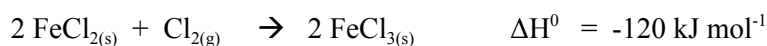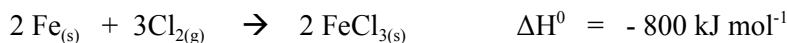# IB:Enthalpy Review Questions

The following review questions are of a slightly different nature than those practiced in the class and will help you for your I.B. Paper 2 examination.

1. When magnesium is added to sulphuric acid (   ) the temperature of the acid rises.
    a) Write a balanced equation assuming $MgSO_4$ and a flammable diatomic gas are the products.
    b) Is the reaction endothermic or exothermic?
    c) Explain what this implies in terms of the chemical potential energy contained in the reactants and products.
    d) Draw an energy level diagram for this reaction. Clearly label the reactant side, product side, the enthalpy of reaction, and the activation energy.

2. Consider the formation of chlorine monoxide (Cl_2O) from its elements.
    a) What bonds must be broken? Does this process absorb or release energy?
    b) What bonds are made? Does this process absorb or release energy?
    c) Explain what is meant by the term "enthalpy change".
    d) If the bonds made are less strong than those broken, will the enthalpy change be positive or negative?
    e) Will the formation of Cl_2O from its elements be and endothermic or exothermic process?

3. When 8.0 g of ammonium nitrate was dissolved in 100 cm^3 of water the temperature fell from 19.0°C to 14.5°C. Calculate the molar enthalpy of solution for ammonium nitrate.

4. 500 g of water was heated, using a camping stove, from 20 °C until it was boiling. Boiling this amount of water with an electrical heater requires 169 kJ of energy.
    a) If the pot was made out of aluminum (specific heat capacity 875 J/kg°C) and it weighed 100 g, how much heat energy was required to heat the pot?
    b) What is the total heat energy required to heat the pot?
    c) When the water started to boil, the stove weighed 14.5 g less than it had initially. How many moles of butane (C_4H_{10}) were used to heat the pot and the water?
    d) What is the heat of reaction, in kJ/mol of butane with air?
    e) The accepted value for the enthalpy of combustion of butane is - 2874 kJ/mol. Explain why you think the two values are different.

5. Iron and chlorine react differently to form iron (III) chloride, not iron (II) chloride, so that it is not possible to directly measure the enthalpy change for the reaction:

$$Fe_{(s)} \quad + \quad 3\,Cl_{2(g)} \quad \rightarrow \quad FeCl_{2(s)}$$
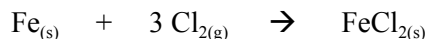
The enthalpy changes for the formation of iron (III) chloride from the reaction of chlorine with iron and with iron (II) chloride are given below. Use these to calculate the enthalpy change for the reaction of iron with chlorine to form iron (II) chloride.

$$2\,Fe_{(s)} \; + \; 3Cl_{2(g)} \quad \rightarrow \quad 2\,FeCl_{3(s)} \qquad \Delta H^0 \; = \; \text{- 800 kJ mol}^{-1}$$

$$2\,FeCl_{2(s)} \; + \; Cl_{2(g)} \quad \rightarrow \quad 2\,FeCl_{3(s)} \qquad \Delta H^0 \; = \; \text{-120 kJ mol}^{-1}$$

6. Given that the enthalpy change for the reaction: $\qquad N_{2(g)} \; + \; 3\,Cl_{2(g)} \; \rightarrow \; 2\,NCl_{3(g)}$
is + 688 kJ mol^{-1}, calculate the bond enthalpy of the N — Cl bond, given that the bond enthalpies in the nitrogen molecule and the chlorine molecule are 944 kJ mol^{-1} and 242 kJ mol^{-1} respectively.

