Name: …… ( ) Class: ……..
Date: …….

Raffles Institution
Year 5 H2 Chemistry 2024

ChemFocus T3W6 – Energetics Part 1

☐— Pre-ChemFocus Activity —☐

- Familiarise yourself with the definitions of all enthalpies by reading through Pages 7 – 17 of your notes.
- Watch the online Info-pack video
  IVY > C2025 – H2 CHEMISTRY > Pages > [ChemFocus] T3W6 Energetics > First video **only**

Notes:

Self-Check Questions

Check your answers at IVY > C2025 – H2 CHEMISTRY > Pages > [ChemFocus] T3W6 Energetics > Remaining videos

1. Complete the following table.

Enthalpy change	Equations
$\Delta H_{combustion}^{\ominus}$ ($CH_4(g)$)	$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$
$\Delta H_{combustion}^{\ominus}$ (C(s))	
$\Delta H_{formation}^{\ominus}$ ($CO_2(g)$)	
$\Delta H_{atomisation}^{\ominus}$ (Na(s))	
$\Delta H_{hydration}^{\ominus}$ ($Na^+(g)$)	
$\Delta H_{solution}^{\ominus}$ (NaC*l*(s))	
$\Delta H_{formation}^{\ominus}$ (NaC*l*(s))	
Lattice energy of NaC*l*(s)	
1st ionisation energy of Na	
1st electron affinity of C*l*	
Bond energy of C*l*−C*l*	
$\Delta H_{atomisation}^{\ominus}$ ($Cl_2(g)$)	
$\Delta H_{atomisation}^{\ominus}$ ($CH_4(g)$)	

2. When 30 cm^3 of 1.0 mol dm^{-3} CH_3NH_2, is added to 25 cm^3 of 1.0 mol dm^{-3} hydrochloric acid in a beaker, the temperature rose by 5.2 °C. The process efficiency is 90%.

Calculate the standard enthalpy change of the reaction, assuming the specific heat capacity of water to be 4.18 J K^{-1} g^{-1}. [2]

3. Use the following data to calculate the standard enthalpy change of solution of ammonium chloride.

Lattice energy of ammonium chloride	–705 kJ mol^{-1}
Enthalpy change of hydration of NH_4^+	–307 kJ mol^{-1}
Enthalpy change of hydration of Cl^-	–381 kJ mol^{-1}

4. Use the following data to construct an energy cycle and hence calculate the enthalpy change for the hydrogenation of ethene gas, $CH_2{=}CH_2(g)$, to ethane gas, $CH_3CH_3(g)$.

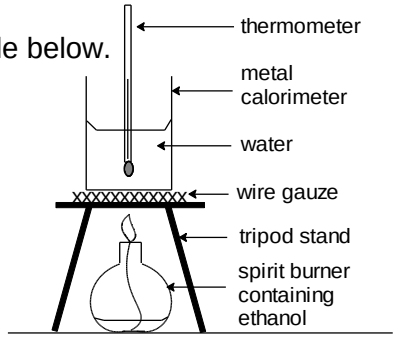
$$CH_2{=}CH_2(g) + H_2(g) \longrightarrow CH_3CH_3(g)$$

Enthalpy change of combustion of $CH_3CH_3(g)$	–1560 kJ mol^{-1}
Enthalpy change of combustion of $H_2(g)$	–286 kJ mol^{-1}
Enthalpy change of combustion of $CH_2{=}CH_2(g)$	–1411 kJ mol^{-1}

Tutorial Discussion Questions (to complete before Chemfocus session)

1a A student carried out an experiment to determine the enthalpy change of combustion of ethanol, CH_3CH_2OH, using the apparatus shown in the diagram.

The results that the student obtained are shown in the table below.



Mass of water / g	100
Initial temperature of water / °C	25.0
Final temperature of water / °C	31.5
Initial mass of burner and ethanol / g	62.57
Final mass of burner and ethanol / g	62.46

(i) Using the above experimental results, determine the experimental enthalpy change of combustion for ethanol. **[3]**

(ii) Use the data below to calculate the standard enthalpy change of combustion of ethanol. **[2]**

compound	$C_2H_5OH(l)$	$CO_2(g)$	$H_2O(l)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	–277.7	–394	–286

(iii) Suggest two reasons for the difference in the two values calculated in **(a)** and **(b)**.

