# IB1 HL Chemistry

## 5. Energetics

**Read**: Zumdahl[2]: Chapter 6 (except internal ennergy and all references to it), Sections: 1 (pp. 241-244) 2 (ignore all references to internal energy pp. 248-252), 3-5; Chapter 8, Sections 5 and 8.

**Presumed knowledge (from GCSE)**

- closed system, open system, exothermic, endothermic, bond enthalpy

**Concepts to be mastered:**

To master a concept, you must be able to do three things:

1. define the concept
2. explain the concept, and
3. give an example of the concept.

**(NB**: Disregard all references to internal energy, internal energy change, and pressure-volume work.)

- Heat, source, sink, state, universe, system, surroundings, boundary,
- isolated system, Laws of Thermodynamics, First Law of Thermodynamics, conservation of energy, equilibrium, thermal equilibrium,
- calorimetry, calorimeter, calorie, Calorie, Joule
- specific heat capacity (specific heat), heat capacity, molar heat capacity,
- enthalpy change, Hess's Law (of Heat Summations), Hess cycle, energy cycle
- enthalpy (heat) of reaction, formation reaction, enthalpy (heat) of formation, combustion reaction, enthalpy (heat) of combustion, neutralization reaction, enthalpy (heat) of neutralization, enthalpy (heat) of fusion, enthalpy (heat) of vaporization, enthalpy (heat) of sublimation, enthalpy (heat) of ionization (ionization energy), bond enthalpy (energy), enthalpy (heat) of solvation, enthalpy (heat) of hydration, enthalpy diagram, bond dissociation energy,
- ionic bond, lattice enthalpy (energy), Born-haber cycle, enthalpy of atomization, electron affinity
- thermodynamic stability, kinetic stability

**Skills to be mastered:**

To master a skill, you must be able to

1. recognize when the skill is needed,
2. recognize what information is needed to execute the skill,
3. execute the skill, and
4. assess whether the skill has been executed correctly.

| | Zumdahl[2] problems | Further problems |
|---|---|---|
| • Express the first law of thermodynamics in terms of thermal sources and sinks. | | |
| • Given three of mass, specific heat, heat gained or lost, and temperature change for a homogeneous system, compute the fourth. | 6.37-46 | |
| • Given two of heat capacity, heat gained or lost, and temperature change for a system, compute the third. | 6. 37-46 | 3 |
| • Given three of mass, molar heat capacity, heat gained or lost, and temperature change for a pure substance, compute the fourth. | | |
| • Perform calculations involving heat exchanges among multiple substances | 6. 37-46 | 3 |

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|---|---|---|
| and systems. | | |
| • Perform calculations to obtain heats of reaction from calorimetric information. | 6. 47, 48 | 7 |
| • Evaluate results of experiment on enthalpy changes | | |
| • Write the formation reaction for a compound or element. | 6. 59, 60 | 6 |
| • Compute heats of reaction from heats of formation. | 6. 61-67 | |
| • Compute heats of reactions from bond enthalpies. | 8. 47-60 | 9 |
| • Construct enthalpy diagrams featuring a particular chemical process. | | 2 |
| • Use enthalpy diagrams or Hess cycles (energy cycles) to compute an enthalpy change for a particular process. | 6. 51-55 | 4 |
| • Relate a chemical reaction's energetics to interconversions between kinetic energy and potential energy and the response of a thermometer | | 2 |
| • Describe compounds as stable or unstable with respect to specified substances, using the enthalpy of reaction or of formation | | 10 |
| • Construct a Born-Haber cycle and determine lattice enthalpy or another energy change | 8. 39-44 | 11, 12 |
| • Explain the difference between experimental and theoretical lattice enthalpy values | 8. 45 | 13, 14 |
| • Distinguish between kinetic and thermodynamic stability | | |

**Further problems**:

1. In an exothermic reaction, what changes cause energy to be released?
2. Magnesium is used in fireworks, and incendiary bombs because it buns fiercely, liberating a great amount of heat. The reaction of magnesium with oxygen is

