Year 13 Science: Thermochemistry and Hess's law

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. How much energy is needed to heat 500 g of water from 18.0 °C to 100.0 °C?

2. 50.0 mL of 1.00 mol L^{-1} HCl and 50.0 mL of 1.00 mol L^{-1} NaOH are mixed and warm by 6.7 °C. Take the mass as 100 g and c = 4.18 J g^{-1} $°C^{-1}$. What is ΔrH per mole of water formed?

3. Write the equation for the standard enthalpy of formation of ethanol, $C_2H_5OH(l)$.

4. A substance has ΔfusH = 15.5 kJ mol^{-1} and ΔvapH = 41.6 kJ mol^{-1} at the same temperature. What is ΔsubH?

5. Use the ΔfH table to calculate ΔcH of methanol: $CH_3OH(l) + 1½O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$.

Exam-style question: fuels from Taranaki gas

Methanol is made from natural gas in Taranaki. Use the ΔfH table where needed.

6. Calculate ΔfH of ethyne, $C_2H_2(g)$, given ΔcH(C_2H_2) = −1300 kJ mol^{-1}, ΔcH(C) = −394 kJ mol^{-1} and ΔcH(H_2) = −286 kJ mol^{-1}.

7. Calculate ΔrH for making liquid methanol: $CO(g) + 2H_2(g) \rightarrow CH_3OH(l)$.

8. Burning 1.20 g of methanol (M = 32.0 g mol^{-1}) heats 250 g of water from 19.5 °C to 34.0 °C. Calculate the experimental ΔcH of methanol.

9. Explain why ΔcH of methanol is less negative when the water formed is a gas, and calculate its value, using ΔvapH(H_2O) = +44.0 kJ mol^{-1}.

Fix the mistake

10. Correct this statement: "q = 0.920 × 4.18 × 21.5, using the mass of ethanol burned."

11. Correct this statement: "ΔcH = q ÷ n = +899 kJ mol^{-1}."

12. Correct this statement: "ΔrH = ΣΔfH(reactants) − ΣΔfH(products)."

13. Correct this statement: "When I reversed the methane combustion equation I kept $\Delta H = -890.3\ kJ\ mol^{-1}$."

Answer key (for parents and tutors)

1. How much energy is needed to heat 500 g of water from 18.0 °C to 100.0 °C?
   $q = 500 \times 4.18 \times 82.0 = 171\,380$ J = 171 kJ.

2. 50.0 mL of 1.00 mol L^{-1} HCl and 50.0 mL of 1.00 mol L^{-1} NaOH are mixed and warm by 6.7 °C. Take the mass as 100 g and c = 4.18 J g^{-1} $°C^{-1}$. What is ΔrH per mole of water formed?
   $q = 100 \times 4.18 \times 6.7 = 2800.6$ J = 2.80 kJ; $n(H_2O) = 1.00 \times 0.0500 = 0.0500$ mol; ΔrH = −2.80 ÷ 0.0500 = −56 kJ mol^{-1} (2 significant figures, set by 6.7).

3. Write the equation for the standard enthalpy of formation of ethanol, $C_2H_5OH(l)$.
   $2C(s) + 3H_2(g) + ½O_2(g) \rightarrow C_2H_5OH(l)$.

4. A substance has ΔfusH = 15.5 kJ mol^{-1} and ΔvapH = 41.6 kJ mol^{-1} at the same temperature. What is ΔsubH?
   ΔsubH = 15.5 + 41.6 = 57.1 kJ mol^{-1}.

5. Use the ΔfH table to calculate ΔcH of methanol: $CH_3OH(l) + 1½O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$.
   ΔcH = [−393.5 + 2(−285.8)] − (−239.5) = −965.1 + 239.5 = −725.6 kJ mol^{-1}.

6. Calculate ΔfH of ethyne, $C_2H_2(g)$, given ΔcH(C_2H_2) = −1300 kJ mol^{-1}, ΔcH(C) = −394 kJ mol^{-1} and ΔcH(H_2) = −286 kJ mol^{-1}.
   Target $2C(s) + H_2(g) \rightarrow C_2H_2(g)$. Use $2 \times (C + O_2 \rightarrow CO_2)$, $1 \times (H_2 + ½O_2 \rightarrow H_2O)$, and the reversed combustion of C_2H_2: ΔfH = 2(−394) + (−286) − (−1300) = −788 − 286 + 1300 = +226 kJ mol^{-1} (Merit for the method with one error; Excellence for +226 kJ mol^{-1} with sign and unit).

7. Calculate ΔrH for making liquid methanol: $CO(g) + 2H_2(g) \rightarrow CH_3OH(l)$.
   ΔrH = ΔfH(CH_3OH) − [ΔfH(CO) + 2(0)] = −239.5 − (−110.5) = −129.0 kJ mol^{-1}.

8. Burning 1.20 g of methanol (M = 32.0 g mol^{-1}) heats 250 g of water from 19.5 °C to 34.0 °C. Calculate the experimental ΔcH of methanol.
   $q = 250 \times 4.18 \times 14.5 = 15\,152.5$ J = 15.15 kJ; n = 1.20 ÷ 32.0 = 0.0375 mol; ΔcH = −15.15 ÷ 0.0375 = −404 kJ mol^{-1}, far less negative than −725.6 kJ mol^{-1} because of heat losses and incomplete combustion.

9. Explain why ΔcH of methanol is less negative when the water formed is a gas, and calculate its value, using ΔvapH(H_2O) = +44.0 kJ mol^{-1}.
   When water vapour condenses, hydrogen bonds form between the molecules and energy is released; if the water stays as a gas, that energy is not released, so less heat is given out overall. Each mole of methanol makes 2 mol of water: ΔcH = −725.6 + 2(44.0) = −637.6 kJ mol^{-1} (Excellence links the energy to attractions forming between water molecules).

10. Correct this statement: "q = 0.920 × 4.18 × 21.5, using the mass of ethanol burned."
    m is the mass of the water being heated, 200 g; the mass of fuel is used only to find n.

11. Correct this statement: "ΔcH = q ÷ n = +899 kJ mol^{-1}."
    The water gained heat, so the reaction released it: ΔcH = −q ÷ n = −899 kJ mol^{-1}.

12. Correct this statement: "ΔrH = ΣΔfH(reactants) − ΣΔfH(products)."
    It is products minus reactants, each ΔfH multiplied by its coefficient.

13. Correct this statement: "When I reversed the methane combustion equation I kept ΔH = −890.3 kJ mol^{-1}."
    Reversing an equation changes the sign: it becomes +890.3 kJ mol^{-1}.