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……

……

……..[2]

2a The standard enthalpy changes of formation of ammonia, hydrogen chloride and ammonium chloride are given below.

$\Delta H_f^{\ominus}[NH_3(g)]$	–46.0 kJ mol^{-1}
$\Delta H_f^{\ominus}[HCl(g)]$	–91.0 kJ mol^{-1}
$\Delta H_f^{\ominus}[NH_4Cl(s)]$	–314.4 kJ mol^{-1}

Gaseous ammonia reacts with hydrogen chloride to form solid ammonium chloride.

$$NH_3(g) + HCl(g) \longrightarrow NH_4Cl(s), \qquad \Delta H^{\ominus}$$

Using standard enthalpy changes given above, construct an energy cycle and show by calculations that the standard enthalpy change of reaction, $\Delta H^{\ominus}$, is –177.4 kJ mol^{-1}. **[3]**

3a Heating lithium in a stream of hydrogen gas produces white crystalline, ionic lithium hydride, LiH.

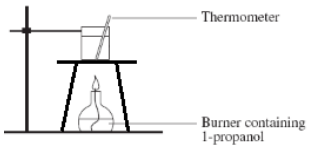
Construct a clearly labelled energy level diagram to calculate the lattice energy of LiH, using the following data, together with relevant data from the *Data Booklet*. **[4]**

Enthalpy change of formation of LiH(s)	-90.5 kJ mol^{-1}
Enthalpy change of atomisation of Li(s)	$+159.5$ kJ mol^{-1}
Electron affinity of hydrogen atoms	-73.0 kJ mol^{-1}

Tutorial Practice Questions (to be attempted **IN CLASS**)

1b A student used the apparatus below for the combustion of propan-1-ol.

M_r of propan-1-ol	60.0
Initial mass of burner and propan-1-ol / g	32.5
Final mass of burner and propan-1-ol / g	31.9
Initial temperature of water / ^oC	21.0
Mass of water heated / g	200



The enthalpy change of combustion of propan-1-ol, C_3H_7OH, is –2021 kJ mol^{-1}. Given that the specific heat capacity of water is 4.18 J g^{-1} K^{-1} and assuming no heat loss, calculate the final temperature of the water. **[2]**

2b (i) Using the data below, construct an energy cycle and calculate the enthalpy change for the following reaction:

$$CH_4(g) + 2O_2(g) \longrightarrow 2H_2O(l) + CO_2(g)$$

Equation	Enthalpy change, ΔH / kJ mol^{-1}
$C(s) + 2H_2(g) \longrightarrow CH_4(g)$	−75.0
$C(s) + O_2(g) \longrightarrow CO_2(g)$	−393.5
$H_2(g) + ½O_2(g) \longrightarrow H_2O(l)$	−285.9

[3]

(ii) The enthalpy change for the following reaction is −801.7 kJ mol^{-1}.

$$CH_4(g) + 2O_2(g) \longrightarrow 2H_2O(g) + CO_2(g)$$

Use this information and your answer to **(i)** to calculate the enthalpy change of vaporisation of water. **[2]**

3b Magnesium nitride, Mg_3N_2, is produced when magnesium metal is burnt in pure nitrogen atmosphere. The lattice energy of magnesium nitride can be calculated from a Born–Haber cycle using information from the *Data Booklet* and the table below.

