Chemical Energetics Tutorial

1 Write thermochemical equations to represent the following statements:

(a) Standard enthalpy change of formation of hydrogen bromide gas is –36.2 kJ mol^{-1}

(b) Standard enthalpy change of combustion of liquid propanol ($CH_3CH_2CH_2OH$) is – 2017 kJ mol^{-1}

(c) Standard enthalpy change of neutralisation of hydrochloric acid and sodium hydroxide is –57 kJ mol^{-1}

(d) Lattice energy of calcium chloride solid is –2237 kJ mol^{-1}

(e) Bond energy of I–I (refer to the Data Booklet for the bond energy)

2 **[N2008 P1 Q32]**
Which reactions represent standard enthalpy changes?

1 $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$

2 $C(g) + 6H(g) \rightarrow C_2H_6(g)$

3 $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

A **1** only **B** **1** and **2** only **C** **2** and **3** only **D** **1**, **2** and **3**

3 The heat liberated in the neutralisation given below is –114 kJ mol^{-1}.

$$2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

By using this information, what is the most likely value for the heat liberated in the following neutralisation?

$$Ba(OH)_2(aq) + 2HCl(aq) \rightarrow BaCl_2(aq) + 2H_2O(l)$$

A –57 kJ mol^{-1} **B** –76 kJ mol^{-1} **C** –114 kJ mol^{-1} **D** –228 kJ mol^{-1}

4 The enthalpy change of neutralisation of ethanoic acid with sodium hydroxide can be found experimentally by mixing known volumes of 1.0 mol dm^{-3} ethanoic acid, CH_3COOH, and 1.0 mol dm^{-3} NaOH. The following results are obtained.
Volume of CH_3COOH used = 40.0 cm^3
Volume of NaOH used = 30.0 cm^3
Initial temperature of mixture = 28.0 °C
Final temperature of mixture = 32.6 °C

(a) Use the data given to calculate the standard enthalpy change of neutralisation of CH_3COOH with NaOH. **[–44.9 kJ mol^{-1}]**

(b) The experiment is repeated with NaOH and HCl and it is found that the enthalpy change of reaction between NaOH and HCl is more exothermic than that calculated in **(a)**. Explain why this is so.

5 When 1.00 g of ethanol in a spirit lamp was burned under a container of water, it was found that 100 cm^3 of water was heated from 15 °C to 65 °C. The process was known to be only 70% efficient.

(a) Suggest reasons why only 70% of heat released by combustion is transferred to the water.

(b) Calculate the standard enthalpy change of combustion of ethanol. **[–1370 kJ mol^{-1}]**

(c) By using the value you have obtained in **(b)** and the following data:
Enthalpy change of combustion of carbon –393.5 kJ mol^{-1}
Enthalpy change of combustion of hydrogen –285.8 kJ mol^{-1}

Calculate the enthalpy change of formation of ethanol.

$$2\ C(s) + 3\ H_2(g) + ½\ O_2\ (g) \longrightarrow CH_3CH_2OH(l) \quad \Delta H_f = ?$$

[–271 kJ mol^{-1}]

6 When 6 g each of carbon, hydrogen and methanol, CH_3OH (l), are completely burnt in oxygen, 196.8, 857.7 and 136.2 kJ of heat are evolved respectively. Calculate the enthalpy change of formation of liquid methanol. **[– 239 kJ mol^{-1}]**

7 The chemical equation for the combustion of propene is as shown below.

$$C_3H_6\ (g) + 4½\ O_2\ (g) \rightarrow 3CO_2\ (g) + 3H_2O\ (l)$$

The table below shows the standard enthalpy changes of formation of the compounds involved in the reaction.

Compound	$C_3H_6(g)$	$CO_2(g)$	$H_2O(l)$	$O_2(g)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	+20	–394	–286	0

(a) Explain why the standard enthalpy of formation, $\Delta H_f^{\ominus}$, of oxygen is zero.

(b) Use the data from the table above to calculate the standard enthalpy of combustion of propene. **[–1930 kJ mol^{-1}]**

8 The yellow chlorine dioxide gas, ClO_2, has been used for many years as a flour-improving agent in bread-making. It can be made in the laboratory by the following reaction:

$$2AgClO_3(s) + Cl_2(g) \longrightarrow 2AgCl(s) + 2ClO_2(g) + O_2(g) \quad \Delta H_r^{\ominus} = 0\ kJ\ mol^{-1}$$

Given that $\Delta H_f^{\ominus}$ of $AgClO_3(s)$ = –25 kJ mol^{-1} and $\Delta H_f^{\ominus}$ of $AgCl(s)$= –127 kJ mol^{-1}. Calculate $\Delta H_f^{\ominus}$ of $ClO_2(g)$. **[+102 kJ mol^{-1}]**

9 One of the most important uses of alkanes is as fuels. In some countries, where crude oil is either scarce or expensive, biofuels such as ethanol are increasingly being used as fuels instead of hydrocarbons.

(a) Define the term "bond energy".

(b) **(i)** Write an equation that represents the standard enthalpy change of combustion of octane, $C_8H_{18}(l)$.

(ii) Use the bond energies given in the *Data Booklet* to calculate a value for the standard enthalpy change of combustion of octane. **[–5130 kJ mol^{-1}]**

(c) The standard enthalpy changes of combustion of three hydrocarbons are given in the table below.

Alkane	**formula**	**$\Delta H_c^\ominus$ / kJ mol^{-1}**
Heptane	C_7H_{16}	– 4817
Octane	C_8H_{18}	– 5470
Nonane	C_9H_{20}	– 6125

(i) Suggest a reason for the discrepancy between the $\Delta H_c^\ominus$ for octane you calculated in **(b)(ii)** and that given in the table.

(ii) Suggest what the regular increase in the values of $\Delta H_c^\ominus$ given in the table corresponds to.

10 Sulfur hexafluoride can be made by reacting sulfur tetrafluoride with fluorine in the gas phase:

$$SF_4(g) + F_2(g) \longrightarrow SF_6(g) \qquad \Delta H_r^\ominus = -434 \text{ kJ mol}^{-1}$$

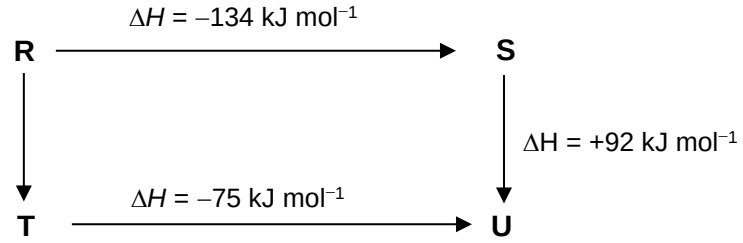
Using relevant data from the *Data Booklet*, calculate an average value for the S–F bond energy.

11 **(a)** Define, with the aid of an equation and using magnesium nitride, Mg_3N_2 (s) as an example, what is meant by the term *lattice energy*.

(b) How would you expect the magnitude of the lattice energy of Mg_3N_2 to compare with that of MgO? Explain your answer.

12 **[N99 P3 Q31]**

The diagram illustrates the energy changes of a set of reactions.



Which statements are correct?

1 The enthalpy change for the transformation U → R is +42 kJ mol^{-1}.
2 The enthalpy change for the transformation **T → S** is endothermic.
3 The enthalpy change for the transformation **R → T** is −33 kJ mol^{-1}

A **1** only **B** **1** and **3** only **C** **2** and **3** only **D** **1**, **2** and **3**