23.2 Enthalpy of Solution and Hydration

https://subarnam.com.np/

Enthalpy Change of Hydration

1. Define enthalpy change of hydration, ΔH_{hyd}.

....

.... [1]

Enthalpy Change of Solution

2. Define enthalpy change of solution, ΔH_{sol}.

....

....

.... [1]

3. Complete Table 8.1 by placing one tick (✓) in each row to indicate the sign of each type of energy change under standard conditions. [1]

Table 8.1

energy change	always positive	always negative	can be either negative or positive
lattice energy			
enthalpy change of hydration			
enthalpy change of solution			

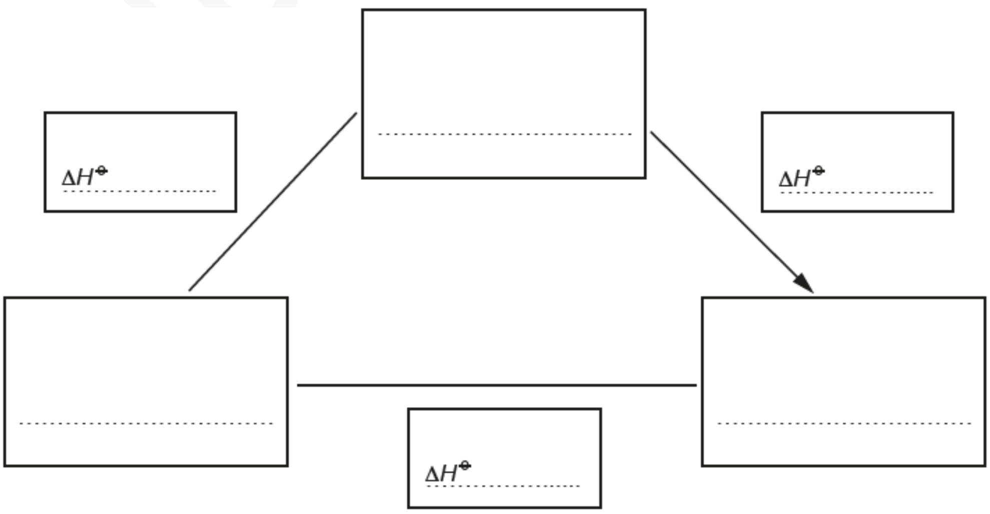
Constructing energy cycles

4. Aluminium fluoride, AlF_3, is an ionic solid.

Complete and label the energy cycle to show the relationship between:

- the enthalpy change of solution of AlF_3, ΔH^o_{sol}
- the lattice energy of AlF_3, ΔH^o_{latt}
- the enthalpy changes of hydration of Al^{3+} and F^-, ΔH^o_{hyd}.

(i) Include state symbols for all substances and ions. [2]



(ii) Relevant data for this question are given.

$\Delta H^{\ominus}_{sol}$ AlF_3 = –209 kJ mol^{-1}
$\Delta H^{\ominus}_{hyd}$ Al^{3+} = – 4690 kJ mol^{-1}
$\Delta H^{\ominus}_{hyd}$ F^{-} = –506 kJ mol^{-1}

Use these data and your energy cycle in (i) to calculate the ΔH^{o}_{latt} of AlF_3.

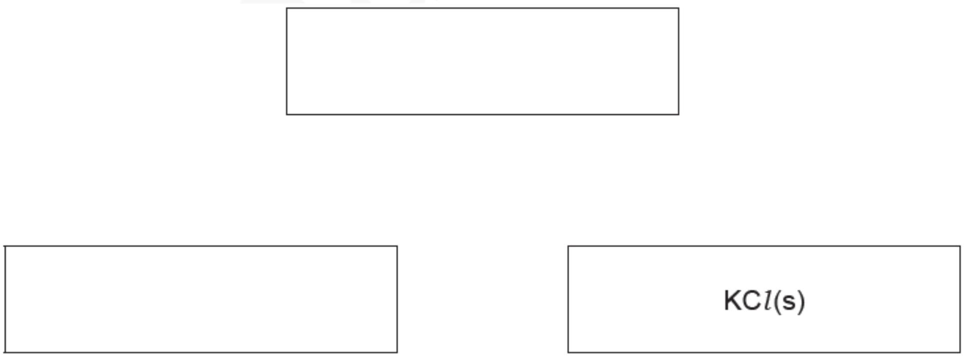
ΔH^{o}_{latt} of AlF_3 = ... (ans = -5999) .... kJ mol^{-1} [1]

