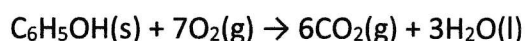


ENERGETICS AHL (HL only)

Please ensure that you have also completed the Core (SL & HL) questions

1. The standard enthalpy of combustion, ΔH_c^\ominus of phenol is $-3050 \text{ kJ mol}^{-1}$.



(a) Using section 12 of the data booklet, calculate the standard enthalpy of formation, ΔH_f^\ominus , of phenol, $\text{C}_6\text{H}_5\text{OH(s)}$, in kJ mol^{-1} .

[3]

$$6\text{C(s)} + 3\text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \xrightarrow{\Delta H_f} \text{C}_6\text{H}_5\text{OH(s)}$$

$+ \text{O}_2 \downarrow$ \uparrow $+ \text{O}_2$

$$6\text{CO}_2 + 3\text{H}_2\text{O}$$

$-2361 \checkmark$ $-8574 \checkmark$

$$\Delta H_f = 6(-393.5) + 3(-285.8) - (-3050)$$
$$= -168.4 \text{ kJ mol}^{-1} \checkmark \text{ allow ecf.}$$

(b) The standard entropy change of formation, ΔS_f^\ominus , of phenol is $-385 \text{ J K}^{-1} \text{ mol}^{-1}$. Calculate the Gibbs free energy change, ΔG^\ominus , for the formation of phenol at 298K, using section 1 of the data booklet.

[3]

$$\Delta G = \Delta H - T\Delta S \quad (\text{kJ}) \quad (\text{J to kJ})$$
$$\Delta G = -168.4 - (298 \times -0.385) \checkmark$$
$$= -168.4 + 114.73$$
$$= -53.67 \checkmark \text{ kJ mol}^{-1} \checkmark \text{ for correct units (J mol}^{-1} \text{ allowed for 53760)}$$

$(-53.7 \text{ 3 sig figs})$

(c) Determine whether the formation of phenol is spontaneous at 298K, give a reason.

[1]

It is spontaneous as $\Delta G \leq 0$ \checkmark

2. The standard enthalpy change of reaction is given for the following process:



The standard entropy, S° , of $\text{C}_8\text{H}_{18}(\text{g})$ is $467 \text{ J K}^{-1} \text{ mol}^{-1}$ and $\text{C}_8\text{H}_{18}(\text{l})$ is $360 \text{ J K}^{-1} \text{ mol}^{-1}$.

(a) Calculate the standard entropy change, ΔS° , for the process.

[1]

$$467 \rightarrow 360 \quad 360 - 467 = -107 \text{ (J K}^{-1} \text{ mol}^{-1})$$

(b) Predict and explain the effect of an increase in temperature on the spontaneity of the process. Use section 1 of the data booklet.

[3]

$$(\Delta G = \Delta H - T\Delta S) \quad \Delta H \text{ is } -ve \text{ and } \Delta S \text{ is } -ve$$

✓ As T increases $|T\Delta S|$ becomes larger ($T\Delta S$ becomes more positive)
✓ and ΔG therefore becomes less negative
✓ (so reaction becomes 'less spontaneous' / at high temperature will become non-spontaneous)

(c) Using section 1 of the data booklet, calculate the temperature, in $^\circ\text{C}$, at which $\Delta G = 0$ for the process, and state the significance of this temperature.

[3]

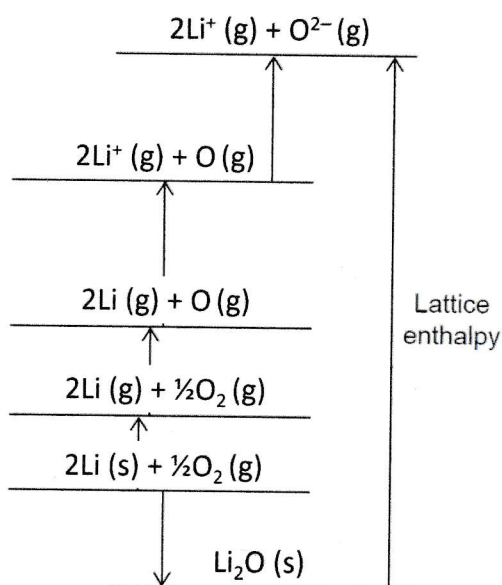
$$\Delta G = \Delta H - T\Delta S \quad 0 = \Delta H - T\Delta S \quad T\Delta S = \Delta H$$

$$T = \frac{\Delta H}{\Delta S} = \frac{-41.5}{-0.107} = 387.85... = 388 \text{ K}$$

or $\frac{41500}{107}$

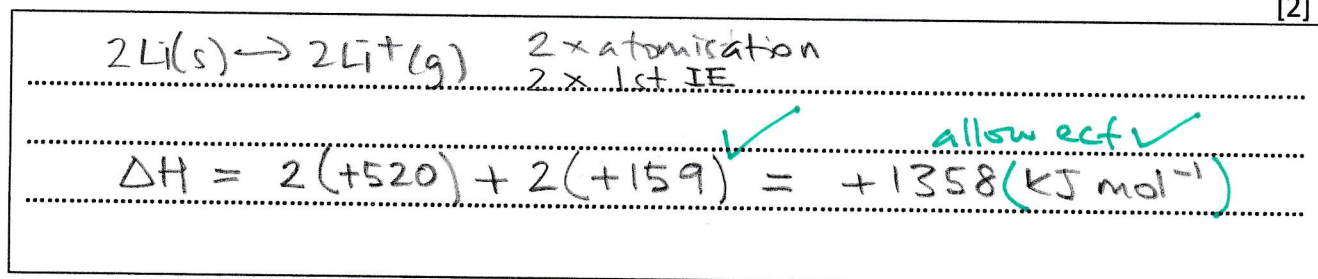
388 K or 119°C is the boiling/condensation point
or eqm between gas/liquid state OWTTE.

