A2 Chemistry

AS + A2

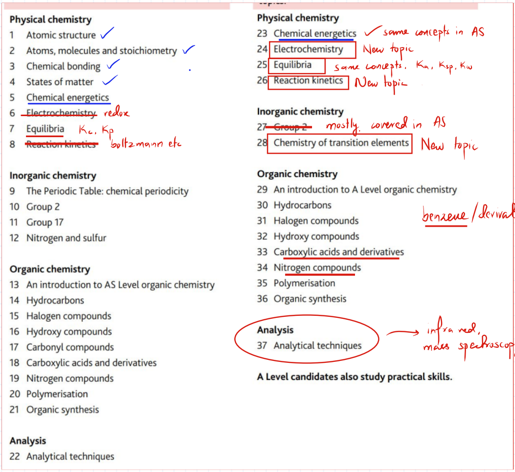
P1, P2, P3

P4 - 40% → structured (similar to P2)
2 hrs - 7/10 questions

P5 - 10%

MEGA
LECTURE

www.megalecture.com
Notes by Sir Fahad H. Ahmad
(whatsapp : +92 323 509 4443)



AS level

Physical chemistry

1 Atomic structure ✓
2 Atoms, molecules and stoichiometry ✓
3 Chemical bonding ✓
4 States of matter ✓
5 Chemical energetics
6 ~~Electrochemistry~~ redox
7 Equilibria Kc, Kp
8 ~~Reaction kinetics~~ boltzmann etc

Inorganic chemistry

9 The Periodic Table: chemical periodicity
10 Group 2
11 Group 17
12 Nitrogen and sulfur

Organic chemistry

13 An introduction to AS Level organic chemistry
14 Hydrocarbons
15 Halogen compounds
16 Hydroxy compounds
17 Carbonyl compounds
18 Carboxylic acids and derivatives
19 Nitrogen compounds
20 Polymerisation
21 Organic synthesis

Analysis

22 Analytical techniques

A2 level

Physical chemistry

23 Chemical energetics ✓ same concepts in AS
24 Electrochemistry New topic
25 Equilibria same concepts. Ka, Ksp, Kw
26 Reaction kinetics New topic

Inorganic chemistry

27 ~~Group 2~~ mostly covered in AS
28 Chemistry of transition elements New topic

Organic chemistry

29 An introduction to A Level organic chemistry
30 Hydrocarbons benzene / derivatives
31 Halogen compounds
32 Hydroxy compounds
33 Carboxylic acids and derivatives
34 Nitrogen compounds
35 Polymerisation
36 Organic synthesis

Analysis

37 Analytical techniques → infra red, mass spectroscopy

A Level candidates also study practical skills.

Entropy S° $J\ mol^{-}\ K^{-}$ → standard conditions

↳ disorder of a system

high entropy → disordered
low entropy → ordered

difficult $\Delta S = -ve$

messy / untidy room → clean, tidy room

high entropy | low entropy
stable state | unstable state / high energy state
low energy state |

easy $\Delta S = +ve$

more probable (infinite possible events)

less probable (just a few possible events)

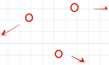
ΔS° Standard Entropy Change

ΔS = +ve gain of entropy.

ΔS = −ve loss of entropy.

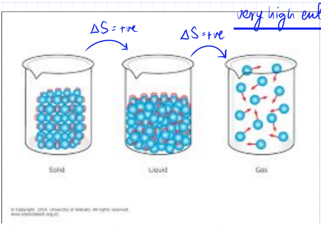
$$H_2O\,(g) \xrightarrow[\Delta S = -ve]{} H_2O\,(s)$$

high entropy



1. Changes of state

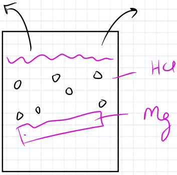
$$\begin{tikzcd} s \arrow[r, "\Delta S = +ve"'] & l \arrow[l, bend left=60, "\Delta S = -ve"] \arrow[r, "\Delta S = +ve"'] & g \arrow[l, bend left=60, "\Delta S = -ve"] \end{tikzcd}$$



very high entropy compared to solids / liquids

2. if moles of gas increase in a reaction ΔS = +ve and vice versa.

