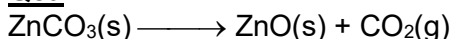




RAFFLES INSTITUTION
YEAR 5 H2 CHEMISTRY 2025
Tutorial 12b – The Periodic Table 2

Answers to practice questions

Q8a



Q8b

The ionic radius of Mg^{2+} (0.065 nm) is smaller than that of Zn^{2+} (0.074 nm). Hence with the same charge, Zn^{2+} has a lower charge density and hence weaker polarising power than Mg^{2+} . As a result, Zn^{2+} distorts the electron cloud of CO_3^{2-} ion in ZnCO_3 to a smaller extent. The covalent bonds within the CO_3^{2-} ion are weakened to a smaller extent as compared to that in MgCO_3 . Therefore, more heat energy is needed to decompose ZnCO_3 . Hence ZnCO_3 will decompose at a higher temperature than MgCO_3 .

Q9a



Q9b

Determine the given three iodates(V):

Assume one iodate(V) given is $\text{Mg}(\text{IO}_3)_2$.

Molar mass of $\text{Mg}(\text{IO}_3)_2 = 374.1 \text{ g mol}^{-1}$

$$\text{Amount of } \text{Mg}(\text{IO}_3)_2 = \frac{2.00}{374.1} = 5.346 \times 10^{-3} \text{ mol}$$

Amount of MgO formed = $5.346 \times 10^{-3} \text{ mol}$

Molar mass of $\text{MgO} = 40.3 \text{ g mol}^{-1}$

$$\begin{aligned} \text{Mass of } \text{MgO} \text{ formed} &= (5.346 \times 10^{-3})(40.3) \\ &= 0.215 \text{ g} \end{aligned}$$

Since the mass of the oxide calculated does not correspond to that of either **XO**, **YO** or **ZO**, $\text{Mg}(\text{IO}_3)_2$ is not among the three given iodates(V).

Hence the given iodates(V) are $\text{Ca}(\text{IO}_3)_2$, $\text{Sr}(\text{IO}_3)_2$ and $\text{Ba}(\text{IO}_3)_2$.

[Note: Calculation needs to be made for at least one of the iodates(V) and then reasoning can be made to deduce the identities of the given iodates(V).]

Comparison of thermal stability of $\text{Ca}(\text{IO}_3)_2$, $\text{Sr}(\text{IO}_3)_2$ and $\text{Ba}(\text{IO}_3)_2$:

- The cationic radius increases from Ca^{2+} to Sr^{2+} to Ba^{2+} .
- This causes the charge density and polarising power of the cations to decrease from Ca^{2+} to Sr^{2+} to Ba^{2+} .
- Hence the extent of distortion of the electron cloud of the IO_3^- anion decreases from $\text{Ca}(\text{IO}_3)_2$ to $\text{Sr}(\text{IO}_3)_2$ to $\text{Ba}(\text{IO}_3)_2$.
- The extent of weakening of the covalent bonds in IO_3^- ion also decreases from $\text{Ca}(\text{IO}_3)_2$ to $\text{Sr}(\text{IO}_3)_2$ to $\text{Ba}(\text{IO}_3)_2$.

- Hence the amount of heat energy and temperature required for decomposition increases from $\text{Ca}(\text{IO}_3)_2$ to $\text{Sr}(\text{IO}_3)_2$ to $\text{Ba}(\text{IO}_3)_2$.
- Therefore, thermal stability increases in the order: $\text{Ca}(\text{IO}_3)_2 < \text{Sr}(\text{IO}_3)_2 < \text{Ba}(\text{IO}_3)_2$

From the graphs, thermal stability of the given iodates(V) increases in the following order:
 $\text{Z}(\text{IO}_3)_2 < \text{X}(\text{IO}_3)_2 < \text{Y}(\text{IO}_3)_2$

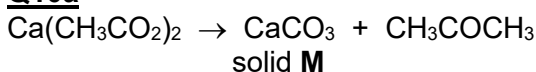
Hence,

$\text{Z}(\text{IO}_3)_2$ is $\text{Ca}(\text{IO}_3)_2 \Rightarrow$ its rate of thermal decomposition is the fastest.

$\text{X}(\text{IO}_3)_2$ is $\text{Sr}(\text{IO}_3)_2 \Rightarrow$ its rate of thermal decomposition is slower than $\text{Ca}(\text{IO}_3)_2$.

$\text{Y}(\text{IO}_3)_2$ is $\text{Ba}(\text{IO}_3)_2 \Rightarrow$ it does not undergo thermal decomposition.

Q10a



Comments:

- The question has clearly stated that propanone is formed. When writing the balanced equation, the structural formula of propanone should be shown, not just the molecular formula ($\text{C}_3\text{H}_6\text{O}$).