3. The Born-Haber cycle for lithium oxide is shown below, not to scale.



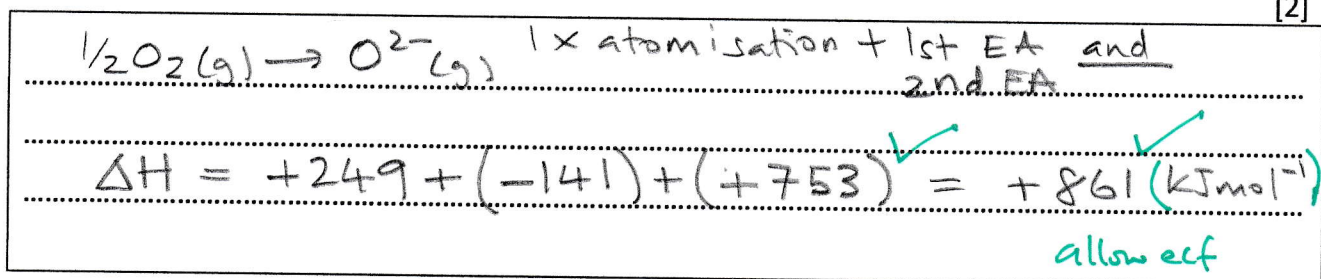
(a) Given that the enthalpy change of atomisation (ΔH_{at}) for lithium is $+159 \text{ kJ mol}^{-1}$, and using section 8 of the data booklet, calculate the enthalpy change for: $2\text{Li}(s) \rightarrow 2\text{Li}^+(g)$

[2]



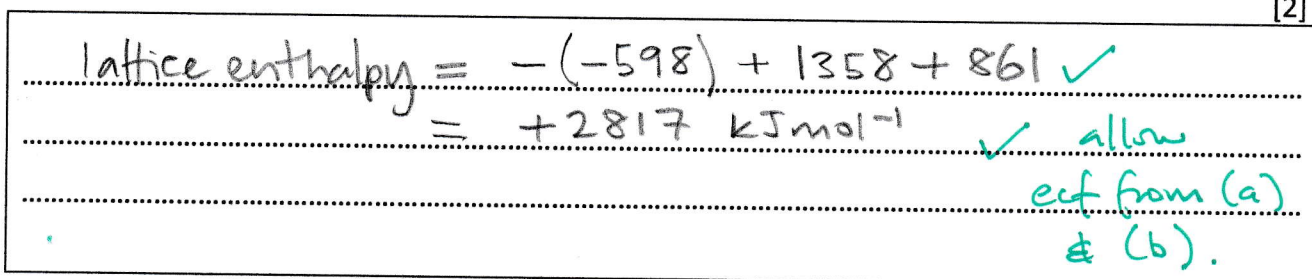
(b) Given that the enthalpy change of atomisation (ΔH_{at}) for oxygen is $+249 \text{ kJ mol}^{-1}$, and using section 8 of the data booklet, calculate the enthalpy change for: $\frac{1}{2}\text{O}_2(g) \rightarrow \text{O}^{2-}(g)$

[2]



(c) Given that the enthalpy change of formation (ΔH_f) for Li_2O is -598 kJ mol^{-1} and using your answers in (a) and (b), calculate the lattice enthalpy for Li_2O in kJ mol^{-1} .

[2]



(d) Justify why Na_2O has a lattice enthalpy of lower magnitude (absolute value) than Li_2O .

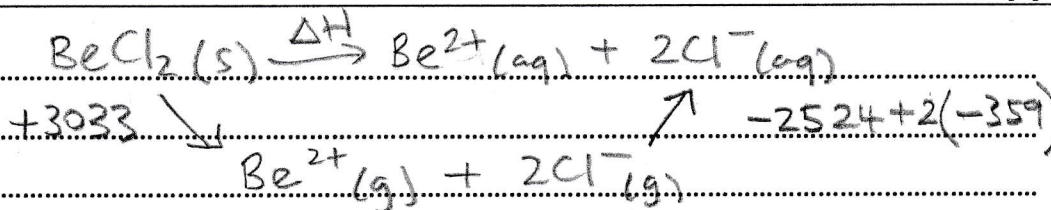
[1]

Sodium ion / Na^+ is larger (so has a lower charge density / has less attraction in the lattice)

4. Beryllium chloride, BeCl_2 , is an off-white crystalline solid.

(a) Calculate the molar enthalpy when solid beryllium chloride is dissolved in water, using sections 18 and 20 of the data booklet.

[2]



$$\begin{aligned} \Delta H &= +3033 - 2524 + 2(-359) \checkmark \\ &= -209 \text{ kJ mol}^{-1} \checkmark \text{ allow ecf.} \end{aligned}$$

(b) Using section 1 of the data booklet and your answer in (a), predict and explain whether you might expect beryllium chloride dissolving in water to be a spontaneous process.

[2]

(Yes, it will be spontaneous) needed ($\Delta G = \Delta H - T\Delta S$)
because ΔG will be negative since ΔH is exothermic and there will be a gain in entropy / ΔS positive (as the solid dissolves)
 ΔH mark
 ΔS mark

(c) The theoretical and experimental lattice enthalpies for BeCl_2 are considerably different. What does this suggest about the bonding in BeCl_2 ?

[1]

It is a mixture of ionic and covalent / not purely ionic

Total Marks 26 (39 minutes)