$$\underbrace{Mg\,(s) + HCl\,(aq)}_{\text{0 moles of gas}} \xrightarrow{} \underbrace{MgCl_2\,(aq) + H_2\,(g)}_{\text{1 mol of gas}} \quad \Delta S = +ve$$



$$\underbrace{CO_2\,(g) + H_2O\,(l)}_{\text{1 mol gas}} \longrightarrow \underbrace{H_2CO_3\,(aq)}_{\text{0 mol of gas}} \quad \Delta S = -ve$$

3. if the states are same across the equation

moles increase ΔS = +ve

moles decrease ΔS = −ve

$$\underbrace{\underset{(g)}{N_2} + \underset{(g)}{3H_2}}_{\text{4 moles of gas}} \xrightarrow[\Delta S = -ve]{} \underbrace{\underset{(g)}{2NH_3}}_{\text{2 moles of gas}}$$

4 - dissolving ionic compounds

ions dissociate, more particles produced

$$\underset{(s)}{NaCl} \longrightarrow \underset{(aq)}{Na^+} + \underset{(aq)}{Cl^-}$$

$$\underset{(aq)}{Ba(OH)} + \underset{(aq)}{Na_2SO_4} \xrightarrow[\Delta S = -ve]{} \underline{\underset{(s)}{BaSO_4}} + \underset{(aq)}{NaOH}$$

$$\underset{S^\circ(R)}{R} \xrightarrow[\Delta S\ ?]{} \underset{S^\circ(P)}{P}$$

$$\boxed{\Delta S^\circ = S^\circ(P) - S^\circ(R)}$$

How do you measure S°

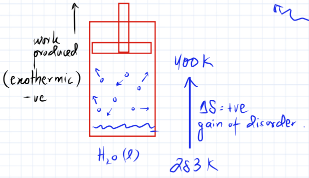
$$\Delta S = -\frac{\Delta Q}{T(K)} \text{(work produced)}$$

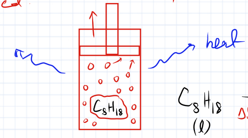
$\longrightarrow$ fuel $\longrightarrow$ car engine $\longrightarrow$ entropy created.

heat produced

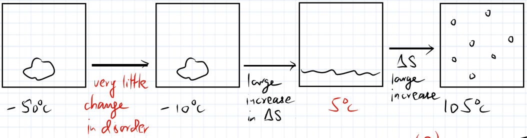
wasted / removed.

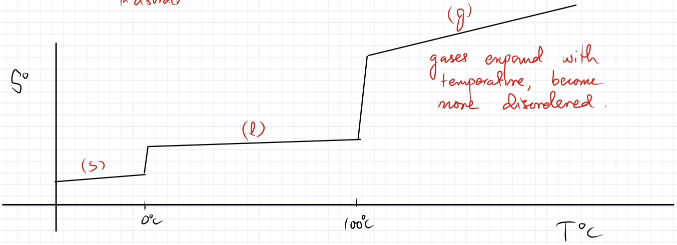
work is produced





$$\underset{(l)}{C_8H_{18}} \xrightarrow[\Delta S: +ve]{} \underset{(g)}{8CO_2} + \underset{(g)}{9H_2O}$$





Gibbs Free Energy

total energy available to a system.

ΔG = work produced due to ΔH + work produced due to ΔS

$$\boxed{\Delta G = \Delta H - T\Delta S}$$

ΔG → KJ/mol

ΔH → KJ/mol

T → Kelvins

ΔS → J K⁻¹ mol

$$\Delta S = -\frac{\Delta Q}{T(K)} \text{ (work produced)}$$

$$\Delta Q = -T\Delta S$$

→ work produced due to ΔS.

make sure units are consistent all KJ or J

$\Delta G < 0$ -ve / exothermic
overall system produces work.
feasible / spontaneous.