	ΔH / kJ mol^{-1}
standard enthalpy change of atomisation of magnesium	+148
sum of the first three electron affinities of nitrogen	+146
standard enthalpy change of formation of magnesium nitride	−461

Self-Check Questions

1. Complete the following table.

Enthalpy change	Equations
$\Delta H_{combustion}^{\ominus}$ ($CH_4(g)$)	$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$
$\Delta H_{combustion}^{\ominus}$ ($C(s)$)	$C(s) + O_2(g) \rightarrow CO_2(g)$
$\Delta H_{formation}^{\ominus}$ ($CO_2(g)$)	$C(s) + O_2(g) \rightarrow CO_2(g)$
$\Delta H_{atomisation}^{\ominus}$ ($Na(s)$)	$Na(s) \rightarrow Na(g)$
$\Delta H_{hydration}^{\ominus}$ ($Na^+(g)$)	$Na^+(g) + aq \rightarrow Na^+(aq)$
$\Delta H_{solution}^{\ominus}$ ($NaCl(s)$)	$NaCl(s) + aq \rightarrow Na^+(aq) + Cl^-(aq)$
$\Delta H_{formation}^{\ominus}$ ($NaCl(s)$)	$Na(s) + \frac{1}{2}Cl_2(g) \rightarrow NaCl(s)$
Lattice energy of $NaCl(s)$	$Na^+(g) + Cl^-(g) \rightarrow NaCl(s)$
1st ionisation energy of Na	$Na(g) \rightarrow Na^+(g) + e^-$
1st electron affinity of Cl	$Cl(g) + e^- \rightarrow Cl^-(g)$
Bond energy of Cl−Cl	$Cl_2(g) \rightarrow 2Cl(g)$
$\Delta H_{atomisation}^{\ominus}$ ($Cl_2(g)$)	$\frac{1}{2}Cl_2(g) \rightarrow Cl(g)$
$\Delta H_{atomisation}^{\ominus}$ ($CH_4(g)$)	$CH_4(g) \rightarrow C(g) + 4H(g)$

2. $CH_3NH_2 + HCl \rightarrow CH_3NH_3^+Cl^-$

$n_{CH_3NH_2} = \frac{30}{1000} \times 1.0 = 0.0300$ mol

$n_{HCl} = \frac{25}{1000} \times 1.0 = 0.0250$ mol

CH_3NH_2 is in excess, hence $n_{reaction} = n_{HCl}$

$q = mc\Delta T$

$q = (30 + 25) \times 4.18 \times (+5.2) \times \frac{100}{90}$

$= +1328$ J

$\Delta H = -\frac{q}{n} = -(1328 / 0.0250)$

$= -53132$ J mol^{-1}

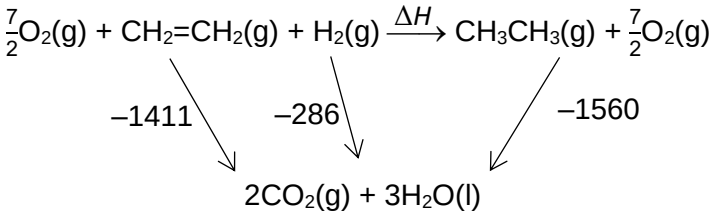
$= -53.1$ kJ mol^{-1}

3. $\Delta H_{sol} = \sum \Delta H_{hyd} - $ L.E.

$= -307 + (-381) - (-705)$

$= +17$ kJ mol^{-1}

4.



ΔH = –1411 + (–286) –(–1560)

= –137 kJ mol^{-1}

Tutorial Discussion Questions

1a (i) $\Delta T = 31.5 - 25.0 = +6.5$ °C

$q = 100 \times 4.18 \times (+6.5)$

$= +2717$ J

mass of ethanol used = 62.57 – 62.46 = 0.11 g

amount of ethanol used = 0.11 / 46 = 0.002391 mol

$\Delta H_c = -(2717 / 0.002391)$

$= -1\ 136\ 344$ J mol^{-1}

$= -1140$ kJ mol^{-1}

(ii) $C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

$\Delta H = \sum \Delta H_f$(product) – $\sum \Delta H_f$(reactant)

$\Delta H_c = [2(-394) + 3(-286)] - [-277.7 + 3(0)]$

$= -1368.3$

$= -1370$ kJ mol^{-1}

(iii)

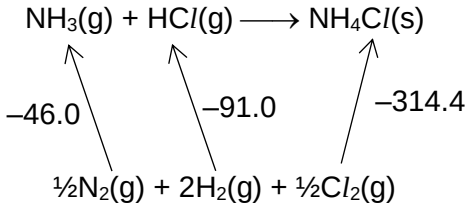
(1) The experiment was <u>not</u> carried out under <u>standard conditions of 298 K and 1 bar</u>.