5. Potassium chloride, KCl, and magnesium chloride, $MgCl_2$, are both ionic solids.

energy change	value / kJ mol^{-1}
standard enthalpy change of solution, $\Delta H^{\ominus}_{sol}$, of KCl	+15
lattice energy, $\Delta H^{\ominus}_{latt}$, of KCl (s)	–701
standard enthalpy change of hydration, $\Delta H^{\ominus}_{hyd}$, of K^{+}	–322
standard enthalpy change of hydration, $\Delta H^{\ominus}_{hyd}$, of Cl^{-}	–364
standard enthalpy change of solution, $\Delta H^{\ominus}_{sol}$, of $MgCl_2$	–155
lattice energy, $\Delta H^{\ominus}_{latt}$, of $MgCl_2$(s)	–2493

(a) Complete the energy cycle involving the enthalpy change of solution and the lattice energy of potassium chloride, KCl, and the relevant enthalpy changes of hydration. Label your diagram.

State symbols should be used. [2]



(b) Use the data in Table 1.1 to calculate the enthalpy change of hydration of magnesium ions, Mg^{2+}.
Show your working.

$\Delta H^{\ominus}_{hyd}$ of magnesium ions, Mg^{2+} = ... (ans= -1920) .... kJ mol^{-1} [2]

6. Use the data in Table 1.1 to calculate the enthalpy change of the solution of potassium iodide, KI.

process	enthalpy change, ΔH / kJ mol^{-1}
$K^+(g) + I^-(g) \rightarrow KI(s)$	–629
$K^+(g) \rightarrow K^+(aq)$	–322
$I^-(g) \rightarrow I^-(aq)$	–293

enthalpy change of solution = ... kJ mol^{-1} [1]

7. Some relevant energy changes for $AgNO_3$ are shown in Table 4.1.

energy change	value / kJ mol^{-1}
enthalpy change of solution of $AgNO_3(s)$	+22.6
enthalpy change of hydration of silver ions	–475
enthalpy change of hydration of nitrate ions	–314

(i) Complete the energy cycle in Fig. 4.1 to show the relationship between the lattice energy, ΔH^{o}_{latt}, of $AgNO_3(s)$ and the energy changes shown in Table 4.1.
Include state symbols for all the species. [2]

(i) Calculate the lattice energy, $\Delta H^{\ominus}_{latt}$, of $AgNO_3(s)$.

$\Delta H^{\ominus}_{latt}$ = ... (ans = -811.6) .... kJ mol^{-1} [1]

8. The enthalpy change of hydration of the chloride ion can be calculated using the lattice energy of calcium chloride and the data shown in Table 1.3.

energy change	value / kJ mol^{-1}
standard enthalpy change of solution of $CaCl_2(s)$	–83
standard enthalpy change of hydration of $Ca^{2+}(g)$	–1650
Standard lattice energy of $CaCl_2$	-790

Calculate the standard enthalpy change of hydration of the chloride ion, $Cl^-(g)$. It may be helpful to draw an energy cycle. Show all your working.

$\Delta H^{\ominus}_{hyd}(Cl^-(g))$ = ... (ans= -335) .... kJ mol^{-1} [2]

9. The enthalpy change of hydration can be represented by ΔH_{hyd}.

Write the mathematical expression for the ΔH_{sol} of NaCl in terms of ΔH_{latt}(NaCl), $\Delta H_{hyd}(Na^+)$ and $\Delta H_{hyd}(Cl^-)$.