$\Delta G > 0$ +ve / endothermic.
needs energy
not spontaneous / not feasible.

$$H_2O\,(l) \xrightarrow[\Delta H = +ve]{\Delta S = +ve} H_2O\,(g)$$

$T = 283\text{ K}$ nonspontaneous ΔG = +ve

$T = 383\text{ K}$ spontaneous ΔG = -ve.

$$\boxed{\Delta G = \Delta H - T\Delta S}$$

for -ve

+ve
+ve
small

+ve
-ve
big
higher T

$\Delta S = -ve$
$\Delta H = -ve$

$$H_2O(l) \xrightarrow{} H_2O(s)$$

spontaneous at lower T°c $\Delta G < 0$

nonspontaneous at higher T°c $\Delta G > 0$

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

(-ve) (-ve)

+ve
smaller, so T should be low.

-ve
spontaneous

$$\underset{(l)}{C_8H_{18}} + \underset{(g)}{12.5\,O_2} \longrightarrow \underset{(g)}{8CO_2} + \underset{(g)}{4H_2O}$$

$\Delta H = -ve$
$\Delta S = +ve$

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

-ve +ve

-ve -ve

always
-ve

$$N_2 + 3H_2 \longrightarrow 2NH_3$$

$\Delta H = -ve$
$\Delta S = -ve$

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

-ve -ve

-ve
+ve
smaller / lower T

ΔG	ΔH	ΔS
-ve at higher T	+ve	+ve
never -ve	+ve	-ve
always -ve	-ve	+ve
-ve at lower T	-ve	-ve

$$CaCO_3 \longrightarrow CaO + CO_2$$

$\Delta H = +ve$

$\Delta S = +ve$

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

+ve +ve

−ve
bigger, T is higher

Plug in Values into $\boxed{\Delta G = \Delta H - T\Delta S}$

at what T is the reaction spontaneous

$\Delta G < 0$

$\Delta H - T\Delta S < 0$ solve .

ΔH_f° : 1 mol of substance formed from its elements in std. states

+/−

$\Delta H_f(CO_2)$ $\quad C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$

$\Delta H_f(H_2SO_4(aq))$ $\quad H_{2(g)} + S_{(s)} + 2O_{2(g)} + (aq) \longrightarrow H_2SO_4\ (aq)$

ΔH_f (elements) = 0 .

ΔH_c° 1 mol of ae substance is completely burnt in excess O_2 .

−ve

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

$\Delta H_c\ (CO_2) = \Delta H_c\ (H_2O) = 0$.

$H_2(g) + \frac{1}{2}O_2\ (g) \longrightarrow H_2O\ (l)$

$\Delta H_f(H_2O)$

$\Delta H_c\ (H_2)$

ΔH_n° 1 mol of water formed when an acid and base react .

$2\,NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + \underset{\sim}{2H_2O}$

$2 \times \Delta H_n$

$Ba(OH)_{2\,(aq)} + 2\,HNO_{3\,(aq)} \longrightarrow Ba(NO_3)_{2\,(aq)} + 2\,H_2O_{(l)}$

$2 \times \Delta H_n$

$$\boxed{OH^- + H^+ \longrightarrow H_2O}$$

$\Delta H_n = -57$ KJ/mol for any strong acid / base

for weak acid / bases, value is less exothermic (−52 KJ/mol to −54 KJ/mol

weak acid, does not ionize fully

$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$

Some energy needed for ionization

bond energy calculated for gaseous molecules

$$N_2 + 3H_2 \longrightarrow 2NH_3$$

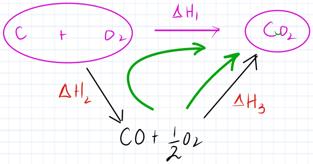
$$N \equiv N \quad 3(H-H) \quad 2(H-\underset{\substack{|\\ H}}{N}-H)$$

$$\boxed{\Delta H = +\text{bonds broken} - \text{bonds formed}}$$

$$(944 + 436 \times 3) - (390 \times 6) = -88\ kJ/mol$$

Hess law

ΔH for a reaction is the same no matter which path is taken.