Q10b

The CaCO_3 sample (i.e. **M**) undergoes partial decomposition to give a white residue.
 This white residue contains both CaCO_3 and CaO .

Method 1

Amount of CaCO_3 formed at 450°C = Amount of $\text{Ca}(\text{CH}_3\text{CO}_2)_2 = \frac{2.0}{158.1} = 0.01265 \text{ mol}$

Let the amount of CO_2 evolved = $y \text{ mol}$.

Amount/mol	CaCO_3	$\longrightarrow$	CaO	+	CO_2
Initial	0.01265		-		-
Change	-y		+y		+y
Final	$0.01265 - y$		y		y

Mass of CaCO_3 in the residue = $(0.01265 - y)(100.1) = (1.266 - 100.1y) \text{ g}$

Mass of CaO in the residue = $56.1y \text{ g}$

$$\frac{\text{mass of CaCO}_3 \text{ in the residue}}{\text{mass of CaO in the residue}} = \frac{70}{30}$$

$$\Rightarrow \frac{1.266 - 100.1y}{56.1y} = \frac{7}{3}$$

$$1.266 - 100.1y = 130.9y$$

$$y = 0.005483$$

Amount of CO_2 evolved = 0.005483 mol

Mass of CO_2 evolved = $(0.005483)(44.0) = \underline{0.241 \text{ g}}$

Method 2

Mass of CaCO_3 formed at $450^\circ\text{C} = (2/158.1)(100.1) = 1.266 \text{ g}$

	CaCO_3	$\longrightarrow$	CaO	+	CO_2
mass after partial decomposition / g	$1.266 - x - y$		x		y

Since mass of white residue = $(1.266 - y) \text{ g}$ and % of CaO in white residue = 30%,

$$\frac{x}{1.266 - y} = 0.3$$

Since amount of CaO formed = amount of CO_2 formed,

$$\frac{x}{56.1} = \frac{y}{44}$$

Solving simultaneous equations, $y = \text{mass of } \text{CO}_2 \text{ lost} = \underline{0.241 \text{ g}}$

Method 3

Mass of CaCO_3 formed at $450^\circ\text{C} = (2/158.1)(100.1) = 1.266 \text{ g}$

Let mass of white residue be $x \text{ g}$ and mass of CO_2 evolved by $y \text{ g}$.

Mass of $\text{CaO} = (0.3x) \text{ g}$

Since $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$, amount of $\text{CaO} = \text{amount of } \text{CO}_2$

$$\frac{0.3x}{56.1} = \frac{y}{44}$$

By conservation of mass, $x + y = 1.266 \text{ g}$

Solving simultaneous equations, $y = \underline{0.241 \text{ g}}$

Comments:

- Candidates should show all essential steps with appropriate units.
- Candidates should keep the answers for intermediate steps to 3 or 4 significant figures.
- The question stated that the white residue contains 70% by mass of solid **M**. Many candidates misinterpreted this information given.

Wrong interpretation:

Mass of CaCO_3 in the white residue = 70% of mass of CaCO_3 formed initially
 $= 0.70 \times 1.266$

Correct interpretation:

Mass of CaCO_3 in the white residue = 70% of mass of white residue
 $= 0.70 \times (\text{mass of } \text{CaCO}_3 + \text{mass of } \text{CaO})$

Q10c

$\text{Ba}(\text{CH}_3\text{CO}_2)_2$ will decompose at a higher temperature. Ba^{2+} ion has a larger ionic radius as compared to Ca^{2+} ion resulting in a lower charge density and weaker polarising power. Hence, Ba^{2+} distorts the electron cloud of the CH_3CO_2^- ions to a smaller extent and thus weakens the covalent bonds within CH_3CO_2^- ions to a smaller extent as compared to Ca^{2+} ion. This results in more heat energy and a higher temperature required for decomposition of $\text{Ba}(\text{CH}_3\text{CO}_2)_2$.

Comments:

- Reference must be made to the ion (Ba^{2+}), not atom (Ba).

Q11(a)(i)

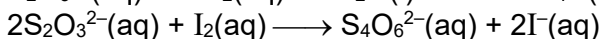
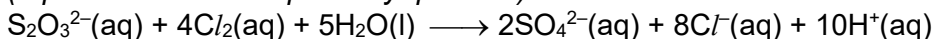
Down Group 17, the value of $E^\ominus$ for $X_2(g) + 2e^- \rightleftharpoons 2X^-(aq)$ becomes less positive and the position of equilibrium of the reduction of X_2 to X^- lies increasingly to the left. Hence, down the group, X_2 has less tendency to be reduced and the oxidising power of X_2 decreases.

Q11(a)(ii)

Chlorine, being a stronger oxidising agent, oxidises thiosulfate to sulfate ions, where the average oxidation state of S increases from +2 to +6.

