Introduction to thermodynamics Part 2: Answers.

1) ΔH when 1mol vaporises $= +43.5\ kJ$

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

$Mr(C_2H_5OH) = 46.07$ Moles = Mass / Mr

$= 0.5 / 46.07 = 0.011\ mol$

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

2) To turn ice → steam requires 3 stages:

i) melting ii) heat water (0 → 100°C) iii) boil the water

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

So need to find ΔH for:

i) 1 mol ice at 0°C → 1 mol water at 0°C. This is the enthalpy change of fusion: $\Delta H_{fus} = \Delta H_{(i)}$

ii) 1 mol water at 0°C → 1 mol water at 100°C.

iii) 1 mol water at 100°C → 1 mol steam at 100°C. This is the enthalpy change of vaporisation: $\Delta H_{vap} = \Delta H_{(iii)}$

$\Delta H_{fus} = +6.01\ kJmol^{-1}$

To calculate ΔH for 1mol H_2O 0°C → 100°C, we need to find its molar specific heat capacity:

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

$n = 1\ mol$

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

$$= -7510\ J = 7.51\ kJ$$

$$\Delta H = +7.51\ kJmol^{-1}$$

Now calculate ΔH_{vap}:

$\Delta H_{vap} = +40.7\ kJmol^{-1}$

Now add all three contributions together.

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

$= +54.2\ kJmol^{-1}$

3) Start by writing down the reaction:

$$C_2H_4\,(g) + H_2\,(g) \rightarrow C_2H_6\,(g) \quad \Delta H = ?$$ ⊛

Then write the thermochemical reactions:

A) Ethene : $2C\,(graphite) + 2H\,(g) \rightarrow C_2H_4\,(g)$ $\Delta H_r = +52.5\ kJmol^{-1}$

B) Ethane : $2C\,(graphite) + 3H_2\,(g) \rightarrow C_2H_6\,(g)$ $\Delta H_r = -83.8\ kJmol^{-1}$

Manipulate these reactions to give the reaction of interest ⊛.

$$[2C\,(graphite) + 3H_2\,(g) \rightarrow C_2H_6] - [2C\,(graphite) + 2H_2\,(g) \rightarrow C_2H_4\,(g)]$$

Rearrange to group terms and cancel:

$$[\cancel{2C}\,(graphite) - \cancel{2C}\,(graphite)] - [3H_2\,(g) - 2H_2\,(g)] \rightarrow [C_2H_6\,(g) - C_2H_4\,(g)]$$

$$= H_2\,(g) \rightarrow C_2H_6\,(g) - C_2H_4\,(g)$$

Rearrange : $C_2H_4\,(g) + H_2\,(g) \rightarrow C_2H_6\,(g)$

using the ΔH_r provided, calculate the required ΔH_r

$$\Delta H_r = \Delta H_r\,(B) - \Delta H_r\,(A)$$

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

$$= -136.3\ kJmol^{-1}$$

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

$$= [6 \times \Delta H_f(FeO) + 3 \times \Delta H_f(H_2O) + \Delta H_f(N_2)]$$

$$- [3 \times \Delta H_f(Fe_2O_3) + 2 \times \Delta H_f(NH_3)]$$

$$= (-2455.2) - (-2564.8) = 110\ kJmol^{-1}$$

Scanned with CamScanner

5) Start by writing out the reaction of interest

$C_{12}H_{22}O_{11}(s) + 12O_2(g) \longrightarrow 12CO_2(g) + 11H_2O(l)$ $\Delta H_c = -5647\ kJmol^{-1}$

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

$-5647 = [12 \times \Delta H_f(CO_2(g)) + 11 \times \Delta H_f(H_2O(l))]$
$- [\Delta H_f(C_{12}H_{22}O_{11}(s)) + 12 \times \Delta H_f(O_2(g))]$

$= [12 \times (-393.5) + 11 \times (-285.8)] - [\Delta H_f(C_{12}H_{22}O_{11}(s)) + (12 \times 0)]$

$= (-4722) + (-3144) - \Delta H_f(C_{12}H_{22}O_{11}(s))$

$= -7866 - \Delta H_f(C_{12}H_{22}O_{11}(s))$

$\Delta H_f(C_{12}O_{22}O_{11}(s)) = -7866 + 5647 = -2219\ kJmol^{-1}$

6. $CH_3OCH_3(g) \xrightarrow{\Delta H_{isom} = \Delta H_1 - \Delta H_2} CH_3CH_2OH(g)$

$\Delta H_1 = 6(C-H) + 2(C-O)$

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

$2C(g) + 6H(g) + O(g)$

- ΔH_1 is the sum of mean bond enthalpies for the bonds in CH_3-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 CH_3-CH_2-OH. This is the enthalpy change when all the bonds are broken in the product. ~~So, when~~

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

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

Add the mean bond enthalpies for CH_3-O-CH_3 to find ΔH_1

$\Delta H_1 = 6 \times (C-H) + 2 \times (C-O)$
$= 6 \times (412) + 2 \times (358)$
$= 3188\ kJmol^{-1}$

Add the mean bond enthalpies for CH_3-CH_2-OH to find ΔH_2

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

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

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

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

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