path 1 path 2

$$\Delta H_1 = \Delta H_2 + \Delta H_3$$

same

$$\Delta H_3 = -\Delta H_2 + \Delta H_1$$

Formula for Hess law

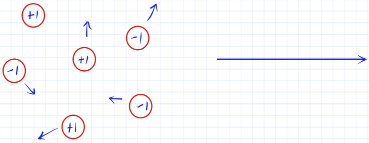
R	$\longrightarrow$	P
ΔH_c		ΔH_c
ΔH_f		ΔH_f

$$\boxed{\Delta H_r = \Delta H_c(R) - \Delta H_c(P)}$$

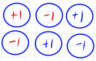
$$\boxed{\Delta H_r = \Delta H_f(P) - \Delta H_f(R)}$$

Lattice Energy ΔH°_{LE} only ionic compounds

Energy released when 1 mol of solid ionic lattice is form its gaseous ions measured under std. cond.



1 mol



ionic bonds formed

exothermic

solid ionic lattice

$Na^{+1}_{(g)} + Cl^{-}_{(g)} \longrightarrow NaCl_{(s)}$

$Mg^{2+}_{(g)} + O^{2-}_{(g)} \longrightarrow \boxed{MgO_{(s)}}$ 1 mol

$Mg^{2+}_{(g)} + 2Cl^{-}_{(g)} \longrightarrow MgCl_{2}\ (s)$

stronger ionic bonds
Lattice energy is more exothermic

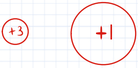
Factors affecting stregnth

1- greater charge on ion, stronger ionic lattice / more attraction

$Na^{+1}Cl^{-1}$	$Mg^{+2}O^{-2}$
801°C	2852°C
MP	MP

1 + 2

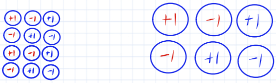
$\text{Charge Density} \propto \frac{\text{charge}}{\text{ionic radi}}$



higher charge density
stronger lattice
more exothermic ΔH_{LE}.

2- Size of ion / ionic radi

smaller ions / stronger ionic bond
(closer to each other, less shielding).

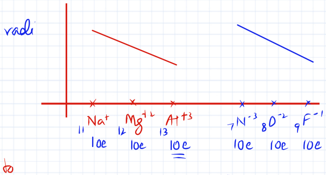


NaCl > KCl
stronger

higher charge density, Na^+ has a smaller ionic radi compared to K^+

NaCl < $MgCl_2$.
stronger.

higher charge density.
Mg^{2+} has smaller ionic radi and greater charge compared to Na^+



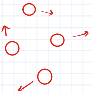
× down the group/size of ions increase

Standard Enth. Ch. of Atomization

+ve / Endo

Energy needed to form 1 mol of gaseous atoms from its elements in its standard form measured under std. cond.

$$\frac{1}{2}\underset{\text{element std. state}}{Cl_{2(g)}} \longrightarrow \overset{1\text{mol}}{Cl_{(g)}}$$



$$\Delta H_{at}(Cl) = \frac{1}{2}\,\underbrace{\text{bond energy}}_{\text{only for gaseous molecules}}(Cl\text{-}Cl)$$

$$Na_{(s)} \longrightarrow Na_{(g)} \qquad \Delta H_{at}(Na)$$

$$\frac{1}{2} I_{2(s)} \longrightarrow I_{(g)} \qquad \Delta H_{at}(I) \neq \frac{1}{2} \times \text{bond energy } (I-I)$$

* I_2 is a solid.

$$\frac{1}{2} H_{2(g)} \longrightarrow H_{(g)} \qquad \Delta H_{at}(H) = \frac{1}{2}\text{ bond energy } (H-H)$$

* smaller atoms make stronger bonds

ΔH_{at} more endothermic for smaller atoms.