7. Depending on whether you consider the chlorine to be converted to the element or to hydrogen chloride, it is possible to write two different equations of combustion of dichloromethane (CH_2Cl_2). Use

enthalpy of formation data to calculate the enthalpy changes of these two reactions. If the experimental value is -578 kJ mol^{-1}, what conclusions can you draw?
Standard enthalpies of formation data in kJ mol^{-1}:

CH_2Cl_2 = -121;   HCl = - 92; CO_2 = -395; H_2O = -286

8. Use the data below, relating to the formation of barium chloride, to calculate a value of the electron affinity of the chlorine atom.

Enthalpy of atomization of Barium	+175 kJ mol^{-1}
Enthalpy of atomization of chlorine	+121 kJ mol^{-1}
First ionization energy of barium	+502 kJ mol^{-1}
Second ionization energy of barium	+966 kJ mol^{-1}
Lattice energy of $BaCl_2$	+2018 kJ mol^{-1}
Enthalpy of formation of $BaCl_2$	-860 kJ mol^{-1}

ANSWERS
1a)$Mg + H_2SO_4 \rightarrow MgSO_4 + H_2$ (b) exothermic c) reactants > products **(2a)** absorb b) release d) positive e) endothermic **(3)** 18.81 kJ mol^{-1} **(4)**a) 7000J (b) 167200 J total heat 174.2kJ (c) 0.25 moles (d) 607 kJ mol^{-1} (e) heat lost to surroundings **(5)** -340 kJ mol^{-1} **(6)** 164 kJ mol^{-1} **(7)** The two values should be -458 kJ mol^{-1} (HCl) and -560 kJ mol^{-1} (Cl$_2$) so the latter is closer to the expectable value **(8)** -363.5 kJ mol^{-1}.

Review II
1.a. Define the terms Δ, ΔH^0_f, ΔS^0, ΔG^0, and explain the significance of their sign.
b. Write an equation, including state symbols, to show the formation of propane.
c. State what the numerical value of $O_{2(g)}$ is expected to be.
d. (i) State what is meant by the term average bond enthalpy. Use Table 10 of the Data Booklet to calculate the enthalpy change, ΔH^0 for the following reaction:

$$C_3H_{8(g)} +   5 O_{2(g)} \longrightarrow 3 CO_{2(g)} + 4 H_2O_{(g)}$$
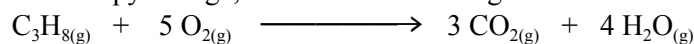
   (ii) Suggest, with a reason, whether the entropy change, ΔS^0, for this reaction would be positive or negative.

2. When solid blue copper (II) sulphate pentahydrate, $CuSO_4. 5H_2O$, loses water the white solid, copper (II) sulphate monohydrate, $CuSO_4. H_2O$, is produced as represented by the following equation:

$$CuSO_4. 5H_2O_{(s)} \rightleftharpoons CuSO_4. H_2O_{(s)} + 4 H_2O_{(g)}$$
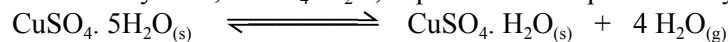
The thermodynamic data for the substances involved in the reversible process are:

	ΔH_f^0 (kJ mol^{-1})	S^0 (J K^{-1} mol^{-1})
$CuSO_4. 5 H_2O_{(s)}$	- 2278	305
$CuSO_4. H_2O_{(s)}$	-1084	150
$H_2O_{(g)}$	- 242	189

a. Calculate the value of ΔH^0 for the above reaction and state what information the sign of ΔH^0 provides about this reaction.
b. Calculate ΔS^0 for the reaction and state the meaning of the sign of ΔS^0 obtained.
c. Identify a thermodynamic function that can be used to predict reaction spontaneity, at 25 °C. Determine the value of this function, stating its units, and state the meaning of the sign obtained. Is $CuSO_4. 5H_2O_{(s)}$ or $CuSO_4. H_2O_{(s)}$ is more stable at 25 °C?
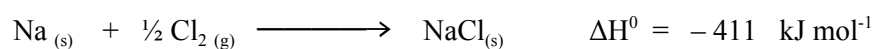d. Determine the Centigrade temperature above which the other compound in (c) is more stable.