(2) There could be <u>heat loss to the surrounding</u> in the experiment. Hence, <u>ΔT is not as high</u> as it should be, causing the calculated <u>ΔH</u> in (a) to be <u>less exothermic</u> than the value calculated in (b).

(3) The <u>heat capacity of the metal calorimeter was not taken into account</u> in the calculations. The calorimeter would have <u>absorbed some of the heat evolved</u> from the combustion i.e. not all the energy evolved is used to heat up the water. Hence, <u>ΔT is not as high</u> as it should be, causing the calculated <u>ΔH</u> in (a) to be <u>less exothermic</u> than the value calculated in (b).

(4) <u>Combustion</u> of ethanol was <u>incomplete</u>, i.e. the heat evolved from the combustion was smaller. Hence <u>ΔT is not as high</u> as it should be, causing the calculated <u>ΔH</u> in (a) to be <u>less exothermic</u> than the value calculated in (b).

2a

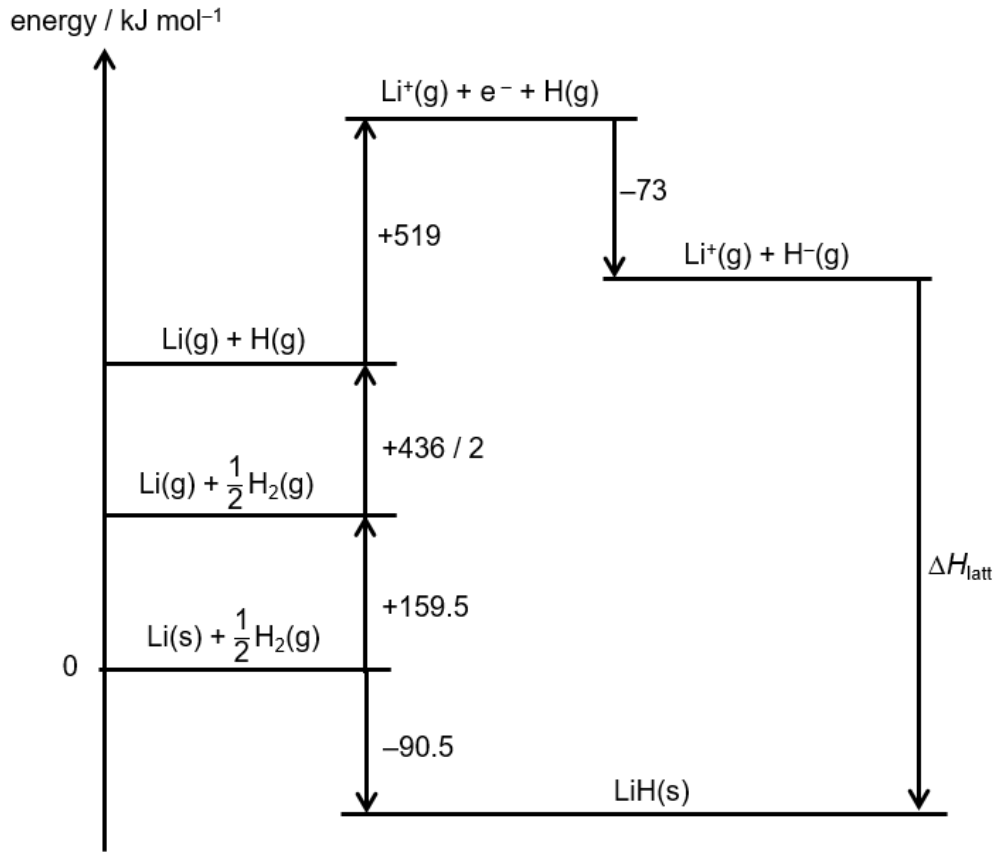


$\Delta H_r = -(-46.0) - (-91.0) + (-314.4)$

$= -177.4$

$= -177$ kJ mol^{-1}

3a



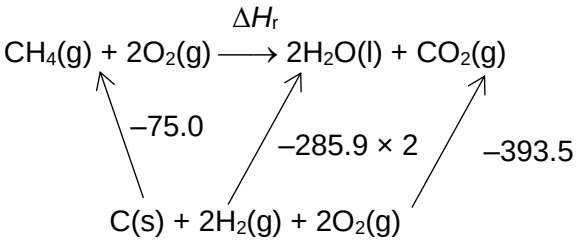
ΔH_{latt} = –(–73) – (+519) – (+436 / 2) – (+159.5) + (–90.5)