   $2\ Mg_{(s)} + O_{2\,(g)} \rightarrow 2\ MgO_{(s)}$

   (a) Draw an enthalpy level diagram for this reaction.
   (b) Is this reaction exothermic or endothermic?
   (c) Which has the larger potential energy, reactants or products?
3. 50.0 g of water at a temperature of 24.1°C are contained in a calorimeter. To this is added 50.0 g of water at 41.7°C. The mixture is stirred immediately and a temperature of 32.6°C is recorded as the maximum temperature reached. What is the heat capacity of the calorimeter?
4. Given the thermochemical reaction

   $2\ NO_{(g)} + Cl_{2(g)} \rightarrow 2\ NOCl_{(g)} \qquad \Delta H^{\theta} = -\ 77.4\ kJ$

   determine the $\Delta H^{\theta}$ for the following reactions
   (a) $NO_{(g)} + ½\ Cl_{2(g)} \rightarrow NOCl_{(g)}$
   (b) $6\ NOCl_{(g)} \rightarrow 6\ NO_{(g)} + 3\ Cl_{2(g)}$
5. Write the chemical reaction corresponding to the enthalpy of formation of $Na_2S_2O_{3(s)}$.
6. Calculate the enthalpy of combustion of methane using standard enthalpies of formation.

   $CH_{4(g)} + 2\ O_{2(g)} \rightarrow CO_{2\,(g)} + 2\ H_2O_{(l)}$
7. The sugar arabinose, $C_5H_{10}O_5$, is burned completely in oxygen in a calorimeter.

   $C_5H_{10}O_{5\,(g)} + 5\ O_{2(g)} \rightarrow 5\ CO_{2\,(g)} + 5\ H_2O_{(l)}$

   The calorimeter is made of metal and contains water. Burning a 0.548g sample caused the temperature to rise from 20.00°C to 210.54°C. The heat capacity of the calorimeter and its contents is 15.8 kJ/°C. Calculate ΔH for the combustion reaction of one mole of arabinose.
8. Write the chemical reaction corresponding to the bond enthalpy of $Cl_{2(g)}$.

9. Use bond enthalpies to calculate the enthalpy change for the following reactions. Use the values given in Table 10 of the Data Booklet.

   (a) $CH_{4(g)} + Cl_{2(g)} \rightarrow CH_3Cl_{(g)} + HCl_{(g)}$

   (b) $CH_2{=}CH_{2\,(g)} + H_2O_{(l)} \rightarrow CH_3CH_2OH_{(g)}$

10. Cis-but-2-ene and trans-but-2-ene can both be converted to butane by the addition of one mole of hydrogen. The enthalpies of these processes are −6.8 and −6.6 kJ/mol respectively. Which of the two compounds is thermodynamically more stable? Explain your answer.

11. Construct a Born-Haber cycle for the formation of KBr(s) from K(s) and $Br_2$(l). Indicate which steps are endothermic and which are exothermic.

12. Given the following data, calculate the lattice enthalpy of $CaCl_2$ in kJ per mole. Energy needed to vaporize Ca(s) = 192 kJ/mol; first ionization energy of Ca = 589.5 kJ/mol; second ionization energy of Ca = 1146 kJ/mol; electron affinity of Cl = −348 kJ/mol; bond enthalpy of $Cl_2$ = 238 kJ/mol of Cl-Cl bonds; energy change for the reaction, $Ca_{(s)} + Cl_{2\,(g)} \rightarrow CaCl_{2\,(s)}$ −795 kJ/mol of $CaCl_2$ formed.

13. Using the table of lattice enthalpies in the data booklet, account for the difference between the members of the following pairs of compounds: (a) NaF, NaCl; (b) LiBr, CsBr; (c) $SrCl_2$, SrS

14. Answer this question by looking at the lattice enthalpies in the data booklet. Which types of compounds show the greatest discrepancies between experimental and theoretical values of lattice enthalpy? What might be a possible explanation for large differences?