H}_{22}\text{O}_{11}(\text{s}))$$

$$= -7866 - \Delta H_f(\text{C}_{12}\text{H}_{22}\text{O}_{11}(\text{s}))$$

$$\Delta H_f(\text{C}_{12}\text{H}_{22}\text{O}_{11}(\text{s})) = -7866 + 5647 = -2219 \text{ kJ mol}^{-1}$$



• ΔH_1 is the sum of mean bond enthalpies for the bonds in $\text{CH}_3\text{-O-CH}_3$.

This is the enthalpy change when all the bonds are broken in the reactant.

• ΔH_2 is the sum of the mean bond enthalpies for the bonds in $\text{CH}_3\text{-CH}_2\text{-OH}$.

This is the enthalpy change when all the bonds are broken in the product.

So, the enthalpy change to make all the bonds in the product from the gaseous atoms is $-\Delta H_2$.

$$\Delta H_{\text{isom}} = \Delta H_1 - \Delta H_2$$

Add the mean bond enthalpies for $\text{CH}_3\text{-O-CH}_3$ to find ΔH_1 .

$$\Delta H_1 = 6 \times (\text{C}-\text{H}) + 2 \times (\text{C}-\text{O})$$

$$= 6 \times (412) + 2 \times (358)$$

$$= 3188 \text{ kJ mol}^{-1}$$

Add the mean bond enthalpies for $\text{CH}_3-\text{CH}_2-\text{OH}$ to find ΔH_2

$$\Delta H_2 = 5 \times (\text{C-H}) + (\text{C-C}) + (\text{C-O}) + (\text{O-H})$$

$$= 5 \times (412) + (347) + (358) + (464)$$

$$= 3229 \text{ kJmol}^{-1}$$

$$\Delta H_{\text{isom}} = \Delta H_1 - \Delta H_2$$

$$= 3188 - (3229) = -41 \text{ kJmol}^{-1}$$