= –914 kJ mol^{-1}

Tutorial Practice Questions

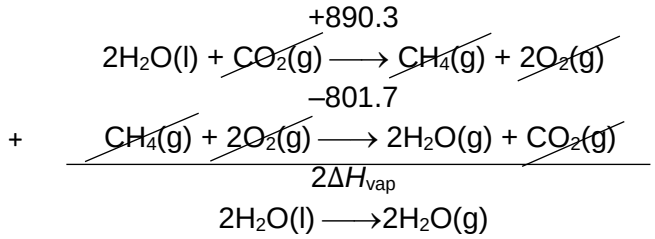
1b mass of propanol used = 32.5 – 31.9 = 0.60 g
amount of propanol used = 0.600 / 60 = 0.0100 mol
$\Delta H = -\frac{q}{n}$
–2021 = –*q* / 0.01
q = 2021 × 0.01
= 20.21 kJ
= 20210 J
q = mc∆T
20210 = 200 × 4.18 × ∆T
∆T = +24.17 °C
final T = 21.0 + 24.17 = 45.2 °C

2b **(i)**



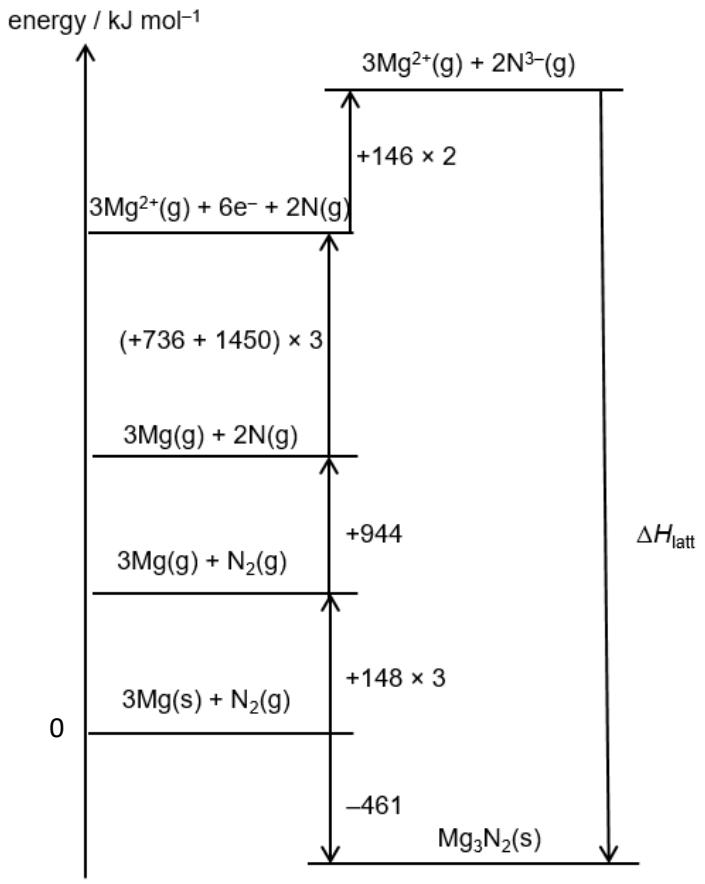
ΔH_r = 2013 = –(–75.0) + (–285.9 × 2) + (–393.5)
= –890.3
= –890 kJ mol^{-1}

(ii)



$2\Delta H_{vap}$ = +890.3 + (–801.7)
ΔH_{vap} = +88.6 / 2 = +44.3 kJ mol^{-1}

3b



L.E. = –146 × 2 – (3)(736 + 1450) – (+944) + (–148 × 3) + (–461)
= –8699
= –8700 kJ mol^{-1}