ΔH_{sol}(NaCl) = ... [1]

10. Use the following data to calculate a value for the enthalpy change of solution of copper(II) chloride, $CuCl_2(s)$. You might find it helpful to construct an energy cycle.

enthalpy change of hydration of Cl^- = –378 kJ mol^{-1}

enthalpy change of hydration of Cu^{2+} = –2099 kJ mol^{-1}

lattice energy of $CuCl_2(s)$ = –2824 kJ mol^{-1}

enthalpy change of solution of $CuCl_2(s)$ = ... kJ mol^{-1} [2]

11. Table 8.2 shows various energy changes that can be used in the following questions.

Table 8.2

energy change	value / kJ mol^{-1}
standard enthalpy change of atomisation of calcium	+178.2
first ionisation energy of calcium	+590
second ionisation energy of calcium	+1145
standard enthalpy change of atomisation of bromine	+111.9
Br–Br bond energy	+192.9
standard enthalpy change of solution of calcium bromide, $CaBr_2$(s)	–103.1
standard enthalpy change of formation of calcium bromide, $CaBr_2$(s)	–682.8
standard enthalpy change of hydration of Ca^{2+}	–1579
first electron affinity of bromine	–324.6
first ionisation energy of bromine	+1140

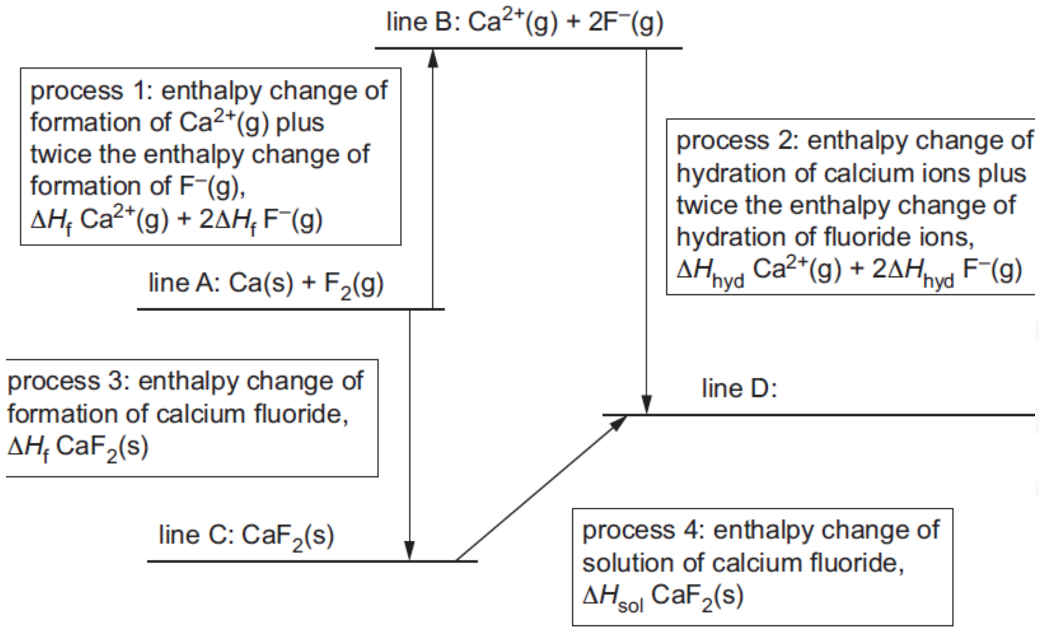
(i) Select and use relevant data from Table 8.2 to calculate the lattice energy, $\Delta H^{\ominus}_{latt}$, of $CaBr_2$(s).
It may be helpful to draw a labelled energy cycle.
Show your working.

$\Delta H^{\ominus}_{latt}$, of $CaBr_2$(s) = ...(ans = -2170.6)........ kJ mol^{-1} [3]

(ii) Select and use relevant data from Table 8.2 and your answer to (i) to calculate the standard enthalpy change of hydration, $\Delta H^{\ominus}_{hyd}$, of Br^-.
It may be helpful to draw a labelled energy cycle.
If you were not able to answer (i), use –2500 kJ mol^{-1} as your value for $\Delta H^{\ominus}_{latt}$, of $CaBr_2$(s). This is not the correct value.
Show your working.

$\Delta H^{\ominus}_{hyd}$, of Br^- = ... kJ mol^{-1} [2]

12. Fig. 2.1 shows an incomplete energy cycle involving calcium fluoride, CaF_2.



(i) Complete line D. Include state symbols. [1]

(ii) The value of the enthalpy change for process 1 can be calculated using the values of five other enthalpy changes, which are not referred to in Fig. 2.1.
process 1: $Ca(s) + F_2(g) \rightarrow Ca^{2+}(g) + 2F^-(g)$
Identify these five other enthalpy changes, using either names or symbols.