3. Describe an experiment that could be conducted in a school laboratory to determine the value of ΔH_{rxn} for a reaction. Show the calculations that would need to be carried out to obtain a value of ΔH. Outline three sources of error in the experimental procedure that could result in a calculated ΔH value that is smaller than the accepted value and suggest a way that these errors could be minimized.
4. A reaction can be represented by: $2 X_2$ + Y_2 $\longrightarrow$ $2 X_2Y$
a. Derive an expression that can be used to find ΔH_{rxn} values found from the bond energies involved.
b. Discuss the fact that ΔH_{rxn} values found from bond energies often differ from those calculated using

2

ΔH_f values. Describe the conditions under which the best agreement is achieved between these two methods.

5.   (a)Consider the following reaction: $N_{2\,(g)}$ + $3H_{2\,(g)}$ $\longrightarrow$ $2NH_{3\,(g)}$

(i)   Suggest why this reaction is important for humanity.   1

(ii)   Using the average bond enthalpy values in Table 10 of the Data Booklet, calculate the standard enthalpy change for this reaction.   4

(iii)   The absolute entropy values, S^0, at 298 K for $N_{2\,(g)}$, $H_{2\,(g)}$ and $NH_{3\,(g)}$ are 192, 131 and 193 J K^{-1} mol^{-1} respectively. Calculate ΔS^0 for the reaction and explain the sign of ΔS^0 2

(iv)   Calculate ΔG^0 for the reaction at 298 K. State and explain whether the reaction is spontaneous.   3

(v)   If ammonia was produced as a liquid and not as a gas, state and explain the effect this would have on the value of ΔH^0 for the reaction.   2

(b)   (i) Define the terms *lattice enthalpy* and *electron affinity*.   2

(ii)   Use the data in the following table and from the data booklet to construct the Born-Haber cycle for sodium chloride, NaCl and determine the lattice enthalpy of NaCl $_{(s)}$.

$Na_{(s)}$ + $\frac{1}{2} Cl_{2\,(g)}$ $\longrightarrow$ $NaCl_{(s)}$ $\Delta H^0 = -411$ kJ mol^{-1}

$Na_{(s)}$ $\longrightarrow$ $Na_{(g)}$ $\Delta H^0 = +108$ kJ mol^{-1} 4

(iii) Describe the structure of sodium chloride.   2

6.   (a)Define the term *standard enthalpy change of formation*, ΔH^0_f.   2

(b)   (i) Use the information in the following table to calculate the enthalpy change for the complete combustion of but-1-ene according to the following equation.   3

$C_4H_{8\,(g)}$ + $6\,O_2$ $\longrightarrow$ $4\,CO_{2(g)}$ + $4\,H_2O_{(g)}$
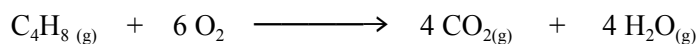
Compound	$C_4H_{8\,(g)}$	$CO_{2(g)}$	$H_2O_{(g)}$
ΔH^0_f (kJ mol^{-1})	+1	-394	-242

(ii) Deduce, giving a reason, whether the reactants or the products are more stable.   2

(iii) Predict, giving a reason, how the enthalpy change for the complete combustion of but- 2-ene would compare with that of but-1-ene based on average bond enthalpies.   1

(c)   Using the data below,

Compound	$C_4H_{8\,(g)}$	$CO_{2(g)}$	$H_2O_{(g)}$	O_2
S^0 (J K^{-1} mol^{-1})	306	214	189	205

calculate for the reaction in (b) at 25 ^{O}C.

(i) the standard entropy change, ΔS^0.   2

(ii) the standard free energy change, ΔG^0.   2

(d) Predict, giving a reason, the spontaneity of the reaction in (b) (i) at both high and low temperatures.   2