Electron Affinity

opposite of Ionization energy

$$Cl_{(g)} \longrightarrow Cl^{+1}_{(g)} + 1e \qquad \text{1st I.E of Cl}$$

$$Cl_{(g)} + 1e \longrightarrow Cl^{-}_{(g)} \qquad \text{E.A of Cl atom.}$$

Energy released or absorbed when 1 mol of gaseous atoms (or ions) gain 1 mol electrons, to form 1 mol of gaseous -1 ions.

$$O_{(g)} + 1e \longrightarrow O^{-1}_{(g)} \qquad \text{E.A of } O_{(g)}$$

$$O^{-1}_{(g)} + 1e \longrightarrow O^{-2}_{(g)} \qquad \text{E.A of } O^{-1}_{(g)}$$

E.A of atom is exo, E.A of ions is endo.

Born - Haber (Ionic Compounds)

↪ measure Lattice Energy

$\boxed{\begin{array}{cc} Mg^{+2} & Cl^{-} \\ Cl^{-} & Mg^{+2} \end{array}}$

$$\begin{tikzcd}
Mg_{(s)} + Cl_{2\,(g)} \arrow[r, "\Delta H_f"] \arrow[d, "{\begin{array}{l}\Delta H_{at}\,(Mg)\\ 2\times\Delta H_{at}\,(Cl)\end{array}}"'] & MgCl_{2\,(s)} \\
Mg_{(g)} + 2Cl_{(g)} \arrow[dr, bend right, "{\begin{array}{l}1st + 2nd\\ I.E\ of\ Mg\ +\ 2\times E.A\ of\ Cl\end{array}}"'] & \\
& Mg^{2+}_{(g)} + 2Cl^{-1}_{(g)} \arrow[uu, bend right, "Lattice\ Energy"']
\end{tikzcd}$$

$$\begin{tikzcd}
2Al_{(s)} + \frac{3}{2}O_{2\,(g)} \arrow[r, "\Delta H_f"] \arrow[d, "{\begin{array}{l}2\times\Delta H_{at}\,(Al)\\ 3\times\Delta H_{at}\,(O)\end{array}}"'] & Al_2O_{3\,(s)} \\
2Al_{(g)} + 3O_{(g)} \arrow[r, bend right, "{\begin{array}{l}2\times(1st+2nd+3rd\ I.E\ of\ Al)\\ (E.A\ of\ O,\ E.A\ of\ O^{-1})\times 3\end{array}}"'] & 2Al^{3+}_{(g)} + 3O^{-2}_{(g)} \arrow[u, bend right, "Lattice\ Energy"']
\end{tikzcd}$$

(i) $K_2O_{(s)}$ (ii) $NaCl$

(iii) MgO (iv) Mg_3N_2

$$3Mg_{(s)} + N_{2\,(g)} \xrightarrow{\Delta H_f} Mg_3N_{2\,(s)}$$

$3 \times \Delta H_{at}(Mg)$
$2 \times \Delta H_{at}(N)$

L.E

$3Mg_{(g)} + 2N_{(g)} \longrightarrow 3Mg^{2+}_{(g)} + 2N^{3-}_{(g)}$

$3 \times$ (1st + 2nd I.E of Mg)
$2 \times$ (E.A of N + E.A of N^- + E.A of N^{-2})

Std. Enth. Ch. of Solution

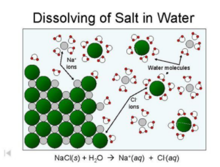
+ / −

Energy released or absorbed when 1 mol of any substance is completely dissolved in water, measured under std. cond.