....

....

....

....

.... [2]

(iii) Complete the expression to give the mathematical relationship between ΔH_{latt} of calcium fluoride and the enthalpy changes for processes 1 and 3.

$\Delta H_{latt} =$

[1]

(iv) Use data from Table 2.1 to calculate a value for the hydration energy, ΔH_{hyd}, of fluoride ions, $F^-(g)$.

	value / kJ mol^{-1}
enthalpy change of solution of calcium fluoride, $CaF_2(s)$	+13
overall enthalpy change of process 1 in Fig. 2.1	+1395
enthalpy change of formation of calcium fluoride	–1214
enthalpy change of hydration of $Ca^{2+}(g)$	–1650

$\Delta H_{hyd}\ F^-(g)$ = ...(ans = - 473)........ kJ mol^{-1} [2]

13. Fig. 2.1 shows an incomplete energy cycle.

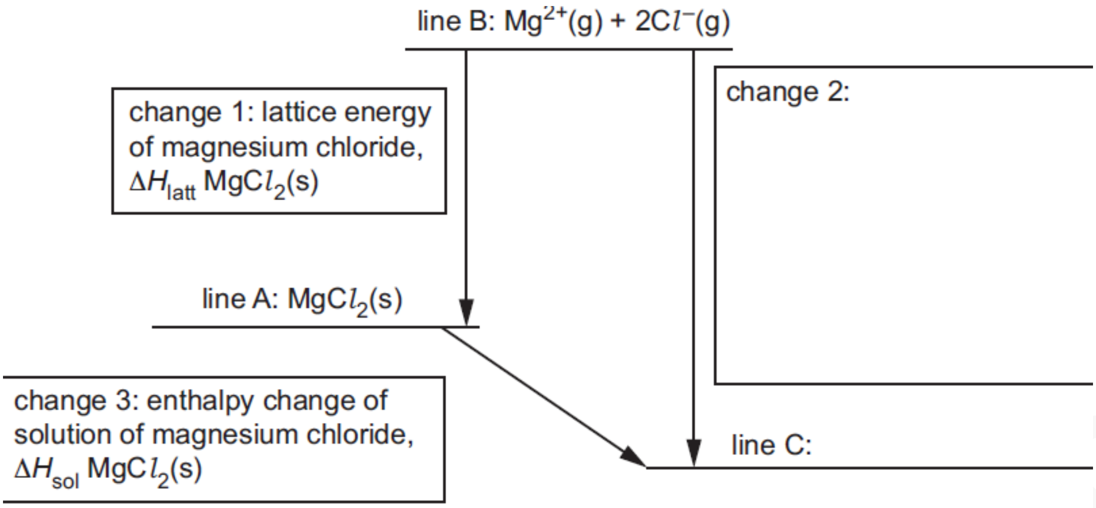


Fig. 2.1

(i) Complete line C on Fig. 2.1. Include state symbols. [1]

(ii) Use both words and symbols to identify change 2 on Fig. 2.1.
Use changes 1 and 3 as examples of how this should be done. [2]

(iii) Calculate a value for the lattice energy of magnesium chloride, ΔH_{latt} $MgCl_2(s)$, by selecting and using appropriate data from Table 2.1.

Table 2.1

energy change	value / kJ mol–1
enthalpy change of solution of magnesium chloride	–155
enthalpy change of formation of magnesium chloride	–642
first ionisation energy of magnesium	+736
second ionisation energy of magnesium	+1450
electron affinity of chlorine	–349
enthalpy change of hydration of Mg^{2+}	–1920
enthalpy change of hydration of Cl^-	–364

ΔH_{latt} $MgCl_2(s)$ = ...(ans = -2493)................. kJ mol^{-1} [3]

14. Table 1.1 gives some data about the halide ions, Cl^-, Br^-, and I^-, and their potassium salts.

halide ion	enthalpy change of hydration, ΔH_{hyd} / kJ mol^{-1}	lattice energy of potassium halide, ΔH_{latt} / kJ mol^{-1}
Cl^-	–364	–701
Br^-	–335	–670
I^-	–293	–629

(ii) The ΔH_{sol} values of these potassium halides are almost constant.
Use the ΔH_{hyd} and ΔH_{latt} data in Table 1.1 to suggest why.