Iodine, being a weaker oxidising agent, oxidises thiosulfate to tetrathionate ions, where the average oxidation state of S only increases from +2 to +2.5.

(equations are not required by question)

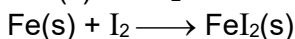
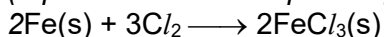


Alternative answer

Chlorine, being a stronger oxidising agent, oxidises Fe to Fe^{3+} (i.e. from Fe to Fe^{2+} , and then from Fe^{2+} to Fe^{3+}), where the oxidation state of Fe increases from 0 to +3.

Iodine, being a weaker oxidising agent, oxidises Fe to Fe^{2+} , where the oxidation state of Fe only increases from 0 to +2.

(equations are not required by question)



Alternative answer

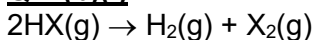
Chlorine, being a stronger oxidising agent, oxidises Br^- to Br_2 / I^- to I_2 .

(equations are not required by question)



Note: We can also compare Br_2 and I^- . Furthermore, only displacement reactions allow us to compare the relative oxidising power of Cl_2 , Br_2 and I_2 . On the other hand, reaction with thiosulfate or Fe only allows us to conclude that Cl_2 and Br_2 are stronger oxidising agent than I_2 .

Q11(b)(i)



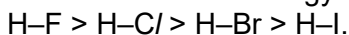
(**Reversible arrows are acceptable too since the extent of reaction depends on the type of hydrogen halides.)

Q11(b)(ii)

The thermal stability of the hydrogen halides decreases down Group 17.

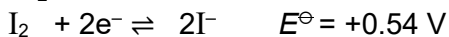
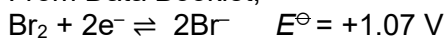
Thermal stability is related to the H–X bond strength. The more endothermic bond dissociation energy of the H–X bond, the stronger the H–X bond and that HX is more thermally stable. Down Group 17, there is less effective orbital overlap between the 1s orbital of H and the valence p orbital of the halogen. Also, the difference in electronegativity between H and the halogens also decrease down the group. This leads to a decrease in bond polarity. Hence, the H–X bond strength decreases down group.

Bond dissociation energy decreases in the order:



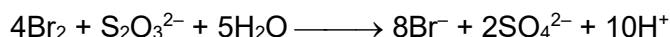
Q12(a)T : I₂U: Br₂**Q12(b)**

From Data Booklet,

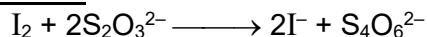
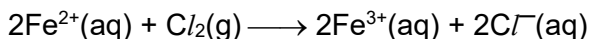
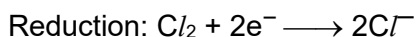
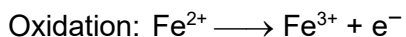


As observed from the less positive $E^\ominus$ values from Br₂ to I₂, the oxidising strength of the halogens decreases down the group.

In the reaction between bromine and thiosulfate, bromine, a stronger oxidising agent than iodine, is able to oxidise sulfur such that the average oxidation state of sulfur increases from +2 to +6.

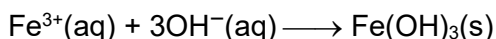


In the reaction between iodine and thiosulfate, iodine, a weaker oxidising agent, is only able to oxidise sulfur such that the average oxidation state of sulfur increases from +2 to +2.5.

**Q13a***Reaction 1: Cl₂ and Fe²⁺*

$$[E^\ominus_{\text{cell}} = +0.59\text{V} > 0 \text{ (reaction is spontaneous)}]$$

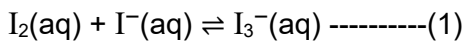
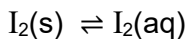
Observation: Pale green solution of Fe²⁺ turns to pale yellow due to the formation of Fe³⁺.

Reaction 2: NaOH and Fe³⁺

Observation: A red-brown ppt of Fe(OH)₃ is formed, which is insoluble in excess NaOH.

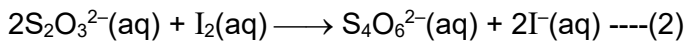
Q13(b)

Reaction 1: I_2 is shaken with KI



Observation: Black crystals of I_2 dissolves to form brown solution due to the formation of the complex I_3^- .

Reaction 2: $Na_2S_2O_3$ reacts with I_2



From (2), $S_2O_3^{2-}$ reacts with I_2 , thus decreasing $[I_2(aq)]$. By Le Chatelier's Principle, position of equilibrium (1) shifts to the left, decreasing $[I_3^-]$, until all I_2 is reacted with $S_2O_3^{2-}$.

Observation: Brown solution is decolourised. (Note: $S_4O_6^{2-}(aq)$ is colourless).