$NaCl_{(s)} \longrightarrow Na^+_{(aq)} + Cl^-_{(aq)}$ / $NaCl_{(aq)}$

ΔH_{sol}	=	−ve	more soluble at lower T°C
ΔH_{sol}	=	+ve	less soluble, more soluble at higher T°C

Dissolving of Salt in Water



NaCl(s) + H₂O → Na⁺(aq) + Cl⁻(aq)

Std. Enth. Ch. of hydration

always exo / ΔH_{hyd} / always exo

Energy released when 1 mol of gaseous ions are completely surrounded by water to form 1 mol of aqueous ions

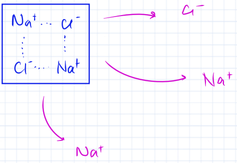
$Na^+_{(g)} + (aq) \longrightarrow Na^+_{(aq)}$

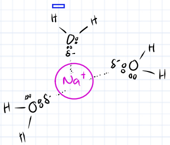
O^{-2} does not have ΔH_{hyd} as it doesn't form aqueous ions

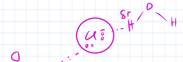
$O^{-2} + H_2O \rightarrow 2OH^-$

instead it reacts

greate charge density
ΔH_{hyd} more exothermic
- smalle ions
- more charge







$H_{\delta+}$ $H_{\delta+}$

for ionic compounds only

$$\begin{tikzcd}
NaCl_{(s)} + (aq) \arrow[rr, "\Delta H_{sol}"] \arrow[d, "\text{Endo } (-L\cdot E)"'] & & Na^+_{(aq)} + Cl^-_{(aq)} \\
Na^+_{(g)} + Cl^-_{(g)} + (aq) \arrow[urr, "\text{Exo } \Delta H_{hyd}(Na^+)\ \Delta H_{hyd}(Cl^-)"'] & &
\end{tikzcd}$$

$$\begin{tikzcd}
MgCl_{2(s)} + (aq) \arrow[rr, "\Delta H_{sol}"] \arrow[d, "(\text{Endo})\ -L\cdot E"'] & & Mg^{2+}_{(aq)} + 2Cl^-_{(aq)} \\
Mg^{2+}_{(g)} + 2Cl^-_{(g)} + (aq) \arrow[urr, "\Delta H_{hyd}(Mg^{2+})\ 2\times\Delta H_{hyd}(Cl^-)"'] & &
\end{tikzcd}$$

$MgSO_4$ $CaSO_4$ $SrSO_4$ $BaSO_4$ →

solubility of sulfates decreases down group 2

Why?

$$\begin{tikzcd}
MgSO_{4(s)} + (aq) \arrow[rr, "\boxed{\Delta H_{sol}}"] \arrow[d, "-L\cdot E"'] & & Mg^{2+}_{(aq)} + SO_{4(aq)}^{2-} \\
Mg^{2+}_{(g)} + SO_{4(g)}^{2-} + (aq) \arrow[urr, "\Delta H_{hyd}"] & &
\end{tikzcd}$$

Endo

Exo

ΔHsol becomes more endothermic down the group.

down the group ionic radii increases so L·E decreases and ΔHhyd both decrease (bigger ions make weaker lattice)

ΔHsol becomes more endothermic down the group.

down the group ionic radii increases so L·E decreases and ΔHhyd both decrease (bigger ions make weaker lattice)

but L·E decreases less compared to ΔHhyd.

$Mg(OH)_2$ $Ca(OH)_2$ $Sr(OH)_2$ $Ba(OH)_2$

$\longrightarrow$ more soluble

Why?

ΔH_{sol} becomes more ~~endothermic~~ exothermic down the group.

down the group ionic radii increases
so L.E decreases and ΔH_{hyd}
both decrease (bigger ions make weaker lattice)

but L.E (Endo) decreases ~~less~~ more compared to ΔH_{hyd} (exo).