………

………

……… [1]

(iii) The enthalpy change of solution of KI(s) is +21.0 kJ mol^{-1}.
Use this information and the data in Table 1.1 to calculate the enthalpy change of hydration of the potassium ion, $K^+(g)$.

ΔH_{hyd} of $K^+(g)$ = ...(-315)............ kJ mol^{-1} [1]

15. (i) Use the data in Table 1.2 to calculate the enthalpy change of solution, ΔH_{sol}, of AgF(s).

energy change at 298 K	value / kJ mol^{-1}
lattice energy of AgF(s)	–955
enthalpy change of hydration of $Ag^+(g)$	–464
enthalpy change of hydration of $F^-(g)$	–506

ΔH_{sol} of AgF(s) = ...(ans = -15)............. kJ mol^{-1} [1]

(ii) Use your answer to (i) to suggest whether AgF is soluble in water at 298 K. Explain your answer.

………

………

……… [1]

Effect of ionic charge and of ionic radius on the enthalpy change of hydration

16. Predict and explain the variation in the enthalpy change of hydration for the ions Na^+, Mg^{2+}, and Al^{3+}.

……

……

……

……

…… [3]

17. Predict and explain the variation in the enthalpy change of hydration for the ions F^-, Cl^-, Br^- and I^-.

……

……

…… [2]

18. Table 1.1 gives some data about the halide ions, Cl^-, Br^-, and I^-, and their potassium salts.

halide ion	enthalpy change of hydration, ΔH_{hyd} / kJ mol^{-1}	lattice energy of potassium halide, ΔH_{latt} / kJ mol^{-1}
Cl^-	–364	–701
Br^-	–335	–670
I^-	–293	–629

(i) Explain the trend in the enthalpy change of hydration of the halide ions.

19. Predict which of the ions, Cl^- or NO_3^-, has the more negative enthalpy change of hydration. Explain your answer.

……

……

……

……

…… [2]

20. The enthalpy change of hydration of the Br^- ion is more negative than the enthalpy change of hydration of the I^- ion. Explain why.

……

……

…… [2]

Solubility of Sulphates and Hydroxides of group 2 metals.

21. Describe the trend in the solubility of the sulfates of magnesium, calcium, and strontium.
Explain your answer.

…….. > …….. > ……..
most soluble least soluble

……………………..

……………………..

……………………..

……………………..

……………………..

.... [4]

Barium sulfate is the least soluble of the Group 2 sulfates.
Explain the trend in the solubilities of the Group 2 sulfates. [3]

22. The sulfates of the Group 2 elements vary in solubility down Group 2.
Give the names of two solutions that could be mixed to form barium sulfate.

…………………….. [1]

23. Table 4.1 gives the enthalpy changes of hydration, ΔH_{hyd}, of three ions, $F^–$, K^+, and Ca^{2+}.

ion	ΔH_{hyd} / kJ mol^{-1}
$F^–$	–506
K^+	–322
Ca^{2+}	–1650

(a) (i) Explain the relative magnitudes of the enthalpy changes of hydration of K^+ and Ca^{2+}. [2]

(iv) The lattice energy, ΔH_{latt}, of calcium fluoride, CaF_2, is –2602 kJ mol^{-1}.
Calculate the enthalpy change of solution, ΔH_{sol}, in kJ mol^{-1}, of CaF_2.

ΔH_{sol} of CaF_2 = ... kJ mol^{-1} [2]

24. The solubility of the Group 2 hydroxides increases down the group.
Explain this trend.

……………………..

……………………..

……………………..

……………………..

…………………….. [3]

25. **(i)** Describe the trend in the solubility of the hydroxides of magnesium, calcium, and strontium. Explain your answer.

.... > .... > ....

most soluble least soluble [4]

(ii) Suggest the variation in pH of saturated solutions of the hydroxides of magnesium, calcium, and strontium. Explain your answer.

……

……

…… [1]

26. Calcium oxide, CaO, reacts with water to form compound A.
Barium oxide, BaO, reacts with water to form compound B.
(i) Identify A.

…… [1]

(ii) Explain why A is less soluble than B.

……

……

……

……

……

…… [3]

...

https://subarnam.com.np/