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Enthalpy changes: solutions

1. Calculate the enthalpy change of hydrogenation of benzene to cyclohexane:

$$C_6H_{6\,(l)} + 3\,H_{2\,(g)} \rightarrow C_6H_{12\,(l)}$$

Standard enthalpy changes of combustion in kJ/mol: benzene –3267, hydrogen –286, cyclohexane -3920

$C_6H_6\ (l) + 7.5\ O_2\ (g) \rightarrow 6\ CO_2\ (g) + 3\ H_2O\ (l) \quad \Delta H = -3267\ kJ$

$3 * [H_2\ (g) + 1/2\ O_2\ (g) \rightarrow H_2O\ (l) \quad \Delta H = -286\ kJ]$

$6\ CO_2\ (g) + 6\ H_2O\ (l) \rightarrow C_6H_{12}\ (l) + 9\ O_2\ (g) \quad \Delta H = +3920\ kJ$

$C_6H_6\ (l) + 3\ H_2\ (g) \rightarrow C_6H_{12}\ (l) \quad \Delta H = -205\ kJ$

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2. Hydrazine, $N_2H_{4\,(l)}$, is used as a rocket fuel. It burns in oxygen to produce nitrogen and steam:

$$N_2H_{4\,(l)} + O_{2\,(g)} \rightarrow N_{2\,(g)} + 2\,H_2O_{\,(g)}$$

a) Calculate the enthalpy change when 1 mole of hydrazine burns. Standard enthalpy changes of formation (in kJ/mol): hydrazine +50.6, $H_2O_{(g)}$ –242

b) How much heat is evolved if 1 tonne of hydrazine burns completely in this way? (H=1; N=14; 1 tonne=1000 kg)

a)

$$N_2H_4\ (l) \rightarrow N_2\ (g) + 2\ H_2\ (g) \quad \Delta H = -50.6\ kJ$$

$$2\ *\ [H_2\ (g) + 1/2\ O_2\ (g) \rightarrow H_2O\ (g) \quad \Delta H = -242\ kJ]$$

$$N_2H_4\ (l) + O_2\ (g) \rightarrow N_2\ (g) + 2\ H_2O\ (g) \quad \Delta H = -534.6\ kJ$$

b)

$$M = (2*14) + (4*1) = 32\ g/mol$$

$$Q = \frac{-534.6\ kJ}{1\ mol} * \frac{1\ mol}{32\ g} * 10^6\ g = -1.67 * 10^7\ kJ$$

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3. Calculate the enthalpy change of formation of bromoethane, $C_2H_5Br_{(l)}$ from the following data

$$2\,C_{(s)} + 2\,H_{2\,(g)} \rightarrow C_2H_{4\,(g)} \quad \Delta H = +52.2\ kJ/mol$$

$$\tfrac{1}{2}\,H_{2\,(g)} + \tfrac{1}{2}\,Br_{2\,(l)} \rightarrow HBr_{(g)} \quad \Delta H = -36.4\ kJ/mol$$

$$C_2H_{4\,(g)} + HBr_{(g)} \rightarrow C_2H_5Br_{(l)} \quad \Delta H = -106.3\ kJ/mol$$

$$2\,C_{(s)} + 2\,H_{2\,(g)} \rightarrow C_2H_{4\,(g)} \quad \Delta H = +52.2\ kJ$$

$$\tfrac{1}{2}\,H_{2\,(g)} + \tfrac{1}{2}\,Br_{2\,(l)} \rightarrow HBr_{(g)} \quad \Delta H = -36.4\ kJ$$

$$C_2H_{4\,(g)} + HBr_{(g)} \rightarrow C_2H_5Br_{(l)} \quad \Delta H = -106.3\ kJ$$

$$2\,C_{(s)} + 2.5\,H_{2\,(g)} + 0.5\,Br_{2\,(l)} \rightarrow C_2H_5Br_{(l)} \quad \Delta H = -90.5\ kJ$$